MANAGING AND MONITORING ENDANGERED SPECIES:
With particular reference to the black rhino in Kenya

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ABSTRACT

A rising human population continues to threaten global biodiversity. The International Union for the Conservation of Nature (IUCN) has increased the number of species it considers to be threatened from 38, 049 (2004) to 44, 838 (2008). There is, therefore, an urgent need for effective conservation action and optimal management, coupled to the need for cost efficiency with the limited funds available for conservation. Until recently, there has been little attempt to identify the most effective means of conserving species by collating results from various projects across the world. This study was designed to evaluate the effectiveness of management, research and monitoring in the conservation of endangered species.

The main aim of the study (September 2003 – February 2010) was to carry out an extensive review of conservation action for 153 terrestrial mammals, classified as endangered and critically endangered (IUCN 2004), and identify potential 'best practice' which could then inform work for other species. Initially, the study involved a global analysis specifically investigating geographic, taxonomic, ecological, and conservation action data for the 153 species. These data were subject to critical analysis using both uni-variate and multivariate quantitative methods including a Random Forest Analysis (RFA) which had the potential to detect relationships between the more than 50 variables included in the data set. For 20 of these species, selected on the basis of them having a monitoring programme in place, an extensive literature review further explored the effectiveness of conservation action.

Case studies for 4 of the above species were then developed through direct contact with conservation scientists involved in their management in situ (Iberian Lynx (*Lynx pardinus*), Spain, black rhino (*Diceros bicornis*), Kenya, Giant panda (*Ailuropoda melanoleuca*), China and San Diego Zoo, California and the Channel Island fox (*Urocyon litteralis*), California). Information from the species reviews and the case studies was used to develop a list of criteria which would potentially be able to identify a well managed and monitored species from basic evidence. The information was also used to identify a possible 'gold standard' of management and monitoring. The main elements of the gold standard were then incorporated into a monitoring design flow diagram. This protocol was used to design a vegetation monitoring system for the habitat of the black rhino in Kenya. The aim of this was to design a reliable and cost effective habitat monitoring system, able to measure the affect of browsing from giraffe, elephant and rhino. A variety of vegetation survey techniques were tested and the effect of using different surveyors was also explored over three field seasons in Kenya.

From the global analysis of 153 separate species from across the world, patterns of threat, conservation strategies and species-specific levels of management were identified. The most prevalent threats were confirmed as habitat loss and degradation, and exploitation (harvesting and/or hunting), but many threats may act together to increase vulnerability to extinction. The RFA revealed that the presence of research and monitoring had a positive association with species trend. This analysis also identified characteristics of species which have good levels of research and monitoring. These included: a critical status (as opposed to 'endangered'), high charisma, living in open habitats (e.g. grasslands), high levels of protection (e.g. legal, protected area) and the threats of persecution, hunting and natural disaster. The need for clear quantification of trends in abundance for species in the endangered category was also identified. Areas of successful conservation action were also indicated, as well as those which may require more work. Such areas may be deemed conservation 'blackspots' as they may not fall under the boundary of geographical 'hotspots'.

For the 20 monitored species, many were found to suffer multiple threats, some of which were common across the species, where others were species specific, and acting to exacerbate their situation. Prioritising specific conservation actions (e.g. specific threat removal) was found to

be just as important as the common conservation actions (e.g. habitat protection). In monitoring, the basic and indirect techniques (e.g. sign surveys) were identified to remain key monitoring tools, alongside additional inventive techniques such as scat detection by dogs. The great potential of incorporating satellite and GIS technology for most threatened species was also recognised. The consistent use of one or two techniques over a long time period was highlighted as good monitoring practice.

Essential criteria to identify a species with good management and monitoring were identified as including good collaboration and co-operation, a fast response and secure funding, as well as documented demographic and ecological information. Elements of a 'gold standard' of monitoring included a strong theoretical background, secure funding, clear goals, a robust, powerful and consistent methodology and analysis techniques which are user friendly. The monitoring design flow chart used these elements and was designed to guide through the initiation, mobilisation and implementation stages of system development to the end goal of the monitoring cycle.

The initial analysis following initiation and mobilisation stages of the system design revealed an optimal and potentially powerful vegetation monitoring methodology. Ecologically, most browsing occurred to trees less than 2 metres tall, which was in accordance with abundance, as the majority of trees were of this height. The majority of damage caused by rhino, elephant and giraffe was judged not to be severe. The optimal monitoring design was suggested as a 20x20m square plot, subdivided into 10x10m blocks. When different surveyors were compared using the data collection technique and the monitoring design, there was some variation between results, even though they recorded data in the same area, used the same techniques, followed the same training and worked under the same conditions. This highlighted the importance of using consistent surveyors for the best results. In comparing the performance of the monitoring system itself on the 15 set monitoring points, to 10 comparison plots and 8 control plots, the method was found to be 'robust' for broad scale data (e.g. number and proportion of trees damaged), but there was more variability for fine scale data (e.g. species-specific browse). The 15 monitoring plots were suitably representative of the reserve but variability in the pattern of browse should be expected. A single index, the damage product score (DPS), which measures both the presence and severity of browse, is suggested. The final field design was found to be powerful enough to detect an 8.4% change in the number of damaged trees (including very minor damage), and a 5.6% change in DPS per year.

In conclusion, this study represents the first time in which varied conservation activities have been brought together to identify common factors which underpin successful conservation initiatives. Although taxonomically biased, it is clear that most successful projects have common qualities: effective communication, adequate funding and timely and sustained action. Overall the most effective and cost effective conservation action is the one which achieves its defined goals. Effective monitoring was found to be a crucial tool for successful conservation, and indeed without such monitoring, there can be no evidence for success or failure. This study has highlighted how relatively simple methods of research can be used to identify significant relationships, and set precedents for effective management and monitoring of individual species and their habitats. It has indicated how an analytical method such as RFA has potential in the work to save endangered species, complementing theories such as the 'hotspot' theory. This study has also followed the identified elements of good monitoring practice to design a detailed monitoring scheme for the black rhino and has made this available to research staff in the field both in Kenya and elsewhere.

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CHAPTER ONE: INTRODUCTION

1.1 The Extinction Crisis

The biota of the Earth is currently undergoing a dramatic transformation and the world is facing an unprecedented extinction crisis with recent rates far exceeding the rates of extinction in the fossil record (Baillie et al 2004, Mooney and Cleland, 2001, Purvis et al, 2000, Magin et al 1994). Spatial patterning, structure and functioning of most of the worlds ecosystems have been changed: there is an increasing list of documented extinctions, mainly due to direct and indirect human activities, creating a situation where human-induced environmental change is the greatest threat to biodiversity (Phillips and Shine, 2004, Mooney and Cleland, 2001, Magin et al 1994). There is every indication that these trends will intensify with a growing human population, even in areas set aside for protection because of global changes that are affecting the atmosphere and the climate (Mooney and Cleland, 2001). What we do (or do not do) within the next few decades will determine the long-term future of a vital feature of the biosphere - its abundance and diversity of species (Myers et al, 2000).

1.2 Causes of Extinction

Extinction can be described as the death of the last individual of a species, or the end of the evolutionary process, thus representing the permanent and irreversible loss of one of life's unique evolutionary and functional forms (Baillie et al 2004, Purvis et al, 2000c). Recent extinction rates are 100 to 1000 times their pre-human levels in well-known, but taxonomically diverse groups from widely different environments (Pimm et al, 1995). Species are lost from an ecosystem either through extrinsic causes, which may be biotic or abiotic, or because of intrinsic or evolutionary changes, with some taxa appearing to be more vulnerable than others (Purvis et al, 2000c).

Understanding the ecological mechanisms that underlie extinction is fundamental to conservation (Owens and Bennett, 2000). It is acknowledged that extinction risk is non random and that not all taxa are equally vulnerable to extinction, however ecological theory offers sometimes conflicting predictions about the species characteristics which correlate with their risk of extinction (Beissinger, 2000, Owens and Bennett, 2000, Purvis et al 2000a). Purvis et al (2000b) analysed a number of species vulnerability hypotheses, with the aim of assessing the relative importance of biological factors in the risk of extinction, and additionally assessing the impact of anthropomorphic pressure. The hypotheses tested were that species with small populations, island endemics, higher trophic levels, slow life histories, complex social structures, large home ranges, and species with characteristics such as being diurnal and having a larger body size, were at a greater risk of extinction. The study indicated that the most influential factors in promoting extinction were occupation of a small geographical range, occurrence at low density, location at a high trophic level in the food chain and possession of low reproductive rates (Purvis et al, 2000b). This study also found that the current severe anthropogenic pressures can overwhelm a species resistance to extinction processes (Purvis et al, 2000b). Collen et al (2006) analysed extinction risk in Asian vertebrates and also found that small geographic range ('area of occupancy' in their study) was associated with extinction risk in mammals, birds and reptiles. Mammals with longer dispersal distances were also vulnerable.

The reasons why some taxa are more prone to extinction than others may be partly due to different mechanisms acting on the different taxa (Owens and Bennett, 2000). Their study focused on comparing the impact on birds of habitat loss, human persecution and introduced predators, to their body size, generation time and degree of habitat specialisation. The results both supported and challenged current extinction theory (Beissinger, 2000). Owens and Bennett (2000) supported predictions that taxa are prone to different extinction mechanisms and that different ecological factors are associated with different extinction mechanisms. They also found it to be unusual for a species to be threatened by both habitat loss and human persecution/introduced predators, with 54% of species being threatened by either factor, and only 27% threatened by both (Owens and Bennett, 2000). Therefore, the ecological mechanisms underlying extinction may differ for lineages of birds threatened by habitat loss, from those which are threatened by human persecution and introduced predators (Beissinger, 2000). They also found that large body size is only associated with threat in species for which the threatening process is persecution and introduced predators, and not habitat loss (Owens and Bennett, 2000, Collen et al, 2006).

The work by Owens and Bennett (2000) indicates that there may be a complex relationship between potential extinction mechanisms and actual risk.
This is also illustrated by the association between body size and extinction risk (Cardillo et al, 2005, Cardillo and Bromham, 2001, Collen et al, 2006). It has been unclear if species with small body size and short generations ('fast lifestyle'), or those with a large body size and long generations ('slow lifestyle') are more or less likely to become extinct (Beissinger, 2000). Cardillo et al (2005), state that many large animal species have a high risk of extinction. Their study found both intrinsic and environmental factors had greater impacts on species with a body mass greater than 3 kilograms. Also, whereas extinction risk for smaller species was driven by environmental factors, environmental and intrinsic factors combined for larger species, thus accentuating the disadvantage of a larger body size (Cardillo et al, 2005). This is supported by an earlier study by Cardillo and Bromham (2001) which explored the link between body size and extinction risk in Australian mammals. They suggested that small bodied species were less threatened than large and medium sized species, however, the positive relationship between body size and extinction risk described was restricted to smaller species, with no relationship within larger species (Cardillo and Bromham, 2001). It was suggested that the real pattern requiring explanation was the relative resistance to extinction of the smallest species (Cardillo and Bromham, 2001). In their study, Collen et al (2006) found large body mass to be associated with extinction risk in game species where persecution was probably the major threat: the direction of the relationship was however reversed for non game species, with smaller species at greater risk. In conclusion, Collen et al (2006) regard understanding the process of extinction to be more important than using indices to measure extinction risk, which have the potential to mask the very biological traits which may predispose extant species to elevated extinction risk (Collen et al, 2006). Lockwood et al (2002) suggest that when a group shares traits that are known to confer a high risk of extinction, members of this group, even those species not currently listed as endangered, should be considered to be more vulnerable than non members.

Whatever the underlying mechanisms, the vast majority of extinctions since 1500 have been within oceanic birds and mammals. Reasons for these two groups featuring could be a combination of factors such as that they are easier to study, there may be a bias of interest (Magin et al 1994, Baillie et al 2004), and they may actually need more space than smaller species. It is possible that the isolated evolutionary history of island species may make them more vulnerable to certain threats (Baillie et al 2004, Magin et al 1994). The degree of specialism developed by island species and their loss of adaptability could arguably make them more extinction prone, or it may just be the nature of living on islands, where species have small populations and small ranges, which makes them more vulnerable. It can be said now that the species most prone to current extinction are rare and local (Pimm et al, 1995), but this does not apply only to island species, extinctions on the mainland may be catching up. Indeed , calculations now suggest that species extinction rates will increase rapidly due to an increase in extinction on continents where there have been fewer recorded extinctions to date (Pimm et al, 2006). If allowed to persist, this would constitute a problem with a far more enduring impact than any other environmental issue (Myers et al, 2000).

1.3 The Human Impact on Species

As indicated above, multiple factors may interact to threaten species (Beissinger, 2000), but it is the influence of human activities on wild species that has grown at an unprecedented rate. If human impacts continue to expand at their present rate, they will threaten many species not currently at risk (Pimm et al, 2006).

People and threatened species are often concentrated in the same area, with the number of threatened species being likely to increase where human population rates of increase are high (Baillie et al 2004). The most commonly recorded threat to the species that have been lost over the past 20 years is habitat destruction, with other major impacts listed as habitat fragmentation invasive alien species, over utilisation, disease, pollution and contaminants, incidental mortality and climate change (Baillie et al 2004).

In total, habitat loss impacts upon 85 – 90% of threatened species within bird, mammal and amphibian groups, with the majority occurring in tropical forests where the most serious habitat loss is taking place (Baillie et al, 2004). Birds are primarily threatened by habitat loss and degradation. When species distribution becomes insular because of habitat loss, populations become more vulnerable to other threats (McLaughlin et al, 2002). About one third of the worlds threatened bird species are at risk from direct mortality because of human persecution, including harvesting, poisoning, egg collecting and capture for trade, and by predation from introduced predators particularly on islands (Beissinger, 2000).

In addition to habitat loss, climate change is considered to be among the most serious current global environmental threats, and it could be considered as one of the most significant factors in future species extinction. (Pimm et al, 2006, Stachowicz et al, 2002). McLaughlin et al, (2002), reported that extinctions of two populations of the checkerspot butterfly (*Euphydryas editha bayensis*) were caused by a combination of habitat loss and regional climate change. Dang et al (2007) analysed instrumental records of earth surface temperatures and found pronounced warming trends over the major biotic regions, starting from the beginning of the 20th century. In their study, global land cover classification data were used to divide the globe into seven regions to study surface temperature changes over different vegetation/surface classes. Statistically significant warming was found from the year 1900 over all regions (except for the ice sheets over Greenland and Antarctica), and an anthropogenic warming trend was detected in six out of seven regions (Dang et al, 2007). Climate change could have drastic effects. It may alter species distribution, abundance, phenology, morphology and genetic composition (Baillie et al, 2004).

Invasive alien species are another major threat in addition to habitat loss and climate change. Whilst it may be possible to find a way of reversing some aspects of global change through societies taking appropriate action, some changes are permanent (Mooney and Cleland, 2001). This is true for biotic exchange, where the mixing of formerly separated biota, and the extinctions these introductions may cause are essentially irreversible (Mooney and Cleland, 2001). Some species introduced into new geographical areas from their native ranges wreak ecological and economic havoc in their new environment, with islands in particular being the recipients of the largest proportional numbers of invaders (Strauss et al, 2006, Mooney and Cleland, 2001). Invasive species bring a variety of threats which can lead to extinction, from direct predation and competition to hybridisation and displacement such as the grey and red squirrel in the UK (Mooney and Cleland, 2001). A population which exhibits adaptive response is more likely to persist when challenged by an invasive species, such as recorded in Australian snakes which display morphological adaptations, reducing their vulnerability to invading toxic cane toads which were introduced in 1935 (Phillips and Shine, 2004).

It is also important to recognise that threats can act synergistically, and therefore need to be dealt with collectively (Baillie et al, 2004, Fahrig, 2001). Climate change and exotic species are two major threats that may act together to impact upon species. A study into ocean warming and non indigenous species invasions found that over long time periods (e.g. decades), warming could facilitate the establishment and spread of introduced species and that, coupled with enhanced global transport of species, increasing ocean temperatures may provide an explanation for increasing rate of invasion by non-indigenous ocean species (Stachowicz et al, 2002).

1.4 Economics and Conservation

Conservationists are unable to assist all species under threat, if only for lack of funding (Lindsey et al, 2005). All too often, conflicts of interest arise between human economic activities and biodiversity conservation, and for private landowners, endangered species could be perceived as a financial liability. (Rondinini and Boitani, 2007, Main et al, 1999). This could result in the incentive to work against conservation, as maintaining high-quality habitats that are home to or attract endangered species may create a loss of future economic options (Main et al, 1999).

Global priorities cannot be fully addressed by biological analysis alone: social and economic factors that drive biodiversity loss must be taken into account and if the extinction problem is due to human action, then modifying human behaviour must be part of the solution (Moran et al, 1997, Shogren et al, 1999). For this reason, economics do impact greatly on conservation, and a number of studies have assessed the cost of species conservation in terms of efficiency, evaluation of schemes, costs of tackling conflicts, the willingness to pay for conservation and why economics matter (e.g. Lindsey et al, 2005, Main et al, 1999, Rondinini and Boitani, 2007, Shogren et al, 1999, Stanley, 2005). Shogren et al (1999) discuss the importance of economics. They state that both human behaviour and economics help determine the degree of risk to a species, that over other expenses it is the cost of species protection which impacts decision making the most, and that incentives are critical in shaping human behaviour, and consequently species recovery.

1.41 Cost efficiency

Cost efficiency is a global problem, affecting international, national and regional efforts to conserve species. Biodiversity conservation can be expensive and ensuring that money is well spent is important if conserving maximum biodiversity is an objective (Moran et al, 1997). Cost efficiency in conservation can be gauged in terms of units of environmental goods (e.g. recovery in population numbers or area of key habitat) conserved per unit money spent (Lindsey et al, 2005).

In recognition of the importance of cost efficiency in conservation programmes, Moran et al (1997) developed an index which measures cost (investment) and benefit (biodiversity indicator, species, richness) to develop a ratio for cost benefit analysis. This 'cost-effectiveness' index could then be applied globally, combining scientific and socio-economic criteria, and used to rank countries. A high ratio indicates low threat and a higher probability of success, and lower costs. As threat and costs increase, and success decreases, the ratio also falls. The authors suggest its use in assessing the priorities for national investments, but also urge caution in interpretation, as rankings are relative and may not absolutely distinguish the performance of one country from another. The national scale may be appropriate for decision making but there is an incomplete picture of biodiversity dynamics at local and regional scales (Moran et al, 1997).

The cost efficiency of current and future conservation strategies in Southern Africa was investigated by Lindsey et al (2007), with focus on the role of donor funding in wild dog conservation. In a strategy aimed at reducing the risk of catastrophic population decline, a metapopulation of African wild dogs (*Lycaon pictus*) was established within South Africa, a process which was calculated as costing 75% of the US$380,000 spent on wild dog conservation between 1997 and 2001 (Lindsey et al, 2005). Funding in wild dog conservation is described as 'critical,' and for support to continue its use must be shown to be effective. The metapopulation scheme was effective in that it exceeded its aim of establishing nine packs, and wild dogs are now successfully established and maintained within eight reserves. However, financially, conserving wild dogs in large protected areas was found to be the most cost efficient strategy, with the establishment of the metapopulation being less cost effective, and the expansion of the programme even less so. Therefore, the authors suggested that donor funding should be directed at reintroducing wild dogs into 'transfrontier' parks when established, and at maintaining the existing metapopulations. It was recommended that expansion of the metapopulation should be limited to state owned reserves and private reserves willing to absorb the costs (Lindsey et al, 2007).

Biodiversity is a global resource, and ownership and therefore contribution to its protection should potentially fall to each individual benefiting from its existence. So are people willing to financially support protection of species? Stanley (2005) assessed the willingness of people to pay towards the conservation of endangered species in Orange County, California, USA. To do this, a questionnaire was distributed to residents, which focused upon willingness to pay additional taxes to support species recovery plans, and to assess a range of benefits which residents attach to preserving species. Results indicated a substantial positive valuation of the public good of habitat designations, with however a wide variation of bids of what they were willing to pay. The public also indicated that compared to single species, they held higher values for groups of species in an ecosystem, suggesting that habitat based conservation programmes which invariably protect a range of species, may garner more support (Stanley, 2005).

1.42 Alleviating conflicts

Species conservation can cause conflicts, particularly with people living in the vicinity of conserved wild populations of animals that can be a threat to their livelihoods or personal safety and restrict access to resources. Schemes to alleviate such issues have been in place around the world and include attempts to control predation from protected carnivores (e.g.Rondinini and Boitani, 2007), incentive and compensation schemes (Main et al, 1999, Naughton-Treves et al, 2003) and the implementation of community conservation or development programmes (e.g. Infield and Adams, 1999, Noss, 1997, Lewis and Phiri, 1998, Infield and Namara, 2001).

1.42.1 Predator control

Conservation plans using anti predator measures to tackle conflicts raised by both wolf (*Canis lupus*) and bear subspecies (*Ursus arctos marsicanus*) populations in Italy, were examined by Rondinini and Boitani (2007). Both carnivores are capable of preying on sheep, and conservation measures considered to prevent or reduce this conflict were electric fences, and guard dogs. Rondinini and Boitani (2007) used habitat suitability models to estimate wolf and bear distributions, and the potential intensity of conflict and the cost of the anti - predator measures was also estimated. Plans which aimed to conserve the two species within areas of low conflict, were compared with the cost of implementing conflict control measures in areas of high conflict. The study found that providing suitable habitat in low conflict areas was much more economically viable. Importantly however, it was recognised that conflict avoidance in this way is not always desirable, as it can drastically reduce conservation options, and currently, most existing suitable habitat for wolves and bears was found to be within high conflict areas. (Rondinini and Boitani, 2007)

1.42.2 Incentives and compensation

A scheme which incorporates incentives is introduced by Main et al (1999), who focus on evaluating costs associated with conservation of habitat necessary for recovery of the Florida panther in southwest Florida, USA. Both land acquisition schemes and permanent conservation easements were discussed and resource conservation agreements (RCA's) were introduced as an alternative. Land acquisition and conservation easements may be incompatible to many landowners, reluctant to sell their property or accept compensation below the development potential of the land. In recognising this, and the fact that native land use was intensifying, RCA's were introduced as a way of achieving habitat conservation objectives while addressing private property owner concerns. An RCA was designed to compensate landowners for sacrificing both agricultural and non agricultural development, and instead maintaining and managing native habitats. Main et al (1999) describe the conflicting views which emerged about how best to conserve panther habitat on private lands. One view was for federal, state and local agencies to continue purchasing 'priority habitat' on private lands. An opposing view argued for continued private ownership with the implementation of resource conservation agreements (RCA's), and their financial incentives. RCA's are a promising incentive-based mechanism to conserve wildlife on private lands, turning wildlife into a commodity rather than an economic liability (Main et al, 1999). However, to prove effective, they would need heavy management, with economic decisions relying on market forces, and good monitoring to prevent 'perverse incentives,' and to make sure required land management practices were properly implemented (Main et al, 1999). When compared to land acquisition and permanent compensation easements, this study found RCA's to be 200-400% less expensive. Therefore, for the assessed c.200,000 hectares of privately owned land in Southwest Florida, an RCA scheme may prove cost effective for conserving wildlife on private lands (Main et al, 1999).

In another North American example, Naughton-Treves et al (2003) explored tolerance of rural people to wolf depredation, preferences regarding wolf management, and the impact of a compensation scheme. In Wisconsin USA, predation of livestock, pets and dogs trained for hunting had been increasing. Results of a survey indicated that people who had lost a domestic animal to any predator were less tolerant of wolves than their rural neighbours who had not (Naughton-Treves et al, 2003). Bear hunters were also found to be greatly concerned by the depredation of hunting dogs, and approved of lethal control. The survey found compensation payments apparently did not improve individual tolerance toward wolves or attitudes to lethal control. Wildlife managers had hoped such payments would improve tolerance and dissuade people from killing in retaliation. Although the compensation payments did not seem to ameliorate individuals grievances against wolves, the authors state it would be a mistake to cut the programme, particularly as ceasing payments could cause retaliation and increased hostility (Naughton-Treves et al, 2003). Interestingly the proportion of landowners using their land for recreational activities was increasing and the livestock producing and bear hunting population was decreasing. It was thought that this may produce higher tolerance, yet ironically, the increased development may further degrade and reduce wild habitat available for the wolves (Naughton-Treves et al, 2003).

Incentive and compensation schemes have also been used in developing nations with varying success. In Botswana, the Department of Wildlife and National Parks is responsible for running a scheme which compensates for livestock depredation by wild animals (Selebatso et al, 2008). However, cheetah are excluded from the scheme, and the additional ban in 2000, of killing of problem cheetah may have contributed to low tolerance from farmers (Selebatso et al, 2008). Selebatso et al (2008) found farmers to be generally supportive of cheetah conservation, although some felt cheetahs should be confined to protected areas. It is suggested that paying compensation for cheetah livestock kills could help the government understand the extent of the conflict, as currently farmers consider there to be no point in reporting livestock losses to cheetah when there is no compensation available (Selebatso et al, 2008). Expanding the compensation scheme could alleviate conflicts and increase understanding however, the costs and benefits of such an expansion would need to be considered (Selebatso et al, 2008).

Crop raiding by elephants is widespread in both Africa and Asia and is a major conservation challenge with its impacts acting to erode local tolerance and impede conservation efforts (Graham and Ochieng, 2008, Jackson et al, 2008, Sitati et al, 2005, Sitati and Walpole, 2006). In Africa, human-elephant conflict compensation schemes are rarely used, due to the failure or unmanageability of the programmes, and the logistical problems of relying on officials to deal with problem elephants (Sitati et al, 2005, Sitati and Walpole, 2006). This means that farmers must rely on themselves to try to prevent crop raiding (Sitati et al, 2005, Sitati and Walpole, 2006). Instead of compensation schemes, studies have focused upon finding effective ways for people to combat the problem of crop raiding elephants before it causes the damage, by not only identifying more susceptible areas, but also by testing various techniques. Particularly important prevention factors were early detection of elephants prior to their entry into a farm, increased guarding effort and the use of deterrents such as fire (Sitati et al, 2005). Other methods used with varying success include passive barriers (e.g.ditches, fences, walls, hedges) and active deterrents (e.g. shouting, banging tins and drums, throwing stones, and burning chillies *(Capsicum spp.)* with active guarding and deterrents being better than passive barriers alone (Sitati and Walpole, 2006). Problems with cost, labourer availability and lack of co-operation between farms and communities may limit the effective use of such deterrents (Sitati and Walpole, 2006)

Jackson et al (2008) suggest an alternative to compensation schemes, with the incorporation into conservation plans of a 'performance payment approach'. This would be designed as a direct payment rewarding farmers for living with elephants rather than compensating individuals for losses (Jackson et al, 2008). This in turn would prevent the lack of incentive to adopt new or revise current practices to reduce crop raiding, due to a compensation scheme being in place (Jackson et al, 2008). Such a scheme could be more successful and easier to manage in conserving many species whose protection conflicts with humans. By supporting communities in this way, people are not only empowered, but such a conservation programme which contributes to alleviating the problem before it occurs may well be more effective than compensation without prevention.

1.42.3 Community conservation

Throughout the tropics, conservation organisations have sought to integrate economic development with conservation projects, in particular, with wildlife managers attempting to include local communities in protected area management through conservation development projects, and community conservation initiatives (Infield and Adams, 1999, Noss, 1997). Both of these schemes assume that nature conservation is impossible without the support and participation of local people, and the expectation is that communities will become vital allies in the wildlife management effort (Lewis and Phiri, 1998, Noss, 1997). In reality, such schemes have achieved varying success.

Infield and Adams (1999) discuss a 'park outreach' programme in a forest reserve established to protect gorillas in Uganda. Here, the strategy of using conventional protected areas is problematic due to high illegal use of the forest for meat, timber and agriculture, caused by a genuine need for land and food as residents live below the poverty line. Such poverty acts to exacerbate local perception that the land was unfairly seized by the government following evictions. Community support or tolerance for the protected area has however been achieved through a community conservation programme, which is reliant upon internal donors, international tourism (predominantly gorilla treks), and continued local support. This programme has moved from education, to revenue sharing, to consumptive resource use in under 10 years, and has bought time, some goodwill, and initiated institutional development to address both local economic needs and conservation goals (Infield and Adams, 1999). However, despite initial success, both the park and the community conservation programme are regarded as fragile (Infield and Adams, 1999).

Community attitudes to a similar programme were explored by Infield and Namara (2001), around Lake Mburo National Park, Uganda. The area was made a national park in 1983, and a community conservation unit set up in 1992. At this point, relations between the people and park staff were so hostile that a project was put in place to develop interaction. Since then the community conservation programme has been involved in education for local schools and adult groups, funded community development projects, supported institutions, initiated resource access and reduced conflicts with wildlife with fences, training farmers and providing seeds and seedlings. In economic terms, the costs levied by the park showed a negative balance, however the survey showed that communities benefiting from the programme were significantly more positive towards the park and wildlife than communities that did not (Infield and Namara, 2001). However, seven years after the start of the programme, the study found that communities were not more positive towards conservation, they were more critical of management, demanded more support and resources than they had received and high levels of poaching and illegal grazing continued (Infield and Namara, 2001). Overall the achievements of community outreach were found to be fragile and easily undone (Infield and Namara, 2001).

A basic determinant of the success of a community conservation scheme may be if individual households are adopting land-use practice in response (Lewis and Phiri, 1998). In their study, Lewis and Phiri (1998) studied the use of wire snares for catching wildlife, and analysed their use as a potential indicator to evaluate community support and understanding for a community conservation programme. The use of snares was found to be so high that they could actually undermine the programme meant to return revenues to the people. Results suggested that residents have adopted snaring as a solution to economic hardship and food shortages, and without increased food and improved finances, residents were unlikely to stop. The problem may even be exacerbated by high visibility donor money - far in excess of money available within the programme which may act to undermine the perceived value of wildlife. Lewis and Phiri (1998) state that primary objectives of supporting local residents need to remain the focus of community conservation projects, and support needs to be legally protected, if such projects are to provide a realistic approach for rural development and conservation in Africa.

Noss (1997) discusses challenges to nature conservation including community conservation programmes, based on field research in the Central African Republic. A number of factors were identified which caused a community structure breakdown, or caused successful programmes to undermine their own objectives. Community conservation or development programmes may cause immigration of people into the area, and the people in the area may be of varied ethnicity, causing potential problems with loyalty across ethnic lines. Programmes may also have to deal with resource tenure problems, causing such issues as open access to resources to outsiders. Economic diversification can also be a factor, where people seize opportunities when they exist as they will not last. Finally, a lack of conservation ethic among local residents can be a major issue, where there is no concern if exploitation is sustainable as they will switch to other resources which may become valuable at a later date. Noss (1997) states that to address such challenges fundamental socio-economic change will be required.

The economic factor in conservation is indeed a critical one, with most if not all endangered species and habitats reliant upon funding or an economic reason for them not to be lost. Conservation programmes have to be cost efficient to be viable, and it may be that schemes focused on mixed species or and/ or habitats are most effective and financially robust. As human populations increase, particularly in developing regions, pressure for resources rises and conflicts undoubtedly occur. Community conservation programmes seem to be fragile, with positive work easily undone, and a sense that local people will always want more, a problem exacerbated by potential immigration into communities with such schemes in place. Schemes which compensate people for losses due to wildlife have also been problematic, and seem largely to be failing. Rather than re-enforcing that the presence of wildlife is not good by paying compensation, schemes which make reward payments could be more positive. By rewarding people for supporting wildlife, with incentive payments for leaving land available, or rewarding people for living with wildlife and its impacts, not only are payments guaranteed and are potentially easier to manage, but people may more readily accept their wildlife as a commodity rather than a liability.

1.5 Conservation strategies

Awareness of the benefits of conserving biological diversity is growing rapidly in many countries, but it remains to be seen whether conservation efforts will increase fast enough, in relation to the rate of destruction, to preserve much of the natural diversity that existed in the last century (Lande, 1988). As well as an ethical dimension to conservation, there may be practical reasons, as areas may hold species of potential medical, agricultural, recreational and industrial value, with a failure to protect them having disastrous consequences (Lande, 1988). Our responses to the impending extinction crises can be categorised under three headings: conserving hotspots, habitat conservation and species conservation.

1.51 Conserving hot spots

Few topics in conservation biology have received as much attention as hotspots of species diversity (Ceballos and Ehrlich, 2006). Myers et al (2000) focused on mammals, birds, reptiles and amphibians, and identified 25 terrestrial hotspots designated for priority conservation based on species endemism and degree of threat. These 25 hotspots were located in a range of habitat types, predominantly tropical forests, nine hotspots were island areas and 16 were located in the tropics, largely in developing countries where threats are greatest and conservation resources scarcest. In total, the 25 hotspots had lost 88% of their primary vegetation, and the hottest hot spots were identified as Madagascar, the Philippines and Sundaland (Myers et al, 2000). It is suggested that through protecting these hotspot areas, more could be achieved towards stemming the current mass extinction, than through any other measure (Myers, 2003, Myers et al, 2000).

In their study of over 4000 non marine mammal species, Ceballos and Ehrlich (2006) assessed and uncovered general patterns in global species distribution. They found that threatened species were concentrated in regions with high species richness but also high human activity. Higher concentrations of threatened species were found to occur in tropical regions of the Western hemisphere, Africa and Asia. Mammalian hotspots of species richness were found in Central America and Northern South America and in equatorial Africa, especially in the East. Most biodiversity was found to lie within developing countries (Ceballos and Ehrlich, 2006).

Although hotspots may indicate areas of high diversity and where species are likely to be threatened there are dangers inherent in the approach. One issue is that species ranges may change as a result of climate change, and a second is that conservation biologists and managers must also carefully consider conservation priorities outside the physical scope of species diversity hotspots (Ceballos and Ehrlich, 2006): many of the species outside of tropical moist forest and Mediterranean shrub lands would fall into this category (Ginsberg, 1999). Myers (2003) does state however, that in using the hotspot approach and conserving the 1.4% of the Earth where the most endangered species occur, this allows for the setting of conservation priorities, but importantly does not mean other areas are of no importance.

Cardillo et al (2006) recognise that global conservation prioritisation can emphasise areas with the highest species richness or areas with many species at risk of extinction, but that these strategies may overlook areas with species which have certain traits which make them more vulnerable to potential human impact, even if that impact is currently low. An extension to the hotspot approach is suggested, which can incorporate patterns of latent extinction risk into conservation planning, thus anticipating and predicting species declines before they begin. Latent risk can be thought of as a measure of the potential for a species to decline rapidly toward extinction, and is calculated by subtracting the current extinction risk of a species from the extinction risk predicted by its biology (Cardillo et al, 2006). A strong negative latent risk indicates species where extinction risk is in excess of that expected from their biology, and high positive latent risk values indicate species for which their biology makes them sensitive to human impact (Cardillo et al, 2006). Their study indicated the presence of 'latent risk' hotspots for mammals. These incorporate not only high biodiversity areas, but also currently under - prioritised areas, where biodiversity may be low at present but where the potential for future loss is severe. They state that latent risk hotspots tend to be in less heavily disturbed regions with comparatively high wilderness value, and it is suggested that by incorporating latent risk patterns into global conservation planning, it may prove one of the most cost-effective means of protecting biodiversity in the long term (Cardillo et al, 2006)

1.52 Habitat conservation

Conservation has traditionally been associated with protection strategies such as the creation of reserves, protected areas or parks (Turner et al, 2006, Brooks et al, 2004, Burns et al, 2003). Protected areas are a major tool for habitat protection, however they alone may not be enough for some species with specific threats: defending individual habitat patches, particularly nature reserves, albeit essential, may only slow the rate of species loss and not prevent it. (Baillie et al, 2004, Spellerberg, 1996). Also, the opportunity for setting aside new reserves is now limited given human population growth and migration into pristine areas (Caro et al, 2004). This pressure can also cause existing reserves to be regarded as islands, with their areas being far smaller than the geographical ranges originally occupied by the species they were designed to protect (Vesarhelyi and Martin 1994). These islands can then act to separate groups of the same species, affecting intrinsic survival factors such as population size, spatial distribution, patches of suitable habitat, and dispersal rates between them (Lande, 1988). There are also many species not yet covered by a protected area (Baillie et al, 2004).

A recently highlighted problem of using protected areas to conserve species is that some species are also already beginning to respond to climate warming trends with recorded shifts in range distribution and phenology (Burns et al, 2003), thus affecting the effectiveness of designated protected areas. Burns et al (2003) studied the effects of rising CO_2 levels on North American national parks and suggested that the parks were not expected to protect current mammalian species within park boundaries due to predicted losses in species diversity (due to climate mediated shifts). There were also predicted influxes due to vegetation changes. These resulted in a shift in mammalian species composition and fundamental changes in community structure (Burns et al, 2003). Such impacts on vegetation due to climate change were also explored by Thuiller et al (2005). They predicted the potential consequences of climate change on 1350 plant species in Europe. For the purpose of their study, they assumed there would be no vegetation species migration out of their current range. Their study predicted more than half the species considered would become vulnerable or committed to extinction by 2080 (Thuiller et al, 2005). Such evidence suggests that relying on existing protected areas to conserve future biodiversity is inadequate. For conservation to succeed, the extent of habitat loss in currently unprotected areas must be greatly reduced. Examination of the best way to extend parks into networks or the implication of species range changes and the need to move protected boundaries is required for protection to remain the best approach for future conservation.

The protection and restoration of natural habitats is still considered the best and cheapest method of preserving the biological diversity and stability of the global ecosystem, and therefore this should be the first priority for conservation (Fahrig, 2001, Lande, 1988). Bruner et al (2001) examined a number of factors impacting on existing designated parks in tropical environments. The claim that the majority of parks were 'paper parks' (parks in name only), was found to be unsubstantiated, and the designated parks were found to be effective in preventing land clearing, but were in need of support to protect against other threats, such as hunting. Their findings suggested that parks should remain a central component of conservation strategies (Bruner et al, 2001).

1.53 Species Conservation

Retaining viable populations in their native habitats is an essential conservation response for ensuring long term persistence of a species (Baillie et al, 2004). As discussed earlier, environmental managers are faced with significant challenges in protecting species, such as limited funds, human population growth, a plethora of specific threats and all in the face of changing climate (Burns et al, 2003, Myers, 2003). The priorities for the allocation of resources to species conservation, such as time and money, are often based primarily on an assessment of threat (Master, 1991).

The Red Data Book is a concept which was pioneered by Sir Peter Scott during the 1960s, and with contributions from zoos, aquaria, other animal collections and the media, it is largely responsible for the growth in public awareness of the problem of depletion and possible species extinction (Magin et al 1994). Today, the IUCN red list of threatened species attempts to be a comprehensive and scientifically rigorous resource. It is based on information provided by scientists, naturalists and conservationists, much of it collated by IUCN/SSC specialist groups, detailing the global conservation status of plants and animals (Rodrigues et al, 2006, Magin et al 1994). The Red List is data driven, receiving primary data and inputs from global networks of experts and using objective criteria for estimating extinction risk and to allocate each species to a specific threat category (Rodrigues 2006). There are nine categories, extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened, least concern, data deficient and not evaluated (IUCN, 2004, Baillie et al 2004). Repeated red lists can provide valuable warning and monitoring of emerging conservation issues (Rodrigues 2006), and it is this assessment of threat from which much species conservation action is based.

Unfortunately, financial support from government and private sources is quite limited and usually materialises only for species with substantial public appeal (Snyder et al 1996). These species, however may have a much wider influence – their existence may directly support others (keystone), arouse public sympathy and can be used to raise awareness and funds through conservation campaigns (flagship), and which if given sufficient habitat area will bring many other species under protection (umbrella) (Caro, 2003, Caro and O'Doherty, 1999, Simberloff, 1998). Flagship species have been used to raise funds and public awareness globally, for example the giant panda used as the World Wildlife Fund (WWF) logo, and locally with the use of birds or mammals as emblems (Caro et al 2004, Caro and O'Doherty, 1999). A crucial role of a flagship species is to provide the local public with direct experience to which they can relate the need for conservation of habitat (Dietz et al 1994). Large, charismatic taxa such as cats, elephants, and primates are important in drawing visitors into zoos (Balmford et al 1996). The umbrella species concept, however, originated as a practical solution to protect species in the wild. (Caro, 2003). Berger (1997) describes how the umbrella approach may be important where human power, funding and expertise are limited.

In Berger's study (1997) in the use of Namibian black rhinos as an umbrella species, a critical attribute for such a species to possess was identified as a high probability of persistence - an attribute that was actually lacking. However, it was stated that desert rhinos possess huge home ranges, and the area required to sustain a viable population would contain sufficiently large populations of other species. Therefore although long term viability was questioned, this does not mean these rhinos couldn't be considered as meaningful umbrella species (Berger, 1997).

These 'surrogate' or 'focal' species concepts have been advocated for the management and conservation of natural environments (Zacharias and Roff, 2001, Caro and O'Doherty, 1999), however, the effectiveness of the strategy has been questioned (Caro et al, 2004, Roberge and Angelstam, 2004, Caro, 2003, Caro and O'Doherty, 1999, Simberloff, 1998, Andelman and Fagan, 2000, Berger, 1997, Lambeck, 1997). Simberloff (1998) discusses the applicability of using species as indicators and flagships. Vertebrate species are often chosen as indicators due to their charisma, with managers feeling obliged to monitor them in the hope that such flagships will reflect the health of the entire system. Simberloff (1998) also states that in order to determine the relative merits and number of potential umbrella species required, an analysis of costs and the likelihood of survival of each species within the umbrella would be needed, but difficult to do. Other problems with this type of management are described as the potential impact of total loss of the focus population, conflicts between management of the focus species versus the management of another species, and the overall costly and inefficient process of single species management (Simberloff, 1998). Andelman and Fagan (2000) go so far as to urge caution against using umbrella or flagship surrogates in planning reserve systems. Roberge and Angelstam (2004) evaluated studies into the umbrella species concept. They stated that conclusions so far have been based on hypothetical reserves, with no study providing a direct evaluation of the basic assumption of the concept, to show that the conservation measures directed at the umbrella species actually protect many other species. This is supported by Caro and O'Doherty (1999) who state that there is no strong empirically based argument that can be made to support the efficacy of an umbrella species in protecting others.

A suggested solution is holistic, ecosystem management, but then, individual species within that ecosystem may then have little perceived importance, with their absence not substantially affecting the whole ecosystem function (Simberloff, 1998). Simberloff (1998) suggests the concept of keystone species as being more effective than the alternatives, where certain species have impacts on many others, far beyond what may be expected from their biomass or abundance. A keystone approach would focus on understanding mechanisms within an ecosystem, may combine some attractive features of single species management, and supporting such a species may support the species it interacts with. It could be found that keystone species management is not efficient, but in researching the possibility, there would be an increase in knowledge about the functioning of the target ecosystem (Simberloff, 1998). This would aid management with an increased understanding of the species and their ecosystems (Simberloff, 1998). It has also been suggested that migratory species may make good umbrella species, and if an umbrella also functions as a keystone, then the integrity of its population partially guarantees the integrity of other species (Caro and O'Doherty, 1999)

The single species management approach, and the investigation of landscape pattern and process are apparently divergent processes, but they cannot be considered alone (Lambeck, 1997). Lambeck (1997) suggests that the attractiveness of the umbrella approach is obvious, with managers able to focus on the needs of one or a few species in order to manage whole communities or ecosystems. The described approach is consistent with the umbrella concept, but instead focuses on a suite of species, each used to define landscape characteristics which must be present within that landscape. The selection of focal species takes place after a decision making process to identify vulnerable species which can be split in to four categories: area limited, resource limited, dispersal limited or process limited. The outcome would be a list of species which could be used to define different attributes which must be present for a landscape to support its constituent flora and fauna (Lambeck, 1997).

The usefulness of these concepts or titles is to assign a species a role in a conservation programme. It must remain clear that these concepts are one conservation tool among many and should be used synergistically with other management techniques. If a pilot study does reveal the 'surrogate' to be useful as a tool for monitoring, delineating an area or for raising awareness and funds, the main conservation project should proceed (Caro and O'Doherty, 1999). It cannot be denied that the use of flagship species has been successful to a large extent when the aim is to raise public awareness, sympathy and finance for specific conservation programmes, particularly when those programmes also involve other species management techniques, such as captive breeding.

1.6 Species Management

Once a species has been identified as requiring conservation action, they have to be monitored and sometimes actively managed. Such active management may involve the establishment and maintenance of an ex situ or in situ captive population and the implementation of a captive breeding programme with the aim of increasing global population numbers. This may then be followed by the possibility of a re-introduction programme involving members of that particular species.

1.61 The Role of Zoos

Zoos and animal collections have increased public awareness of the plight of many species around the world. The first public zoos were created 200 years ago, and since then have evolved from menageries to professionally managed zoological parks and conservation centres (IUDZG/CBSG, 1993). They are established in all parts of the world and receive at least 600 million visitors globally each year, making them prime venues for people to connect with nature and to promote an increase in public and political awareness of the necessity for conservation (Rabb and Saunders, 2005, IUDZG/CBSG, 1993).

Rabb and Saunders (2005) describe how zoos must promote model citizenship (recycling, energy and water conservation, non-polluting fuels, earth friendly food and merchandise) and conservation through managing species collections and expanding knowledge. This is achieved both through focused scientific study (population and reproductive biology, nutrition, behaviour, veterinary medicine), and by relaying powerful conservation messages (Rabb and Saunders, 2005). They do this through being excellent communicators, motivators, providing inspiration and the opportunity for participation, creating recognition for the value of species and natural resources (ecological, economic, cultural, aesthetic, ethical) (Rabb and Saunders, 2005). Zoo visits may be perceived as positive, and associated with feelings of relaxation, happiness, and attentive interest in animals, thus creating the environment and the opportunity to fulfil a conservation goal by educating visitors about the importance of protecting wildlife (Clayton et al, 2008, Mallaphur et al, 2008).

Zoos can also provide support for in situ conservation projects. It is an aim of the World Zoo Conservation Strategy (WAZA, 2005) to raise funds for in situ work where possible from visitors, individuals, corporations, charitable trusts or other sources. Zoological institutions also coordinate or participate in their own field-based conservation projects (practical, educational, scientific research) as well as research within the zoo (WAZA, 2005). The goal of such research is to contribute directly to the conservation of wild nature, preferably the protection of habitats and declining species (WAZA, 2005). Experienced personnel within zoos can also be influential in their involvement with specialist groups within the Species Survival Commission of the IUCN, and can also engage in political discussions, and contribute to conferences and debates (WAZA, 2005). Zoos may be considered as agents for conservation, and their animals are ambassadors for their species (Rabb and Saunders, 2005)

1.62 Captive Breeding

In recent years there has been a tremendous increase in the use of captive breeding (often in zoos) for recovering endangered species. The ambition is usually to reintroduce species into the wild. However the role of such programmes in species conservation remains widely debated with arguments ranging from allowing species to go extinct, through to fully aiding declining species (Snyder et al 1996, Tenhumberg et al 2004, Earnhardt 1999). Captive and reintroduced species populations are valuable when declining species are fully aided, they however have no perceived value should extinction be allowed to proceed (Earnhardt, 1999). Tenhumberg et al (2004) regard small populations to be inherently in danger of extinction, and that the best strategy in building population numbers quickly is through propagation in captivity. They stated that the emphasis on a captive population makes intuitive sense and that once a captive population is established, it is best to maintain it as a safety net, only releasing animals if the captive population is close to its carrying capacity (Tenhumberg et al, 2004).

Snyder et al (1996), although recognising the participation of captive breeding institutions in recovery programmes, state that captive breeding should not be invoked as a species recovery tool simply because a wild population falls below what may be determined to be a minimum viable size. They also discuss that it is often assumed that self sustaining captive populations can be readily established for most threatened taxa, but survivorship and reproduction has proved difficult for many species in captive conditions. It is also the case that for many endangered taxa, effective captive management and husbandry regimes are still unknown even after years of experimentation. Captive breeding alone, is also not a viable alternative due to limited facilities, inevitable genetic changes, phenotypic changes, a loss of wild behavioural traits and adaptation to the captive environment, even when comprehensive genetic management is used (Snyder et al 1996, Lande, 1988). This makes it difficult for captive strains to be re-established in the wild (Snyder et al 1996, Lande, 1988). It is because of such problems, causing 'progressive domestication' that any general expectations that endangered species can be preserved in captivity without significant change should be abandoned (Snyder et al, 1996). An important point is that captive breeding can become an end in itself, potentially undermining habitat preservation, with a captive population giving the false impression that a species is safe, so that destruction of habitat and wild populations can proceed (Snyder et al 1996).

Captive breeding is also widely regarded as less cost effective than in situ preservation, so far saving only a handful of species from total extinction and being most successful for charismatic mega-fauna which evoke public interest (Magin et al 1994). Propagation of endangered species in captivity, for example, in zoos and arboreta, has the potential to contribute significantly to global conservation efforts, however zoo breeding programmes rely on species reproducing reliably in captivity and there is disproportionate emphasis on mammals, particularly larger bodied taxa, even though annual per capita costs were found to increase strongly with body mass (Balmford et al 1996, Lande, 1988). The advantages of sperm banks and the possibilities of artificial insemination are clear, with reduced cost and impacts of translocating animals within breeding programmes, and the creation of an insurance policy for the future protecting donors and even entire species from extinction (Wildt, 2003). However, more research is required as the technique and the success rate is different for each species (Wildt, 2003). Critics also suggest that the overall cause of conservation could be substantially enhanced if much of the funding available to the zoo community were used to support the in situ protection of habitats and wildlife (Magin et al 1994). Gippoliti and Carpeneto (1997) suggest that there should be greater competition for funds between in situ and ex situ conservation activities as captive breeding is considered as exceptionally expensive, and not feasible for the majority of tropical species or unstable developing countries.

The pros and cons of captive breeding are issues which seem set to continue into the future of conservation biology. In conclusion here, Snyder et al (1996) state that vulnerable wild populations may still be far more viable than captive populations given the many problems associated with captive breeding and reintroduction. Also, efforts should be limited to species that truly need captive breeding, and such a programme should be properly implemented and integrated closely with protection of wild populations and habitats. It is felt by others however, that captive breeding could potentially save many species for which in situ efforts alone may prove to be inadequate (Magin et al 1994). In addition captive breeding must focus on species with realistic prospects of reintroduction as without re-introduction from captivity into the wild, conservation breeding is a failure (Balmford et al 1996, Ebenhardt 1995).

1.63 Re-Introduction

Reintroduction is an attempt to re-establish a species in an area which was once part of its historical geographical range, but in which it has become extinct (Kleiman et al 1994). Many endangered species have been reintroduced into the wild after captive propagation, examples include the red wolf (*Canis rufus*), Arabian oryx (*Oryx leucoryx*) and Pere Davids deer (*Elaphurus davidianus*) (Woodford and Rossiter 1994). Reintroductions may be considered as a successful end to a captive breeding programme, but are also inherently risky.

Smith (1999) details the successful but problematic reintroduction and recovery of the Gray wolf in North America. By the 1960's, only around 500 wolves remained on the continental United states after being relentlessly killed for preying on livestock, after their natural prey had been eliminated by man. Attitudes towards the environment began to change in the 1960s, and by 1973 the passing of the US Endangered Species

Act (ESA) required recovery of animals and plants made rare by humans. Plans to recover wolf populations in the Rocky Mountains were problematic and were met with adamant opposition from local people. Actual planning to restore wolves started in 1974, but this was not completed until 1994. By this time a special designation under the ESA had been made regarding wolves, where they had full protection to recover, but it would be legal for a livestock owner to kill a wolf if it was actively attacking livestock. Following this period, wolves were successfully captured in Canada and re-introduced to Yellowstone and Idaho in 1995 and 1996. This release consisted of 31 wolves, in seven family groups. In Yellowstone, the groups had been augmented in pens by introducing a male and female prior to the breeding season, a strategy which proved successful. Since the reintroductions, population growth has been high and by 1998 most of the suitable habitat had been settled, with wolves also occupying areas outside of the park. Major prey has been Elk, with rare livestock kills. The reintroduction programme was planned to have five years of release because of high dispersal mortality, but this did not happen, therefore only two years were necessary. Wolves may be one of the most challenging species to manage in North America, since they need large land areas and may kill domestic stock (Smith, 1999). This programme has been successful, but any wolf re-introduction requires extensive planning and public support (Smith, 1999)

Reintroduction of the Mexican wolf (*Canis lupus baileyi*) into the south western united states initially was not so successful. The Mexican wolf was extirpated from the wild by the mid 1900's (Parsons, 1999). Parsons (1999) details the programme which began with the establishment of a captive population of wolves in the 1980s following the capture of five wild wolves between 1977 and 1980. In 1998, 11 wolves were released after years of captive breeding and months of preparation and acclimatisation. The wolves killed successfully following their release, and there were no reports of livestock losses. Unfortunately, 5 of these wolves were shot, 1 went missing, 3 were re - captured and returned to captivity, and the remaining 2 alpha males were captured, paired with new females and re-released. In 1999, three additional family groups were released. At this time, the free ranging population numbered 24, with an additional litter of wild born pups. The reintroduction programme has been legally opposed, its success rests on the fates of released wolves and their offspring, and human tolerance of their presence in the wild (Parsons, 1999).

Fortunately, by the end of 2007, the wild population in Arizona and New Mexico had successfully grown through natural reproduction, translocations, and initial releases, to a minimum of 52 wolves and 12 packs (Mexican Wolf Blue Range Reintroduction Project, 2007).

The European lynx (*Lynx lynx*) has also had an interesting reintroduction history. Following virtual extinction in the 18th and 19th century in the Alps of Europe, lynx were reintroduced in the 1970s into several sites (Breitenmoser et al, 1999) Unfortunately, after subsequent releases, the exact number of lynx reintroduced is unknown, there was no habitat evaluation prior to release, little or no post monitoring or research at the release sites and today lynx are permanently present in only two regions of the Alps (Breitenmoser et al, 1999). The lynx found adequate habitat and prey, but poor acceptance from people, with illegal killing still a significant threat (Breitenmoser et al, 1999). Breitenmoser et al (1999) identify three important considerations when reintroducing large carnivores. These are that the establishment of a viable population may take some decades, the site considered must comprise the whole area of recovery and not just the release sites, and involvement of the public in order to gain broad acceptance is crucial with both recovery plans and subsequent management being communicated (Breitenmoser et al, 1999). What this example shows is that good planning, management and monitoring may act to maximise the potential success of a species reintroduction.

Wilson (*2004*) discusses the feasibility of reintroducing large carnivores into the UK, and suggests that due to a lack of suitable habitat and public opposition, reintroducing wolves (*Canis lupus*) and brown bears (*Ursos actus*) may meet with substantial opposition: the Lynx (*Lynx lynx*) may merit assessment, but there are two principle arguments against a reintroduction - the lack of suitable forest habitat and the potential impact on rare native wildlife. Hetherington et al (2008) however, discuss the potential habitat network available for the European lynx (*Lynx lynx*) in Scotland. Connectivity between the highlands and Southern uplands was found to be weak but with mitigation efforts to reduce the barrier impact of busy roads, movement of lynx could then be facilitated. Also, based on prey availability, it was estimated that Scotland could support a population of around 400 lynx (Hetherington et al, 2008). Therefore with good planning and management, the potential of reintroducing a large carnivore into the UK may be possible, but reliant upon public support and prior habitat management.

A good example of a successful re-introduction story is that of the red kite in the UK. From fewer than 100 pairs remaining in Wales, a series of reintroductions from 1989 onwards has resulted in more than 500 breeding pairs surviving in seven localities outside of Wales (RSPB, 2007). There are still threats such as illegal poisoning, secondary poisoning and interference, but with continued support from landowners and managers, the public, and with continued protective legislation, the red kite's recovery can be considered as one of the 20th centuries conservation success stories (RSPB, 2007).

Other recent successes in avian reintroductions include the Mauritius Fody and the Echo parakeet (Cristinacce, 2008, Woolaver et al, 2000) Cristinacce et al (2008) describe a programme to establish a population of critically endangered Mauritius fodies on the island of Ile aux Aigrettes, which began in 2002. This involved harvesting threatened nests from the wild, and releasing captive reared chicks. During four breeding seasons (2002 – 2006) 29 nests were harvested, 88% of these eggs were hatched, and 99% of these chicks were raised successfully. By January 2008, the released population of supplementary fed Mauritius fodies on Ile aux Aigrettes contained 50 pairs, increasing the number of breeding adults of this species by around 50% (Cristinacce et al, 2008).

Once considered the rarest parrot in the world, the echo parakeet is now one of the most intensely managed avian species, recovering from around 8 individuals, to around 100 by the year 2000 (Woolaver et al, 2000). Captive breeding and release has played a part in the species' recovery alongside other management such as habitat protection, predator control with recent emphasis on clutch manipulation, downsizing of broods, regular nest monitoring, predator control and nest cavity improvement (Woolaver et al, 2000). There is optimism that the reintroduction programme can continue to provide a strong contribution to the species recovery and has already released 13 birds to the current population, 8 of which were females of breeding age, two of which have produced healthy fledglings (Woolaver et al, 2000)

These examples have highlighted both positive and negative experiences with reintroduction programmes. Morally, the value of reintroducing species into their former environment where they are meant to roam goes without question, but are there other reasons? Rees (2001) discusses whether there is a legal obligation to reintroduce species into their former habitats, particularly as reintroduction programmes are considered an important feature of global conservation efforts. Legalities however appear to have inconsistencies, with problems based on the definition of a native species, and legal challenges to reintroductions involving predators. Rees (2001) states that the success of reintroduction programmes rely on clear scientific and legal guidance, co-operation between programme implementers and legislators, guidelines to aid the co-operation of governments, and also the support of the public. Favourable responses from public consultations however cannot guarantee the success of a species reintroduction programme, assuming it is ecologically sound, because a relatively small proportion of the human population is capable of having a disproportionately large effect, for example with legal opposition to the wolf reintroduction in America (Rees, 2001). It seems that greater emphasis needs to be placed on garnering public support in the long term, for species reintroductions to ultimately be successful.

Another consideration is the actual species at which such programmes are aimed, particularly when considering the issue of public support. Such an issue could be expected to have greater prevalence when considering a large carnivore for reintroduction (Rees, 2001, Wilson, 2004). Also, are reintroduction programmes imbalanced, and aimed at species which are more charismatic? Seddon et al (2005) discuss the possibility of there being taxonomic bias in reintroduction projects and found that the distribution of projects between plants, vertebrates and invertebrates was significantly different. The research found that vertebrates were overrepresented in comparison to their prevalence in nature, and within vertebrates, both mammals and birds were overrepresented, fish under represented and reptiles and amphibians were found to be generally in proportion to their prevalence in nature (Seddon et al, 2005). Within the mammals, it was found that the distribution of reintroduction projects generally followed the prevalence of species, with the exception of Artiodactyla and Carnivora, both of which were over-represented (Seddon et al, 2005). It was suggested that by focusing reintroductions on charismatic vertebrates, this could serve to garner public support and incidentally protect the persistence of other and lower order taxa, with the key being not to divert conservation resources away from species most in need (Seddon et al, 2005). Therefore, reintroduction programmes may even support conservation of other species, but are they broadly successful, and if not, why not?

Reintroductions of captive managed animals are widespread, and may be potentially important interventions to save species from extinction, most however are unsuccessful, particularly when captive bred animals are used (Mathews et al, 2005, Griffin et al, 2000, Earnhardt 1999). Successful projects tend to extend over many years, release large numbers of animals and with investment in local communities through conservation education and local employment (Beck et al 1994, Kleiman et al 1994). There are however many risks to consider. The causes of failure in reintroductions of captive-bred animals vary greatly, ranging from the failure to correct the original causes of extirpation, to behavioural deficiencies in released animals (Snyder et al 1996). Mortality due to predation is a principal cause of reintroduction failure (Griffin et al, 2000). Following release, the animals must find shelter, nesting material, food, establish a territory, and escape predation. In surviving to reproductive age they then must reproduce and leave viable offspring, ensuring that enough of the released animals are able to avoid the population's immediate extinction (Mathews et al 2005). The post release survival of reintroduced animals is therefore likely to be influenced by the possession of survival skills and the capacity to learn behavioural responses in a new environment, such as having the ability to withstand predators, disease and competitors. (Shepardson, 1994, Mathews, 2005). Adaptation to a release environment may be achieved by environmental enrichment, changes in rearing conditions or by pre release training (Mathews et al 2005). Griffin et al (2000) critically evaluated the usefulness of training animals to cope with predators as part of reintroduction and translocation programmes. They found that pre-release training had the potential to enhance the expression of pre-existing anti-predator behaviour, and recommended its inclusion as an integral part of pre-release propagation programmes (Griffin et al, 2000).

Another major threat to the survival of any species is the loss of genetic variability, therefore active management of populations in order to preserve genetic variability is essential and the genetic composition of captive and reintroduced populations is therefore critical (Vasarhelyi and Martin 1994, Earnhardt 1999). Earnhardt (1999) suggests that to establish reintroduced populations and simultaneously maintain captive ones, both genetic and demographic trade offs are required. While removal of captive individuals is essential for reintroduction, the selection of specific individuals alters the existing genetic composition of the captive population, thus creating a conflict (Earnhardt, 1999). There is no ideal management strategy, and it is possible that programmes with large captive or reintroduced populations may be less likely to consider genetics as a reintroduction issue (Earnhardt, 1999). Conversely managers may determine that such consideration is essential as genetic material in a small population is limited and the resources must be used wisely (Earnhardt, 1999).

One such small population where genetic considerations should figure highly is that of the Mauritius Kestrel. This species, endemic to Mauritius, has recovered from 4 known wild individuals in the 1970s, to current estimates of between 400 and 800 (Ewing et al, 2008) Ewing et al (2008) carried out a conservation genetic analysis in the form of a pedigree analysis on a small reintroduced population of the Mauritius kestrels in order to determine whether there had been genetic deterioration since its reintroduction, in addition to a recorded deterioration during captive breeding. Results showed that the already genetically impoverished kestrel was further inbred, with around 25% of all matings occurring between closely related birds. The kestrel had also suffered a loss in genetic variation. It was stated that the retention of remnant variation is an important conservation priority. With limited conservation options due to the rarity of the species, remedial strategies, such as a translocation scheme to promote artificial gene flow and preserve genetic variation, were recommended (Ewing et al, 2008). What this study highlights, is the importance of close monitoring post release. The achievement of a reintroduced population does not mean that population is safe, in fact problems, particularly genetic issues associated with captive breeding, can be exacerbated. Haig et al (1990) carried out a study on Guam Rails (*Rallus owstoni*) which were extinct in the wild in 1986, but reintroduced in 1989. The aim of the study was to determine the management option which best replicated the genetic diversity of the founder population. It was illustrated that some of the most common population management or reintroduction approaches may result in a significant loss of genetic diversity, however, certain genetic management options, such as choosing pairs which equalise founder contribution, maximise allelic diversity and that maximise founder genomes, may actually increase it (Haig et al, 1990).

The risk of disease must also be a major consideration. All reintroductions or translocations of wild animals should incorporate disease prevention and screening procedures as there is a risk that both zoo bred and ranch raised animals, as well as wild caught stock, may bring new pathogens into a release area, possibly causing disease amongst co-existing immunologically naive wild and domestic animals (Snyder et al 1996, Woodford and Rossiter, 1994). Not only is there a risk of infection within the wild population, but animals born and bred on a distant continent will also lack immunity or resistance to infections at their release site (Woodford and Rossiter, 1994).

Snyder et al (1996) considers that although techniques in captive breeding and reintroductions have been improving, their role in the recovery of endangered species is limited, for reasons already introduced. Such techniques then, should be employed when other viable alternatives are unavailable, should not be a long term strategy, and captive breeding should always be simultaneous with efforts to maintain, augment or re-establish wild populations (Snyder et al, 1996).

1.7 Monitoring: a key tool for conservation

Human-mediated environmental changes have resulted in appropriate concern for the conservation of ecological systems, and it is now becoming increasingly important to monitor unintended consequences of these anthropogenic changes on natural populations (Nichols and Williams, 2006, Schwartz et al, 2006). It is obvious that monitoring should be an essential tool in all aspects of conservation strategies which have been introduced, including the monitoring of genetic diversity, population change following reintroduction and remaining population size in the wild.

Issues surrounding the design and implementation of effective monitoring systems have been discussed widely (Joseph et al, 2006, Nichols and Williams, 2006, Schwartz et al, 2006, Field et al, 2005, Battersby and Greenwood, 2004, Evans and Hammond, 2004, Harris and Yalden, 2004, Smart et al, 2004, Smyth and James, 2004, Wallace et al, 2004, Watson and Novelly, 2004, Carlson and Schmiegelow, 2002, Caughlan and Oakley, 2001). Such issues will be explored in chapter three of this thesis. What can be stated here is that monitoring is a key component of active conservation and/or conservation science, but it is a complex task, involving the repeated and systematic collection of data over a long time scale (decadal), in order to detect changes and provide information on status and trends (Nichols and Williams, 2006, Smyth and James, 2004, Watson and Novelly, 2004, Wallace et al, 2004). An aim of monitoring for conservation is the ability to advise on how management could be modified in order to reverse undesirable changes and better achieve conservation targets (Battersby and Greenwood, 2004).

In managing threatened species, monitoring population size is an essential pre-requisite for an effective management and monitoring programme, and recording change in response to impacts on populations followed by effective protection is crucial (Joseph et al, 2006, Smart et al, 2004, Harris and Yalden 2004). There can also be special requirements, for example, using habitat availability monitoring to detect long term trends in island species populations, or the monitoring of every element of the invasion of an alien species to detect trends in distribution and abundance (Harris and Yalden, 2004, Smart et al, 2004). It may also be considered an advantage to monitor as many species as possible, particularly common species, as any change in their population could be measured more accurately than that of scarcer species, and they may be found on more sites or in greater densities (Battersby and Greenwood, 2004).

The detection of a decline can then be viewed as a trigger for active conservation and as a mechanism for setting conservation priorities (Nichols and Williams, 2006). Bell et al (2007) reviewed results from 6 years of monitoring marine turtle nesting sites in the Cayman Islands. Intensive monitoring was found to raise resource constraints for wildlife managers. However it provided a baseline for future monitoring, and meant correlative analysis could be achieved (Bell et al, 2007). The surveillance of threats such as egg poaching was also possible, leading to alleviation measures protecting egg clutches from illegal off take (Bell et al, 2007).

Surrogate species can be incorporated to monitor or solve conservation problems, and indicator species can be an effective monitoring tool (Caro and O'Doherty, 1999). Landsberg and Crowley (2004) describe how plants are not only components of biodiversity in their own right, but can also be useful indicators, reflecting the physical environment (climate, weather, topography, soils), responses to land use pressures, and they are also relatively easy to measure and monitor. Where they have limited utility is in monitoring specific threats to non - plant species, e.g. to monitor the impact of a new predator. Where plants can be used in this situation however, is to indicate the impact of an alien species on the habitat (Landsberg and Crowley, 2004).

Monitoring can not only be based on habitats or direct populations - genetic monitoring has also proved to be a powerful tool. Schwartz et al (2006) describe how DNA and population genetic data can provide valuable information for monitoring both captive and natural species of management, conservation and ecological interest, information which may often be difficult or impossible to obtain via other methods. This type of monitoring is already useful in evaluating the effects of habitat fragmentation, and in monitoring genetic changes in captive populations, as well as genetic consequences of releasing captive bred animals into wild populations (Schwartz et al, 2006). Although DNA markers may seem an added expense, they can replace expensive field costs involved in other techniques (Schwartz et al, 2006).

Whereas research activities are adaptive and relatively quick to develop, test and review, monitoring systems are not so, there is little opportunity to review and adapt the programme easily to answer new questions, as they require consistency over time (Watson and Novelly, 2004). The decision to embark on a monitoring system should only be made once it has been established that it is the optimal way to inform management on the best decision to be made, before resources are committed to the design and implementation of an unnecessary system. (Joseph et al, 2006, Watson & Novelly 2004). One problem is how to choose between monitoring methods, and a key factor is how much money is available (Joseph et al, 2006) Re-current funding for a consistent monitoring programme, with outcomes only evident some years into the process, can be a problem, so to be successful long term, benefits of such a programme must justify the costs involved (Watson and Novelly, 2004, Caughlan and Oakley, 2001)

The process of developing a monitoring system is complex, involving conception, planning and delivery, and it is in fact defining the purpose of a monitoring programme that may be the most challenging, (Landsberg & Crowley 2004, Smyth and James, 2004, Watson & Novelly 2004, Caughlan and Oakley, 2001). In some situations, monitoring of a biological system is required before active management (Nichols and Williams, 2006) However, Watson and Novelly (2004) describe the considerable investment made into the research and development of monitoring techniques and in implementing range monitoring systems across Australia from the mid-1970s. In many cases, these techniques were never put into operation, and the range-monitoring systems themselves were discontinued before reporting on a single reassessment cycle. Therefore, if the purposes are poorly understood and unfocused, outcomes of monitoring programmes may then result in expensive, ineffective and possibly counterproductive management action (Smyth and James, 2004).

Many key attributes of an effective monitoring system have been identified. These will be explored in chapter three, but in short, key attributes include good theoretical knowledge, identification and prioritisation of goals and purpose, short and long term objectives, recognition of limitations, large spatial coverage monitoring a variety of species and/or habitats, use of good data collection and analytical techniques and available resources, regular feedback and to be achievable, sustainable, efficient and overall cost effective – minimising financial costs but maximising the benefits (Joseph et al, 2006, Nichols and Williams, 2006, Schwartz et al, 2006, Field et al, 2005, Battersby and Greenwood, 2004, Evans and Hammond, 2004, Harris and Yalden, 2004, Smart et al, 2004, Smyth and James, 2004, Wallace et al, 2004, Watson and Novelly, 2004, Carlson and Schmiegelow, 2002, Caughlan and Oakley, 2001) . Another important element is longevity, the longevity of a monitoring system is crucial to its value; a monitoring system does not become of value until it has a significant past (Wallace et al, 2004)

It must be kept in mind that the monitoring system is no more than a tool used to help answer certain questions, but irrespective of scale, all aspects of monitoring design can be informed and controlled by theory and hypothesis which underlie it, with objectives determining the conclusions and actions that follow (Nichols and Williams, 2006, Field et al, 2005, Watson and Novelly, 2004).

1.8 Research Outline: Managing and monitoring endangered species

1.81 Justification

Effective and successful management and conservation strategies require a thorough grounding in conservation biology, where factors contributing to species extinction are understood, and where the theory and practice of monitoring and managing endangered species occupies a prominent place (Smith et al, 2006, Vasarhelyi and Martin, 1994).

Many key conservation issues have been highlighted by the introduction. Evidently, environmental change induced by human life is intensifying and global species extinction rates are increasing, with vertebrates seemingly at great risk.

An understanding of the broad geography of endangerment is vital to review the effectiveness of individual conservation actions and to identify critical areas in which to concentrate efforts. It is however worrying that the 'hot spot' approach to conservation action may act to exclude extremely valuable natural commodities. Needless to say, conservation action is essential and the value of individual habitats and species cannot be overstated. The conservation of habitat and species should go hand in hand, with habitat conservation forming a critical element of any conservation programme aimed at a species.

The introduction outlines some of the many threats which may be acting together to deplete biodiversity. Principle threats include habitat loss, hunting and harvesting, alien species, and increasingly now and into the future, climate change. Identifying the specific threats that endanger species is essential in any management and monitoring strategy to protect them. In fact, much conservation action is based on the assessment of threats to a species, for example, through the IUCN red list categorisation.

Once a species has been identified as requiring conservation, it requires management and monitoring, but are such programmes effective in protecting the species for which they are designed? There may be a way of measuring if the results of species management programmes and monitoring systems satisfy the effort. In other words can success be measured for example in relation to species status and trend? It may be possible to determine if species with management and monitoring programmes have an improved status or trend compared to those without, and to identify characteristics of species who have management and monitoring, and those who do not. Target species can also become conservation ambassadors, but once they are assigned this role, are they effective tools, and do the species which could be described as ambassadors receive more research and monitoring? Does active species management have an effective role in global conservation or is there evidence that management, such as captivity, actually promotes depletion in the wild? If that is the case, then the success of species management such as captive breeding and reintroduction could be limited on a global scale.

Monitoring has been introduced as a key tool in active conservation programmes, but how widely is it implemented? The principles of research and monitoring exist widely but they may not be implemented or carried out in the correct way. There may be both good and bad research and monitoring strategies in use, and it could be possible and useful to identify a good standard. The application of such theory can then be applied to monitoring programmes which are in use, and it can then be discussed if enough conservation strategies use effective monitoring. Also, having identified elements of a good monitoring system is it possible to design one which is powerful enough to answer management questions but is also cost effective to run?

In order to promote successful species conservation there requires a greater understanding and important communication of both the magnitude of threats and alleviation measures employed. Management and monitoring techniques which are already under way, or which need to be implemented, must be developed and improved specifically for each species, but by incorporating broad scientific knowledge, so that as a whole such programmes can move forwards and effectively fight the high risk of extinction facing global biodiversity.

1.82 Aims

The goal of this research is to evaluate the role of management, research and monitoring in the conservation of endangered species. The focus is on critically endangered and endangered terrestrial mammals listed as such by the IUCN 2004, with particular reference to the black rhino in Kenya.

1.82.1 Principle aims:

1. To identify the geographical and taxonomic patterns in the types of threat faced by mammals and the strategies employed in their conservation.
2. To determine which species have management, research and particularly monitoring programmes in place
3. To examine if there is a *gold standard* of management and particularly monitoring practice
4. To judge the effectiveness of management and monitoring programmes for conserving threatened land mammals
5. To develop a monitoring programme for use in the conservation of a critically endangered species

Terrestrial mammals are the focus of this study as, for many, their biology is well known, they feature in species management programmes, are important conservation ambassadors and unfortunately many are threatened with extinction. The two IUCN threat categories of 'critically endangered' and 'endangered' include a large number of animals which are under extreme threat of extinction, a sub sample of such species will be analysed. Species within these categories are also thought more likely to have research and monitoring programmes in place, than those that are less threatened. To achieve the principle aims, four orders of critically endangered and endangered land mammals are focused upon: Artiodactyls, Perissodactyls, Carnivores and Primates.

1.82.2 Aims of Chapter 2: Global analysis

1. To identify the geographical and taxonomic patterns in the types of threat faced by terrestrial mammals and the strategies employed in their conservation.
2. To identify species with a good level of management, research and monitoring in place.

Initially, I will carry out a global review of critically endangered and endangered land mammal species. This will identify geographical and taxonomic patterns in the types of threat faced by mammals and the strategies employed in their conservation. Particular emphasis will be placed on the presence of research and the type of monitoring programmes employed. A random forest analysis will be used to classify species on the basis of individual characteristics and to identify possible predictors for determining a species status, trend and level of research and monitoring. Concepts such as flagship and umbrella species will be considered and a number of species will be identified as existing or possible conservation ambassadors.

1.82.3 Aims of Chapter 3: Species management and monitoring

1. To increase understanding of practical management and monitoring strategies employed for threatened land mammals.
2. To examine if there is a *gold standard* of monitoring practice
3. To judge the effectiveness of management and monitoring programmes for conserving the threatened land mammals

Following the global review, twenty species identified as having monitoring programmes, and which could be considered as flagship species, are subjected to a literature review to compare the monitoring strategies used, and to give an overview of their results to date. I also use direct contact with conservation professionals to develop case studies on the research and monitoring associated with the black rhino (*Diceros bicornis*) in Kenya, Iberian lynx (*Lynx pardinus*) in Spain, Californian Channel Island fox (*Urocyon litteralis*)in North America and the giant panda (*Ailuropoda melanoleuca*) in China. The results of the literature review, interviews and field visits are analysed and discussed. A set of criteria for a well managed and monitored species is developed and assigned to information collected about the 20 monitored species. A list of best practice for monitoring is outlined and a flow diagram for designing a monitoring system is suggested.

1.82.4 Aims of Chapter 4: A vegetation monitoring system for a black rhino sanctuary

1. To develop a monitoring programme for use in the conservation of a critically endangered species
2. To design, test and implement a monitoring system powerful enough to detect a change in browsing damage within a black rhino sanctuary over a 5 year period
3. To incorporate both power and cost effectiveness into the monitoring system design and address the problem of bias caused by different people collecting monitoring data.

Having identified some of the requirements and outcomes of successful monitoring programmes, a monitoring system for the Black rhino is developed and tested. This has particular emphasis on monitoring the impact of rhinos on their habitats and possible interactions with other species in enclosed reserves, which is one of the key management issues in rhino conservation.

Chapter Two: Global Analysis

2.1 Introduction

The 2008 update of The IUCN Red List includes 44,838 of the worlds' species, increasing from 38,047 in 2004. (Baillie et al, 2004, IUCN, 2008). These species are classified according to their extinction risk, and assigned one of nine categories (Extinct (EX), extinct in the wild (EW), critically endangered (CR), endangered (EN), vulnerable (VU), near threatened (NT), least concern (LC), data deficient (DD) or not evaluated (NE)) (IUCN, 2003). For the threatened categories (CR,EN,VU), there is a range of quantitative criteria, and meeting any one of these qualifies a taxon for listing at that level of threat (IUCN, 2003). The criteria (A-E) are aimed at detecting risk factors across the broad range of organisms and the diverse life histories they exhibit. The criteria specifically quantify: (A) a declining population (past, present and/or continuing), (B) geographic range size, and fragmentation, decline or fluctuations, (C) small population size and fragmentation, decline, or fluctuations, (D) very small population or very restricted distribution and (E) quantitative analysis of extinction risk (IUCN, 2003).

Of all the species included on the red list, 2% are Extinct or Extinct in the Wild, 38% are threatened with extinction (with 3,246 Critically Endangered, 4,770 Endangered and 8,912 Vulnerable species), 8% are Near Threatened, and 12% are data deficient (table 2.1) (IUCN, 2008). Many of the increases in these numbers are due to improved documentation for many more species (IUCN, 2008). Of the number of species which had a genuine change in Red List status between 2007 and 2008, 82% became more threatened, 18% became less threatened (IUCN, 2008).

The IUCN (2004) documents the total number of species extinctions to be 784 since 1500ad, but this is only documented extinctions, the actual number will be much higher (Baillie et al, 2004). Of the worlds' animal species, 7,266 were listed as threatened with extinction in 2004 (Baillie et al, 2004). A steady and continuing deterioration in the status of the worlds bird species has been seen from 1988 to 2008, and at least 42% of all amphibian species have declining populations (IUCN, 2008). For mammals, nearly one-quarter (22%) of mammal species are now globally threatened or Extinct, and 836 (15%) are Data Deficient. In comparison to all of the mammal orders, 5 have significantly more threatened species than would be expected: Sirenia (dugongs and manatees), Perissodactyla (equids, rhinos and tapirs), Artiodactyla (e.g. deer, antelope, cattle, sheep, goats), Primates and Carnivora (e.g. cats, dogs, bears) (Baillie et al, 2004). Of the 214 species of Artiodactyla, 38% are threatened with extinction, as are 30% of the 281 species of Carnivore, 39% of the 296 species of Primate and 82% of the 17 species of Perissodactyla (Baillie et al, 2004). Understanding the factors what make each species vulnerable to extinction is critical in the conservation of endangered species. The red list has undeniably played a large part in current efforts by providing a highly accessible resource for further conservation research, initiating conservation action, being used to direct funding and to develop in country legislation.

Conservation biology is faced with pinpointing which species are threatened, identifying why this is so, and then prescribing ways of preventing local extinctions (Michalski and Peres, 2005). Priority setting exercises tell us, at best, what to conserve first, not how to conserve it and there can be many influencing factors such as scale (e.g. political, geographical), scope (e.g. taxonomic, biotic), species (e.g. phylogenetic, biological), objectives (e.g. more species or greater viability of a species), and achievability (e.g. political, financial) (Valenzuela-Galván et al, 2008).

Chapter 1 introduced the biodiversity hotspot theory. Spathelf and Waite (2007) found only one of the 25 hotspots, Madagascar, to contain an excess of primate and carnivore evolutionary history. It was suggested that by neglecting areas not identified as hotspots, there could be potential losses of ecological productive natural areas which also have a large ecosystem contribution (Spathelf and Waite, 2007). Such a suggestion is supported by the findings of Valenzuela-Galván et al (2008) who conducted a prioritisation exercise for 47 terrestrial carnivores in North and Central America. The study identified its own hotspots but found that these could not be used reliably to direct conservation planning. Instead defining conservation priorities and proposing optimal networks representing all carnivores in a region, would direct conservation resources more efficiently.

Although habitat destruction may be considered the most serious threat to biodiversity, in reality many threats act together to make a species vulnerable. There have been studies to examine the effect of threats, and the characteristics of species that possibly make them more susceptible within primates, carnivores and artiodactyls (Chapman et al, 2006, Michalski and Peres, 2005, Price and Gittleman, 2008). Effects of forest degradation and fragmentation on primate and carnivore species in Amazonia, Brazil, were examined by Michalski and Peres (2005). The study found patches of forest occupied by a number of primate and carnivore species assemblages were significantly larger than unoccupied patches. Results also indicated that recent human disturbance within forest patches were key determinants of local extinction rate, with fragments protected from extractive activities being far more likely to retain a full complement of species (Michalski and Peres, 2005). Many primate populations are increasingly threatened by anthropogenic actions with few taxa of primates occurring outside of the tropics, most are rare with a small geographic range or latitudinal extent and /or low density, and therefore are at high risk of extinction (Chapman et al, 2006, Harcourt, 2006).

Chapman et al (2006) reviewed the causes of decline in African primates and found threats to be many, varied and complex, with the correlation among threats exacerbating their impacts. The study identified four major interrelated threats of deforestation, bushmeat harvest, disease and climate change. It is also stated that given the rate of global deforestation and the fact that primates appear to be particularly vulnerable to habitat loss, it is surprising that so few species have gone extinct in recent years. To advance conservation efforts for primates in Africa, efforts with political, socio-economic and adaptive management and research fronts will be required (Chapman et al, 2006).

For artiodactyls, Price and Gittleman (2008) state that double the mammalian average of artiodactyls are threatened with extinction. An investigation of the biological, environmental and human influences on extinction risk, found that artiodactyls at greatest risk live in economically less developed areas, have older weaning ages and smaller geographic ranges (Price and Gittleman, 2008). Different biological traits also elevate vulnerability to extinction in Artiodactyls, for example, hunted artiodactyls with slower reproductive rates are more at risk of extinction (Price and Gittleman, 2008).

Although there are no specific studies examining extinction risk of the perissodactyls, it can be said that this order, containing tapir, equids and rhinos, all have particularly large body sizes. Analysis of traits such as body size and its association with extinction risk has been carried out a lot on mammals. As a results of such studies it can be suggested for perissodactyls, as there may be an association between larger body size and higher extinction risk (Cardillo et al, 2005, Cardillo and Bromham, 2001, Collen et al, 2006, Purvis et al, 2000b), this factor may exacerbate the many other threats which act to raise the risk of extinction in this mammal order.

Much of the research into biological traits associated with extinction risk in mammals has been theoretical. Some of the more proximate predictors or associations with the success, or otherwise, of the management of highly threatened species have not been examined. A number of different success/failure measures can be used, e.g. whether a species is endangered or critically endangered, and whether their populations are known to be declining, stable or increasing, alongside a measure of the quality of management in place. It is clear that for terrestrial mammals, four orders in particular are threatened disproportionately. This chapter therefore focuses on land mammals listed by the IUCN as critically endangered and endangered (IUCN, 2004), and which belong the four orders, Artiodactyla, Perissodactyla, Carnivora, and Primates. Some of the factors which may be associated with the level of threat to a species, and which determine successful conservation will be investigated. Also, there are specific questions, such as does the presence of research and monitoring, regardless of quality, achieve anything, does it aid in preventing extinction or just allow it to be watched? Research and monitoring certainly provides a framework for wildlife managers to develop further questions, and even to notice events within species populations which occur in response to threatening factors. Does such knowledge actually provide managers with the ability to take action in alleviate threats, or to improve a species' resistance to them?

Comparisons of species trend to order and status will be made, and species status will also be compared to geographic location, range, habitat type, threats, legal protection (including CITES listing), occurrence within a protected area, and the presence of research, monitoring and species management techniques. The most significant threats will also be identified and the level of research, monitoring and species management will be graded and compared to all the variables. A small survey of public perception will also be used to act as an indication of the contribution of 'charisma' in the conservation of a species.

2.12 Aims and Objectives

2.12.1 Aims:

1. To identify the geographical and taxonomic patterns in the types of threat faced by terrestrial mammals and the strategies employed in their conservation.
2. To identify species with a good level of management, research and monitoring in place.

2.12.2 Objectives:

- To collate data on the geographic distribution, habitat type, types of threat, and conservation strategies for critically endangered and endangered terrestrial mammal species.
- To assess the levels of research and monitoring in place.
- To identify associations between the levels of research and monitoring and variables such as geographic distribution, habitat type and types of threat and species charisma and flagship status.
- To grade each species in terms of the level of species management and monitoring in place.

2.2 Method

2.21 Collating species information

Information from the International Union for Conservation of Nature and Natural Resources (IUCN) Red list (IUCN 2004), CITES (CITES 2004) and the World Conservation Monitoring Centre (WCMC 2004) websites was studied and collated. The resulting table contained more than 60 columns with information for 42 critically endangered, and 111 endangered land mammals from the 4 focus orders (appendix 1).

Variables included the scientific and common name for each species, the corresponding IUCN red list category, the year each species was last assessed and became listed as critical or endangered, the current population trend and the order of each species. For analysis, each species was given a number based alphabetically on their Latin name.

Population trend was recorded as 0 (unknown), 1 (increasing), 2(stable), 3(decreasing) and the orders were coded as 1 (Artiodactyla), 2 (Primates), 3 (Carnivora) and 4 (Perissodactyla). The number of range countries was simply recorded as a number. Many variables were recorded as 1 (presence) or 0 (absence) for each species. These variables included the continents on which each species occurred and the habitat type it can be found in. Other variables recorded in this way were threat (habitat loss and degradation, harvesting (hunting), accidental mortality, changes in native species dynamics, human disturbance, alien species, natural disasters, persecution, pollution and intrinsic factors such as range restriction, low density, high infant mortality, low reproductive success, inbreeding, skewed sex ratios, limited dispersal and poor recruitment) and inclusion in CITES listing (CITES 2004). CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) is an international agreement between governments whose aim is to ensure the international trade in specimens of wild animals and plants does not threaten their survival (CITES 2007) The species covered by CITES are listed in three appendices according to the degree of protection they need.

There were then a number of variables which were recorded as 0 (absence), 1 (presence), 2 (some), 3 (needed i.e. a clear statement of need from the IUCN, for some species a variable may be absent but not needed). These variables were protected area, legal protection, ex situ population, captive breeding programme, research (population and range, biology and ecology, trends and threats) and monitoring programme. A number of these variables were combined and scored to create two more variables: Species Management Grade (SMG) and Research and Monitoring Grade (RMG). The SMG was based on the number of species management techniques put in place for each species, namely an ex situ population, captive breeding programme and re-introduction programme. The grades were 0 (no species management technique), 1 (one technique), 2 (two techniques), 3 (all three techniques in place). The RMG was based on the information collected about each research category and if there was a monitoring programme in place. For this grading allocation of 0-5, the scores are defined in table 2.2, with 0 being the poorest grade, and 5 being the best.

2.22 Charismatic species survey

A survey involving 39 of the 42 critically endangered species was distributed to 30 members of the public from seven professions (management, care, sales and marketing, design and construction, trade, academic and those still at school). Each species was represented by clear colour picture of the same size, and where possible showing a full face and body shot (Google image 2005). Only the critical species were used as they represented a good sample size, but one that was not overwhelming for the participants, they represented all four orders, and most had a picture available for use. The three species not represented in the survey did not have a picture available. The survey asked each person to grade every animal from 1 to 3, ranging from least (1) to most (3) charismatic. Charismatic was described as 'cute,' 'humanistic,' 'pretty,' with lots of 'character', 'cuddly,' 'beautiful' and pleasing to look at, however, it was stated that every individual has their own idea on what makes an animal attractive.

2.23 Analysis

2.23.1 Simple Statistics

In order to identify the presence of simple interrelationships between variables, the analyses investigate a mixture of independent variables, and variables which may be regarded as dependent. This initial investigation analysed the variables in the random order in which they are represented in the table (appendix 1). Variables which were analysed include trend, geography, habitat, threat, protection, species management, research and monitoring. Also, by using the results of the grading system (SMG and RMG), management and monitoring was also investigated.

Initial analysis involved cross correlating much of the data set, then calculating proportions and percentages in order to identify patterns. Chi-squared tests were also used to discover any significant associations. Finally, Spearmans rank correlations and a Kruskal Wallis test, were used to explore potential relationships and differences in the results of the charismatic species survey. At the end of this simple analysis, a decision was made to use the variables of 'status', 'trend' and Research and Monitoring Grade 'RMG' as dependant variables for further investigation.

2.23.2 Random Forest Analysis.

This type of analysis and its features could prove extremely useful in categorising endangered species based on a wide range of variables. It also has the potential to be one of the best classification methods (Fielding pers.comm). This analysis has never been used to assess species endangerment, however it has been applied to large data sets with many variables, particularly with gene expression data in the medical profession. (e.g. Lunetta et al, 2004, Pang et al, 2006). The potential for the application of such an analysis to the global analysis data set was deemed to be both credible and intriguing.

A random forest™ (Breiman and Cutler,2004) analysis was carried out on the global data using the R Console programme (Liaw and Wiener, 2006). This analysis concentrates on 3 variables: status (critical or endangered), trend (unknown, increasing, decreasing, stable) and research and monitoring grade 0-5 (RMG), and investigates associations with each other and with the other variables collected (geographic location, range, habitat type, threats, the level of protection, species management). The application of a multivariate approach is important to untangle the many potential inter-correlations between the variables in the data set, and to rank the importance of the variables as predictors of status, trend and RMG.

The focus of the analysis was to reveal characteristics of species rather than distinguishing causal relationships. Characteristics were then compared with the aim of identifying, for example, if species which are increasing are more or less likely to have a good RMG score. This analysis also aimed to identify possible 'misclassifications' and so suggest which species, according to their characteristics, are predicted as being more threatened or less stable then they are currently thought to be. As the focus is to look for patterns, the three dependent variables investigated here are used as independent variables in other analyses.

Following Fielding (2007) the analysis works by randomly selecting 75% of the total data and creating a decision tree, which uses the independent variables to classify species into different scores of the dependent variable. The remaining 25% of the data (species) are then run through the tree and the success of their classification recorded. This is repeated 1000 times with random selection of species in the training (75%) and testing (25%) groups. An 'importance score' is generated for each variable which indicates how useful it is as a classifier across all of the analyses. A larger score identifies an important predictor variable, therefore indicating a more influential variable in the classification (Fielding, 2007), which in this case is classifying status, trend and RMG. Importance statistics are calculated for how important each variable is in terms of allocated species into the individual scores of trend, status and RMG and a mean decrease in accuracy score (MDA) identifies the most influential variable overall for a given category of analysis (status, trend RMG). The analysis also generates a 'confusion matrix' indicating possible misclassifications based on variable characteristics (Fielding, 2007). An example in this case would be a classification of a species as endangered (because its characteristics are similar to the other species in the endangered category) whereas it is currently classified by the IUCN as critically endangered. The species are allocated in this way by the use of 'votes', which are the equivalent of probabilities of group membership. For example at the outcome of the analysis, a species with a vote score of 0.51 for endangered and 0.49 for critically endangered will be classified as endangered, even though the decision is marginal.

Random forest has been found to be more efficient that standard univariate screening methods in ranking true disease associated with certain genetic information from data sets consisting of hundreds and thousands of single nucleotide polymorphisms (SNPs) (Lunetta et al, 2006). Pang et al (2006) used random forest to analyse gene expression data and to identify important genes and interactions between them, something that commonly used single gene based methods of analysis neglect. The analysis was found to be useful in identifying genes that were good classifiers and predictors than other single gene methods (Pang et al, 2006). Therefore, an analysis such as random forest which deals with very large data sets, may then be ideally suited and provide a way of analysing the many variables which coincide to make a species threatened with extinction.

2.3 Results.

2.31 Identifying patterns

2.31.1 Trend

When the population trend of all 153 species is examined, 41.8% have an unknown trend, 41.2% are in decline, 15% have a stable trend and only 2% of species have an increasing trend. The endangered species account for all of those with an unknown trend.

All of the 42 critically endangered species in this study have a known trend, 21 (50%) are thought to be stable and 15 (36%) are in decline. Only 2 of the critically endangered species here are thought to have an increasing trend, the red wolf *Canis rufus* and the black rhino *Diceros bicornis*. Of the 111 endangered species in this study, 64 (58%) have an unknown population trend. For those that do have an identified trend, the majority (43%) are in decline. Only 1 species is on the increase, the golden lion tamarin *Leontopithecus rosalia*, and 2 species have been recorded as stable, the Arabian tahr (*Hemitragus jayakari*) and *Microcebus myoxinus,* a primate with currently no common name. Proportionally, of all the species with an increasing and stable trend 67% and 91% respectively are critically endangered, and of those in decline 70% are endangered. Therefore, there are proportionately more critical species in the increasing, and in particular the stable trend category when compared to the endangered ones.

The known trends can be split into good (increasing and stable) and bad (decreasing). When comparing known trend to status, 54.7% of the critically endangered species have a good trend, where this can only be said for 6.4% of the endangered species (figure 2.1). There is a significant difference between species trend when compared to status (χ^2 =25.1, df=1, p=<0.001).

In each of the four orders, the majority of species are in decline. Only a small proportion in each order is stable, this is particularly true for carnivores whereby only a small number of species in this order are stable. An even smaller proportion of species are seen to have an increasing trend, none for Artiodactyla. Perissodactyla have a similar proportion of species in decline and stable, and a greater proportion on the increase compared to the other orders included in this analysis (figure 2.2). However, a chi-squared test reveals there to be no significant association between order and population trend ($\chi^2 = 14.3$, df = 3, p = 0.113).

When species trend (good, declining, unknown) is split by continent (figure 2.3), a general pattern is that most continents have more species with declining and unknown trends than good trends. When related to the number of countries each species is found in, it is clear that there are more species within 1 – 3 countries than which occur in 4 or more (figure 2.4), but there is no significant difference in trend when compared to the number of countries in which each species occurs ($\chi^2 = 0.44$, df = 2, p = 0.801).

2.31.2 Geography

The number of critically endangered and endangered species found in each continent is illustrated in figure 2.5. The greatest number of critically endangered and endangered species occurs in Asia, followed by Africa then South America. In total, the majority of species whose existence is under threat occur in Asia.

Of the critically endangered and endangered species 60% and 50% respectively have a range of only one country (table 2.3). The majority of these single country range species are found in Asia then South America for the critically endangered species. For the endangered species, most animals with a single country range are found in Asia, followed by Africa and then South America (table 2.4).

2.31.3 Habitat

When considering the habitat in which each species can be found, 12 critically endangered (29%) and 14 endangered species (13%) occur in more than one habitat type. The majority of both critically endangered (64%) and endangered species (59%) rely on forest habitat (figure 2.6)

2.31.4 Threat

The threats suffered by species under study here are listed in table 2.5. Results show that 83% and 87% of critically endangered and endangered species respectively are threatened by habitat loss and destruction. 69% and 66% respectively are threatened by harvesting or hunting. Figure 4 illustrates the threats suffered as a total by all the species under study, and clearly shows habitat loss and harvesting or hunting to be the major threats. Others include range restriction, alien species, changes to native species dynamics, accidental mortality and persecution. When considering the number of threats suffered by each species, 79% of critically endangered, and 72% of endangered species have more than one threat affecting their survival. 4 critically endangered species have 5 or more threats, these species are, from Asia, Prezewalski's Gazelle (*Procapra przewalskii*), from Africa, Ader's duiker, (*Cephalophus adersi*), from Africa and Europe, the Mediterranean monk seal (*Monachus monachus*), and from North America, the Californian channel island fox (*Urocyon littoralis*). There are 12 endangered species with 5 or more threats, these are, from Asia, the giant panda (*Ailuropoda melanoleuca*), the markhor (*Capra falconeri*), the lion tailed macaque (*Macaca silenus*), and Gee's golden langur or golden leaf monkey (*Trachypithecus geei*). From Africa, the Ethiopian wolf (*Canis simensis*), the nubian ibex (*Capra nubiana*) the mountain zebra (*Equus zebra*) and the African wild dog (*Lycaon pictus*). From Europe is the marine otter or sea cat (*Lontra feline*), from South America the huillin or southern river otter (*Lontra provocax*) and the giant Brazilian otter (*Pteronura brasiliensis*) and finally from Europe, North and South America, the northern sealion (*Eumetopias jubatus*). Of the critically endangered species 9 are recorded as suffering from only one threat, this is also the case for 32 endangered species. Of these 41 species, 25 (61%) are under threat from habitat loss or degradation, 2 (5%) are under threat from harvesting or hunting, 2 (5%) are suffering range restriction and 12 (29%) of them are recorded as suffering from an unknown threat. These 12 species may have more than one threat acting on them but currently the reason for their threatened population is unknown.

When considering what appear to be the most significant threats, on every continent over 50% of their critically endangered and endangered species are threatened by both habitat loss and degradation, and harvesting or hunting (figure 2.7). In Africa, Asia, South America and Europe over 80% of their critically endangered and endangered species are threatened by habitat loss. On most continents, the threat of habitat loss outweighs the threat of hunting except for North America where the reverse is true, and in Oceania where both threats are equal. Chi- squared analysis reveals there to be no significant association between the continent a species occurs in and the threats of habitat loss and harvesting/hunting ($\chi^2 = 0.804$, df = 5, p = 0.977)

There are 7 threats which affect more than 10% of all the species in the study (habitat loss and degradation, harvesting and hunting, accidental death, change in native species dynamics, alien species, persecution and intrinsic range restriction). Chi-squared analysis found no association between these threats and status (critical or endangered) and between these threats and known trend (good = increasing or stable, bad = declining) (status: $\chi^2 = 1.85$ df = 6 p = 0.93 trend: $\chi^2 = 7.17$ df = 6 p = 0.31). There was a significant association between the top 7 threats and research and monitoring grade (RMG) ($\chi^2 = 35.6$ df = 6 p = <0.001), whereby most species with these threats received low levels of research and monitoring (RMG <3). However, for species threatened by accidental death, a change in native species dynamics and persecution, more achieved a good level of research and monitoring (RMG ≥3) than not.

2.31.5 Protection

The number of species in this study that can be found in protected areas is 26 (62%) critically endangered and 56 (50%) endangered. Of the 16 critically endangered and 55 endangered species which do not occur in protected areas, 6 (38%) critical and 13 (24%) endangered animals are recorded as needing protected area status. Regarding legal protection, 17 (40%) critically endangered species and 38 (34%) have legal protection, of these animals 6 critical and 14 endangered species require more. Of the 25 critically endangered species and 73 endangered species which have no legal protection, 1 critical and 5 endangered species are recorded as requiring it.

Of the critically endangered species in this study 17 appear on CITES appendix 1, along with 52 of the endangered species (*CITES 2006*), where trade is only allowed in exceptional circumstances as the species are threatened by extinction (*CITES, 2007*). Of the critically endangered and endangered species, 13 and 24 respectively appear on appendix 2 (*CITES, 2006*), where species may not be threatened with extinction, but their exploitation needs to be controlled to prevent unsustainable use (*CITES, 2007*). On appendix 3, 1 critically endangered and 2 endangered species are listed, (*CITES, 2006*) where one or more range countries have asked for controls in the trade of a species (*CITES, 2007*).

2.31.6 Species Management

The number of species which have some kind of species management such as an ex-situ population, a captive breeding programme and re-introduction into the wild have been identified (figure 2.8). In total, 50% of critically endangered and 56% of endangered species included in this study have ex situ populations in zoos or private collections around the world (*IUCN 2004, WCMC 2004, ISIS, 2004*). Of the critically endangered and endangered species, 24% and 23% respectively are recorded as having a captive breeding programme, and 12% and 9% respectively are recorded as having a re-introduction programme. There are 5 critically endangered species that are recorded as being successfully re-introduced into the wild, these are the addax (*Addax nasomaculatus*), the Red Wolf (*Canis rufus*), Ader's duiker (*Cephalophus adersi*), Pere david's deer (*Elaphurus davidianus*) and the California channel island fox (*Urocyon littoralis*). The 10 endangered species which are recorded as having been re introduced are the European bison (*Bison bonansus*), the sea otter (*Enhydra lutris*), Cuvier's or edmi gazelle (*Gazella cuvieri*) the Addra or dama gazelle (*Gazella dama*) the golden lion tamarin (*Leontopithecus rosalia*), the African wild dog (*Lycaon pictus*), the European mink (*Mustela lutreola*) the Arabian or white oryx (*Oryx leucoryx*), the Orang utan (*Pongo pygmaeus*) and finally the cotton headed tamarin (*Saguinus oedipus*).

The number of species achieving each species management grade (SMG) which was applied to the management information for each species, are shown in table 2.6. In total 42% of the 153 species in this study have a species management grade of zero, meaning they are represented only by a wild population. In total, 10% of species have a SMG of 3, meaning these 15 species have an ex situ, captive breeding and a re-introduction programme. Chi-squared analysis reveals there to be no significant difference between species status and SMG ($\chi^2 = 0.041$, df = 3, p = 0.998).

2.31.7 Research and Monitoring

Evidence of research, in terms of population and range, biology and ecology, trends and threats, as well as evidence of a monitoring programme being in place, were recorded. It was found that 19 (45%) of critically endangered and 44 (40%) of endangered species have some form of research and monitoring, and 23 (55%) critical and 63 (57%) endangered animals were recorded as having no form of research at all. Of the 42 critically endangered species and 111 endangered species in this study only 8 (19%) and 16 (14%) respectively are recorded as having an established, repeated monitoring programme in place, that's a total of 24 of 153 animals in this study (16%).

Following the application of the research and monitoring grade (RMG) to each species(table 2.7), those species with an RMG of zero are confirmed as 23 (55%) of critically endangered and 63 (57%) of endangered species, that is 56% of all the species in this study who have no evidence of research or monitoring. Only 8 (5%) of animals (3 critically endangered and 5 endangered species) have a RMG of 5 where almost all aspects of research are carried out and they are recorded as having a monitoring programme in place. These animals are the black rhinoceros (*Diceros bicornis*), the Iberian lynx (*Lynx pardinus*) the Californian channel island fox (*Urocyon littoralis*) the Ethiopian wolf (*Canis simensis*) the Asiatic wild dog (*Cuon alpinus*), the Eastern or mountain gorilla (*Gorilla beringei*) the huillin or Southern river otter (*Lontra provocax*) and the African wild dog (*Lycaon pictus*). Only 7 critically endangered and 24 endangered species, that's a total of 20% of the animals in this study, scored a RMG of 3 or more, which would indicate a sufficient level of research. Chi – squared analysis reveals there to be a significant association between RMG and status ($\chi^2 = 11.1$, $df = 5$, $p = 0.049$), indicating that an endangered species is more likely to achieve a lower RMG grade than a critically endangered species, however the significance of this analysis is borderline (rounded $p = 0.05$).

2.31.8 Management and Monitoring

Of all the study species, 90 (59%) are recorded as acheiving some or all of the species management categories (ex situ population, captive breeding, re-introduction), of these, 21% also have a monitoring programme in the wild. Of those species receiving no management, only 9% are monitored. Regarding the 64 species that have some research into one or more categories (population, range, biology, ecology, trends, threats) 34% also have a monitoring programme in place. Of the species with no research indicated, only 2% are monitored.

When considering the impact of species management, research and monitoring on species' population trend, it appears that the higher the SMG (the more species management in place) the less likely the species will be in decline. (figure 2.9a). Interestingly it can be seen that proportionally, the more management that is applied, (the higher the SMG) the less likely it is for a species to have a stable population, this is also true for RMG (figure 2.9 b). Proportionally, the higher the RMG (the greater the level of research and monitoring) the more likely a species will have an increasing trend, and in general, species are less likely to be in decline (figure 2.9 b).

In comparing SMG and RMG to geographic location, it can be seen that in proportion to the number of critically endangered and endangered species each continent holds all, except for South America, have some form of species management for more than half their species (figure 2.10). For the comparison of RMG across continents, the grades have been split into minimal RMG (for grades less than 3) and good RMG (for grades of 3 and above indicating a good level of research). Only North America has proportionally more than half its species achieving a good RMG. For the remaining continents only Europe has good RMGs. When comparing the presence and absence of SMG and good RMG to geographic location, it appears that all continents have a greater amount of species management in place, than none at all, except for South America. (figure 2.11). Most continents have a higher proportion of species with no research and monitoring, than species with good levels (RMG $\geq$3), only for North America is the reverse true (figure 2.11).

2.31.9 Charismatic Species

The species included in the survey are listed in table 2.8. The top three species were the Iberian lynx, *Lynx pardinus*, the red wolf, *Canis rufus* and the Sumatran orang-utan, *Pongo abelii.* The species with the three lowest rank scores were the tamaraw, *Bubalus mindorensis,* Visayan warty pig, *Sus cebifrons,* Grey ox, *Bos sauveli,* and finally the pygmy hog, *Sus salvanius.*

The total charisma scores were used to give an independent indication of the potential impact of charisma on variables such as species trend, species management and research and monitoring. The scores were found to be significantly related to both trend and research and monitoring grade (RMG) (Spearmans rank correlation trend: r_s = -0.311, p=0.027, RMG: rs = 0.284, p = 0.04), but not to species management grade (SMG) (r_s = 0.209, p=0.101). Therefore a high charisma score is related to an increasing trend and a greater level of research and monitoring, but not to species management.

When the species and their charisma scores are separated into their orders, the carnivores achieve the highest mean score, followed by perissodactyls, then primates and finally artiodactyls. Carnivores also achieve the highest maximum score, and the artiodactyla achieve the lowest maximum and minimum scores. (figure 2.12). There is a significant difference between the charisma scores for each mammal order (Kruskal Wallis H = 12.2, df = 3, p = 0.007).

2.32 Random Forest Analysis results

2.32.1 Status

When considering the top three Mean Decrease in Accuracy (MDA) scores, the variables of trend, Africa and South America were identified as being the most important predictors for distinguishing a species' status. Table 2.9 displays predictor values and MDA figures calculated by the analysis. The highest MDA figures indicate the most important classifier, i.e. they can distinguish a critical status from an endangered one. Therefore a species trend (increase, stable, decline) and its geographical location (Africa and South America) are variables which are associated with whether a species is critically endangered or endangered. At this point, the direction of the distinction is not known, i.e. whether a critical status is associated with being in or out of Africa, these particular relationships will be examined later.

Using the confusion matrix generated by this analysis, of 111 species classified as endangered, 8 have characteristics which suggest they actually have a high probability of being critically endangered. These 8 species are the white whiskered spider monkey (*Ateles marginatus*), Nubian Ibex (*Capra nubiana*), Sclators guenon (*Circopithecus sclateri*), Bearded saki (*Chirpotes satanas*), Arabian tahr (*Hemitragus jayakari*), *Microcebus myoxinus*, the Arabian Oryx (*Oryx leucoryx*) and the Saola (*Pseudoryx nghetinhensis*). Conversely, of 42 species currently classified as critically endangered, 30 have been identified as having characteristics better suited to a classification of endangered.

The 'votes' generated by the analysis have been used here to predict the status each species is most likely to belong to. The prediction is based on converting each vote to a percentage followed by identifying the highest percentage.

Results for the 8 'misclassified' endangered species are highlighted in table 2.10 alongside species possibly 'misclassified' as critically endangered. Of these species, 9 are calculated as >70% more likely to be endangered, based on the variables included in this analysis. These species are the grey ox (*Bos Sauveli*), tamaraw (*Bubalus mindorensis*), Bactrian camel (*Camelus bactrianus*), black rhino (*Diceros bicornis*), broad nosed gentle lemur (*Hapelemur simus*), black lion tamarin (*Leontopithecus chrysopygus*), Iberian lynx (*Lynx pardinus*), Brazilian bare faced tamarin (*Saguinus bicolour*), and the Saiga antelope (*Saiga tatarica*).

2.32.2 Trend

'Unknown' habitat type, legal protection and natural disaster were, overall, calculated as the most important variables for predicting trend (increase, decrease, stable). The variables which appear to be associated with an increasing trend (they have the highest predictor values) include firstly SMG followed by re-introduction, RMG, protected area, monitoring, captive breeding, Asia, shrub land and forest (Table 2.11). The variables which distinguished a decreasing trend (with the highest predictor values for that trend) were natural disaster and threat research. A stable trend was distinguished firstly by the variables of unknown habitat type and natural disaster (with the two highest predictor values) followed by legal protection, CITES, population range research, forest habitat, change to native species dynamics, South America, alien species, grassland and artificial habitats and finally low density.

The confusion matrix suggests that of the 64 species identified as having an unknown trend, 18 have been predicted as having decreasing populations and 2 stable. Also, out of the 3 species recorded as having an increasing population, the analysis predicts 2 species to be in decline, and 1 to be unknown. A similar prediction is made for the 23 species recorded as having a stable population. Of these, 13 are predicted to be in decline, and 10 are predicted to have an unknown status based on their characteristics. Finally, of the 63 species recorded as being in decline, 14 have the characteristics of an unknown trend, whereas 1 species has been predicted to be stable, this species is the white rumped black leaf monkey (*Tracypithecus delacouri*).

2.32.3 Research and Monitoring Grade (RMG)

The overall top three predictors for RMG were accidental death, legal protection and protected area (table 2.12). A number of variables were also identified as distinguishing species with the best level of research and monitoring (RMG = 5). These variables include grassland, harvesting and hunting, natural disaster, legal protection, shrub land habitat, persecution, limited dispersal, trend and change in native species dynamics (these variables all achieved the highest predictor values) followed by captive breeding, South America, unknown habitat type and alien species.

The confusion matrix for this analysis suggests that of 86 species recorded as having no research and monitoring (RMG = 0), 5 species have been predicted as sharing characteristics of species with an RMG of 2, and 5 species have been predicted as having an RMG of 3, indicating that this level of research would have been expected for those species. Interestingly, for all the species assigned a RMG of 1 – 5, most predictions are that species share characteristics with those who have an RMG of 0. For species with a RMG of 2, 5 of these have been predicted as having characteristics of species with a grade of 3, indicating the level of research could be improved.

Of the 32 species with a RMG >3, indicating a good level of research and monitoring, only 2 species were predicted as having a RMG of 5. For these 2 species it is predicted that the best level of research and an established monitoring programme should be attainable. These 2 species are the red wolf (*Canis rufus*) and the Tiger (*Panthera tigris*).

2.32.4 Prediction direction

Variables have now been identified which may distinguish status and trend of a species, and those with a good level of research and monitoring. In order to understand the direction of the predictions made by the analysis, mean and median values have been calculated for the predictor variables from each category, from the original dataset. By looking at the highest mean and median values, it is possible to distinguish the direction in which that particular variable is influencing the classification, for example, an identified strong predictor variable for status, may be better at predicting a critical status than an endangered one, and vice versa.

For status (table 2.13), there are 3 variables that were identified as being good predictors (they had the 3 highest prediction values). The higher calculated mean value shows that the trend variable is able to distinguish a critical species from an endangered one, and in particular that species with stable or declining trends (trend = 2 or 3 in dataset) are more likely to be critical. The remaining variables classify in the direction of endangered, therefore African and South American species are more likely to be endangered than critically endangered. The median values in this case are not a useful aid to interpretation due to the number of zeros present, therefore although not statistically appropriate for non-continuous data, the means are more useful.

The mean values remain the most useful tool for interpretation when considering the top three predictors for trend and RMG. For trend (table 2.14) both the unknown habitat and legal protection variables are able to distinguish an unknown trend from the others. Therefore species with an unknown habitat are more likely to have an unknown population trend, as are species in need of legal protection, or only provided with a small amount (legal 2 or 3 in dataset). The natural disaster variable distinguishes in the direction of a stable trend, therefore species threatened by natural disaster are more likely to have a stable population. For RMG (table 2.15), the variable of accidental death can distinguish a RMG of 3 or greater, with the largest mean value being for a RMG of 4. Therefore, species threatened by accidental death are more likely to have good levels of research and monitoring. The legal protection variable is able to distinguish a RMG of 3 or less. The highest mean was for a RMG of 0, meaning species without, or with little legal protection, are more likely to be species with no, or with poor levels of research and monitoring. Finally, the protected area variable distinguishes a RMG of 2 or less, with the highest mean being for a RMG of 1. Therefore, species which are not found within a protected area, or are in need of such protection, are most likely to be those with poor research and monitoring in place. Table 2.16 provides a summary of predictor variables and interpretation.

2.4 Discussion

2.41 Factors of endangerment

2.41.1 Species status and trend

For the four orders in this study, results concur with trends identified by the IUCN (IUCN, 2008, 2004, Baillie et al, 2004) whereby every order is generally in decline. This study found there to be no significant difference in trend between the artiodactyla, perissodactyla, primates and carnivora.

Random Forest Analysis (RFA) found that species with declining or stable trends are more likely to be critically endangered rather than endangered. Presence in Africa and South America was associated with an endangered status over a critically endangered status.

A number of species were also identified as having characteristics better suited to a classification of endangered or critically endangered, although they are currently classified in the other category by the IUCN (2004). This does not mean they are misclassified, instead it may indicate the requirement for more focused conservation action. In particular, species classified as critical have been identified as having the potential to be fairing much better by the analysis, considering the variables included. It is also likely that other factors, not included as predictors, are impacting on such species. These species include the Iberian lynx (*Lynx pardinus*) and the black rhino (*Diceros bicornis*), and results here suggest that the factors thought to be threatening these species should be scrutinised again. For the endangered species with characteristics better suited to a critical status, results may indicate that current conservation work is successfully maintaining these species at a better status than what could be expected. These species include the Arabian oryx (*Oryx leucoryx*)

A need for quantification of population trends for endangered species has been highlighted by this study. Trends are well known for the critically endangered species, but 58% of the endangered species have an unknown trend. Also, more than half of the critically endangered species have a good trend (increasing or stable) compared to only 6.4% of the endangered species for which trend is known. This suggests that once a species is recognised as being critical, then action is taken as reflected in the higher percentage of critical species with a good trend. If this is true, there may also be differences in other variables such as legal protection, the level of species management, and research and monitoring between critically endangered and endangered species. The association between trend and status was found to be significant, indicating the need for focused research on trends, particularly for endangered species and more generally for those with an unknown trend.

RFA found that of the 42% of species with an unknown trend, 28% were predicted to be in decline. The potential application of such a result is supported by the fact that the analysis matched the classification of 48 out of 63 (76%) species listed as having a declining population by the IUCN (*2004*). Of the remaining species with an unknown trend, 14 were 'kept' in that category and two species, the mountain nyala (*Tragelaphus buxtoni)* and pig tailed langur (*Simias concolor*), were predicted to have a stable trend.

Species with unknown trends were also those where their habitat was unknown and there was little or no legal protection. This firstly indicates the obvious need for attention with species for which there is little information. Secondly, this supports the suggestion that the allocation of legal protection goes hand in hand with the presence of research and monitoring, as those with better legal protection are more likely to have known trends.

2.41.2 Threats and their geographical and taxonomic patterns

The identification of why species are threatened is an important part of setting priorities for conservation action (Michalski and Peres, 2005, Valenzuela-Galván et al, 2008). In agreement with the IUCN (IUCN, 2008, 2004, Baillie et al, 2004), the two most prevalent threats were identified as habitat loss and harvesting or hunting. More than 80% of the critically endangered species, and more than 60% of the endangered species analysed, were suffering due to the threats of habitat loss and hunting. For most continents, the threat of habitat loss outweighs the threat of hunting, except for North America where it seems the reverse is true. Overall however, there was no significant difference between continent, and the threats of habitat loss and harvesting or hunting, therefore supporting the fact that these threats are not geographically biased, but are globally the most significant threats to species.

The analysis identified more than 70% of species to have more than one threat. This indicates that threats may act together to increase vulnerability, with a greater number of threats combining to increase the level of risk. This is supported by the studies of Chapman et al (2006), Harcourt (2006), Michalski and Peres (2005), Price and Gittleman (2008), who all recognise the synergistic nature of threats on mammals, and especially the growing threat of anthropogenic actions on species survival. This is recognised in particular in forest habitats (Chapman et al, 2006, Michalski and Peres, 2005), and with over 60% of the species analysed relying on forests, it is no surprise that habitat loss and degradation is indeed the most common threat.

In this study, there were 7 threats identified to be affecting more than 10% of the species (habitat loss and degradation, harvesting and hunting, accidental death, change in native species dynamics, alien species, persecution and intrinsic range restriction). These threats were found not to be associated with status and known trend, and therefore are affecting species equally whether they are critically endangered or endangered, and across all trends. However, the 7 threats were associated with the level of research and monitoring in place. Specifically, the threats of 'accidental death', 'change of native species dynamics' and 'persecution' were all associated with a good level of research and monitoring (RMG ≥ 3), with the remaining threats associated with lower levels (RMG <3). This suggests that those species suffering such acute threats with more visible consequences of direct human impact (accidental death, persecution), or where more than one species is involved (change in native species dynamics), are more likely to have more intensive research programmes. It is arguable that there may be more funding available, or it may be easier to acquire for species suffering specific threats with such direct impacts, and which may also have more accessible alleviation measures. For example, preventing accidental death e.g from road collisions, could be alleviated by specific control measures once quantification of the threat has been achieved.

This study has identified the possible existence of conservation 'black spots'. For example, endangered species were concentrated in Asia, less than half of endangered species in South America had some form of species management, and South America also had lower levels of research and monitoring in comparison to other continents. Specific areas of Asia and South America are indicated as hotspots by Myers et al (2000) (Brazil's Cerrado, and Atlantic forest, Central Chile and Western Equador, South Central china, Indo Burma, Western Ghats and Sri Lanka, Sundaland, Walacea and the Phillipines), but large areas of these continents are not. In agreement with the thoughts of Spathelf and Waite (2007), who also saw the danger in neglecting areas not identified as hotspots: it is important in light of the unbalance of endangerment and conservation action identified, that such areas are not undervalued in their ecological importance due to 'hotspot' geography. What analysis, such as undertaken in this study, can do is identify potential areas where conservation action needs to be improved. 'Hotspot' analysis could be qualified by information on trend and a RMG system, with hotspots with poor trends and low RMG receiving more resources. A scheme could also be prioritised alongside the conservation of hotspots, in the form of focused effort zones aimed at balancing conservation work and preventing the unnecessary loss of equally valuable species that may live outside of current hotspot areas.

2.42 Conservation action

2.42.1 The presence of species management

More than 40% the species included in this analysis are only represented by a wild population, obviously making in situ conservation critical to their survival. In addition, more than half can be found in protected areas and 71% appear on CITES listing, however less than half of the species have other forms of legal protection in place. Of all the species, 59% receive some form of active species management (ex situ population, captive breeding, re-introduction).

There was no association between species status and species management grade (SMG), so critical species appear not to receive more species management than endangered species. Only 10% of species under study achieved a SMG of 3, meaning they have an ex situ population, captive breeding programme and reintroduction programme. This is not necessarily a negative point as it may just reflect the fact that in situ conservation is the obvious priority for many species, and that ex situ programmes may be difficult or impossible. However, of those species that have an ex situ population, only 10% have a reintroduction programme, which may indicate an isolation of captive individuals from what could be considered one of the main purposes of their existence. Alternatively, this could indicate that conditions, in captivity, in the wild, or during the process of reintroduction, are currently not facilitating the opportunity for successful reintroductions, or that they are not currently necessary or appropriate.

Interestingly, species with a higher SMG are less likely to have a declining trend. This suggests that for the species analysed, the presence of species management, particularly with reintroduction, is indeed supporting species population trends in the wild. It is also possible that there is a positive effect of species management regarding ex situ populations. In other words by using ambassador species in such a way to raise awareness and funding, and to increase scientific understanding of a species, this may promote the success of in situ measures (Clayton et al, 2008, Rabb and Saunders, 2005, Mallaphur et al, 2008, WAZA, 2005)

2.42.2 The presence of research and monitoring

Research is a critical process for effective conservation. Results of research are vital in assessing threats, suggesting ways to protect a species and in setting priorities for conservation (Michalski and Peres, 2005,Valenzuela-Galván et al, 2008). For more than half of the species analysed, there was no evidence of research and monitoring, and only 20% of species achieved a 'good' research and monitoring grade (RMG) of 3 or more. Only 5% of species achieved a RMG of 5, indicating the presence of research into most of a species' population, range, biology, ecology, trends and threats and an established monitoring programme. In total, only 16% of species had any evidence of a monitoring programme in place. This result is worrying as it confirms the suspicion that true trends for many species cannot be known.

Research and monitoring grade (RMG) was found to be associated with both status and trend - species with a higher RMG were found more likely to have an increasing trend, and a critical status. This indicates that research helps to support an increasing trend, and that potentially, a critical status increases the chances of research and monitoring being put in place. There were more endangered than critically endangered species with a RMG of 2 or more, but a greater number of endangered species had no RMG at all. Proportionally, more critically endangered species had some form of RMG than species with an endangered status, supporting the possibility that a lower status results in less research and monitoring.

What is also evident from results here is that with a higher level of research, a species is more likely to be monitored, as only 2% of species with no other research are monitored, compared to 34% of species which are both researched and monitored in the wild. Potentially any research taking place on a species may develop into monitoring, but this may not always be the case. A similar situation is true for species with some form of management (SMG), with 21% of species with management programmes also being monitored in the wild, compared to only 9% that have monitoring programmes but no species management. It is possible that monitoring may form part of, and be a requirement of such species management.

RFA was also applied to RMG results. Predictor variables which were associated with the best RMG included grassland and shrub land habitat. This makes sense, as species in these habitats may be more possible to study due to greater visibility, especially compared to thick forest. Other predictors included the threats of harvesting or hunting, natural disaster, persecution, limited dispersal and change in native species dynamics. A good level of research may be in place for species which are under threat from hunting and persecution as part of a programme to alleviate conflict with people. A programme to combat the effects of natural disaster, or a recovery programme may also involve a good level of research. It also makes sense that species with limited dispersal are associated with a good level of research as these species may be within confined areas, possibly surrounded by a human population, and research may be a part of the species management. These species may also be easier to study than those with larger ranges. Where a change in native species has been recorded, it also corresponds with the idea that the native species would then be researched and monitored in response to those changes and as part of management action to alleviate the consequences.

The remaining predictor variables for the best RMG are trend and legal protection. This may suggest that if trends are known then there is a good chance that there is research and monitoring in place, and that research and monitoring may be a requirement of the legal protection, and it may be easier to secure funding and access to species which are of legal 'value'. This is supported by the analysis, as the less legal protection that is in place, the lower the RMG. Therefore the presence of legal protection appears to increase the presence of research.

When considering the presence of any RMG, accidental death was identified as a strong predictor for identifying species with a RMG ≥ 3, and protected area was a strong predictor for species with a RMG ≤ 2. This can be interpreted again that those species in direct conflict with man in the form of accidental death (e.g. road collisions or entanglement in fishing nets) are highly likely to receive good research and monitoring. Species which are not found in protected areas receive less research and monitoring. This suggests that research and monitoring is part of the protected area management, and/or that species within demarcated boundaries are more accessible and potentially easier to study.

2.43 Potential flagship species

The Iberian lynx, *Lynx pardinus*, the red wolf, *Canis rufus* and the Sumatran orang-utan, *Pongo abelii* were scored as the 3 most charismatic species by the small public survey in this study. Therefore out of the 39 species represented, these three species may have the potential to be conservation ambassadors in the form of flagship species. There was a significant difference in the scores per order, with carnivores achieving the highest overall score, followed by perissodactyla, primates and finally artiodactyla. It could be argued that the two top orders contain what could be perceived as 'impressive' species, including the felids and canids and rhinoceros families, and that the survey group deemed these to be the most charismatic species overall.

Total scores were found to be related to trend and RMG – species with high scores were more likely to have an increasing trend and more research and monitoring. Charisma was not related to SMG, suggesting that on the whole, if a species requires species management it receives it regardless of its charisma.

2.44 Applicability of Random Forest Analysis

This study has shown that Random Forest Analysis (RFA) can detect associations and differences between variables associated with critically endangered terrestrial mammals, but by using extrinsic rather than intrinsic variables. This is in contrast to most research so far, where patterns in extinction risk have usually been related to intrinsic biological variables such as species body size (e.g. Cardillo et al, 2005, Cardillo and Bromham, 2001, Collen et al, 2006, , Owens and Bennett, 2000, Purvis et al, 2000b). In this study, RFA identified variables which can distinguish critically endangered from endangered species, and variables associated with good or poor levels of research and monitoring. Also, it has been shown that a classification procedure such as RFA may be particularly useful for predicting the values for 'unknown' variables, which has clear advantages in the work to protect threatened species.

Analysis using decision trees is less restrictive than other classification techniques. Advantages include a capability to analyse non linear data and non-additive relationships, variables or predictors can be used more than once in a tree so that their effect can be context dependent, there is no requirement for normality, outliers can be isolated with no effect on other cases and missing values can be dealt with by generating surrogates (Fielding, 2007). In some Decision Tree methods there may be some instability, with small changes to the data used for the analysis creating significant changes to the generated tree (although not necessarily to the final predictions). RFA overcomes such problems, (e.g. by detecting the importance of each variable, and detecting important interactions and associations between cases) while remaining clear to interpret (Fielding, 2007). Overall RFA is accurate, efficient and fast (able to handle thousands of predictors).

Following the results revealed here, RFA has great potential in targeting work to save endangered species, by possibly filling in the gaps in our knowledge which may be preventing effective conservation action, and by better identifying where work is needed. Simply stated, RFA can identify key variables in a large data set, which includes many variables and a mix of data types, exactly the type of data generated by the many factors threatening species and putting them at risk of extinction.

2.5 Conclusions

- Allocation of a critical status may consequentially increase the level of conservation action, particularly research and monitoring, thus helping to improve a species' trend.

- Species most likely to be critically endangered are those with declining or stable trends, whereas endangered species are associated with presence in Africa and South America.

- Species with legal protection are more likely to have known trends, and there is a clear need for quantification of population trends, particularly for endangered species

- Threats act synergistically to increase extinction risk, with the most significant global threats to species being habitat loss and degradation, and hunting or harvesting.

- This study has identified the potential existence of conservation 'black spots', which may be neglected by 'hotspot' geography.

- Presence of species management and research and monitoring has a positive association with population trend.

- Good research and monitoring is most likely to be in place for:
  - Critically endangered species
  - Species with specific or more visible threats (e.g. direct human impact, natural disaster), that are easier to study (e.g. in open habitats, with limited dispersal), or where research may be part of management (e.g. species has legal protection or occurs in a protected area).
  - Charismatic species

- RFA has great potential in the work to save endangered species and could complement the 'hotspot' theory as it has the ability to:
  - detect relationships between extrinsic extinction risk variables
  - highlight successful conservation, or areas requiring focused action
  - identify characteristics associated with good research and monitoring

Categories	2004	2008
Assessed Species	38,047	44,838
Threatened (CR, EN, VU)	15,589	16,928
Extinct/extinct in the wild	844	869
Near threatened	3,700	3,513
Data deficient	3,580	5,570

Table 2.1: Species in IUCN categories
Based on IUCN updates 2004 and 2008 (Baillie et al, 2004, IUCN, 2008)

RMG	Definition
0	No or minimal evidence of any research into a species' Population, Range, Biology, Ecology, Trends and Threats (PRBETT), and no evidence of a monitoring programme in the past or present
1	Some evidence of one category or more of the species' PRBETT, but no evidence of a monitoring programme in the past or present.
2	Evidence and evaluation and possible continuation of one or two categories of the species' PRBETT, but no monitoring programme established in the past or present.
3	Evidence and continuation of research into 2 or more categories of a species' PRBETT and the initial stages or past evidence of a monitoring programme, or evidence of a monitoring programme but no other research.
4	Strong evidence for present research into a species' PRBETT (2 or more categories), and evidence of a present monitoring programme.
5	Present research into most of a species' PRBETT and an established monitoring programme.

Table 2.2: RMG definitions
Research and monitoring grade (RMG) definitions (0-5) based on the presence of monitoring and/or research into a species' population, range, biology, ecology, trends and threats.

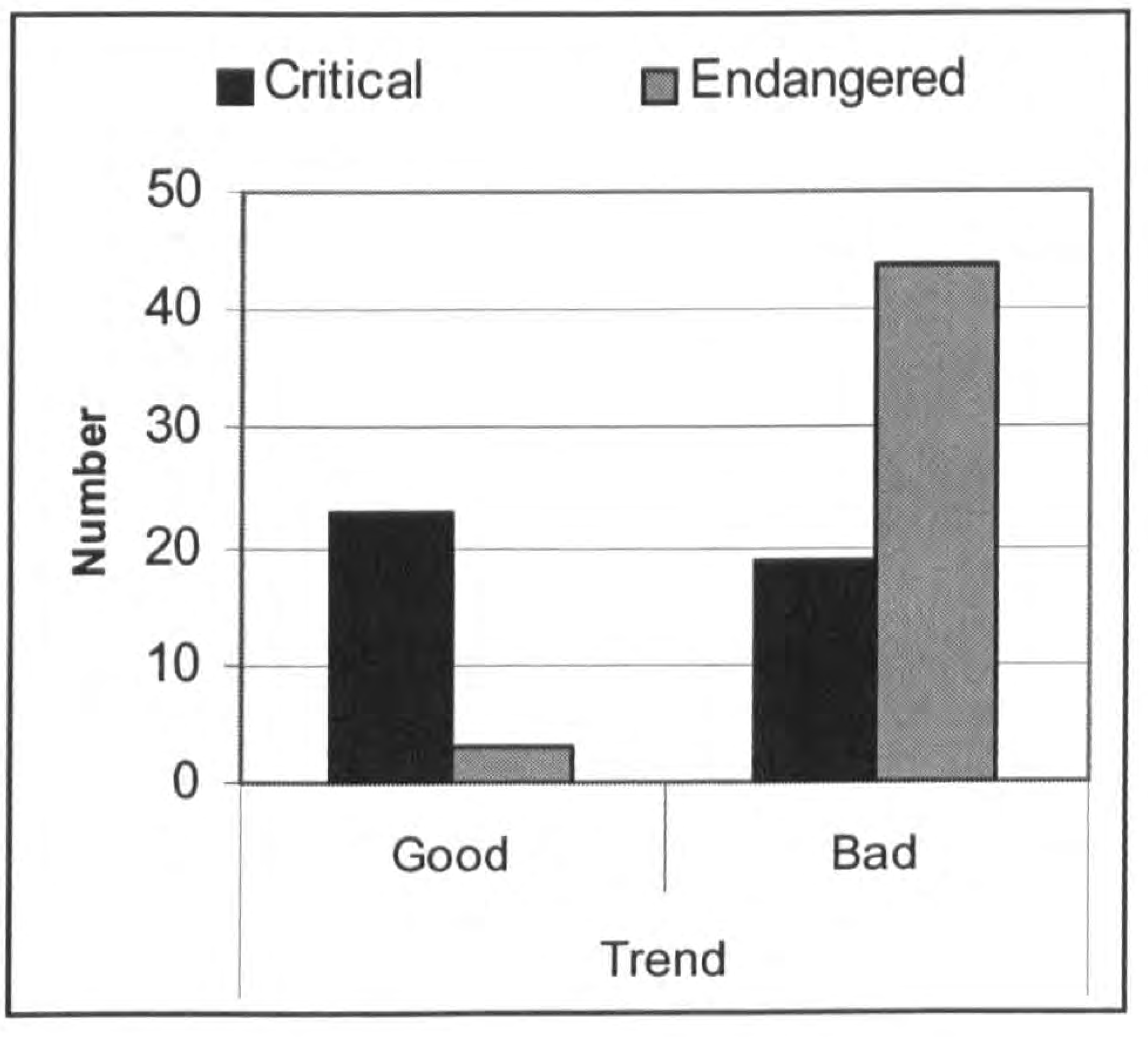


Figure 2.1: Status and known trends
Species trend (good = increasing or stable, bad = declining) compared to status (Critical / Endangered)

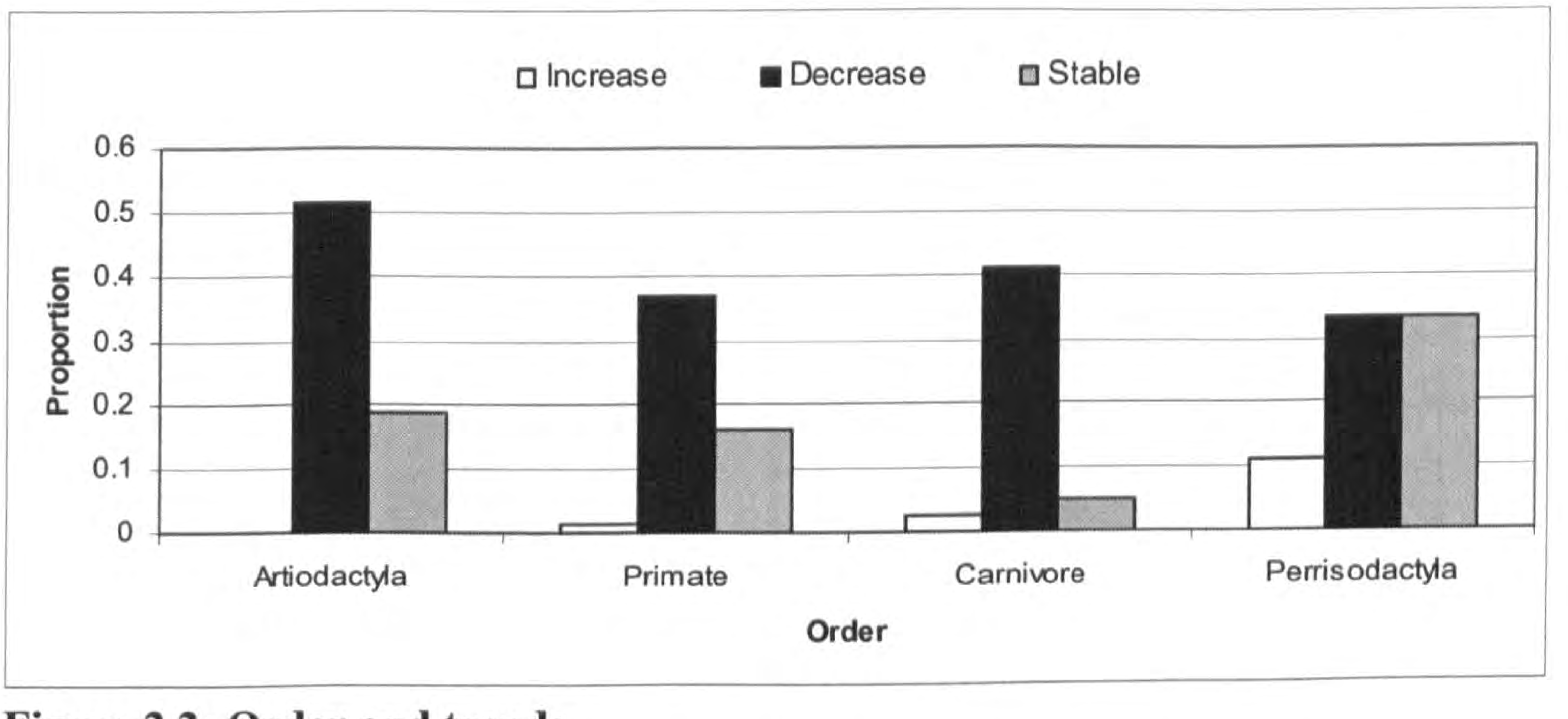


Figure 2.2: Order and trends
Proportion of species in each order with an increasing, decreasing and stable trend.
(Number of animals in each order: artiodactyla = 37,primate = 68, carnivore = 39, perissodactyla = 9)

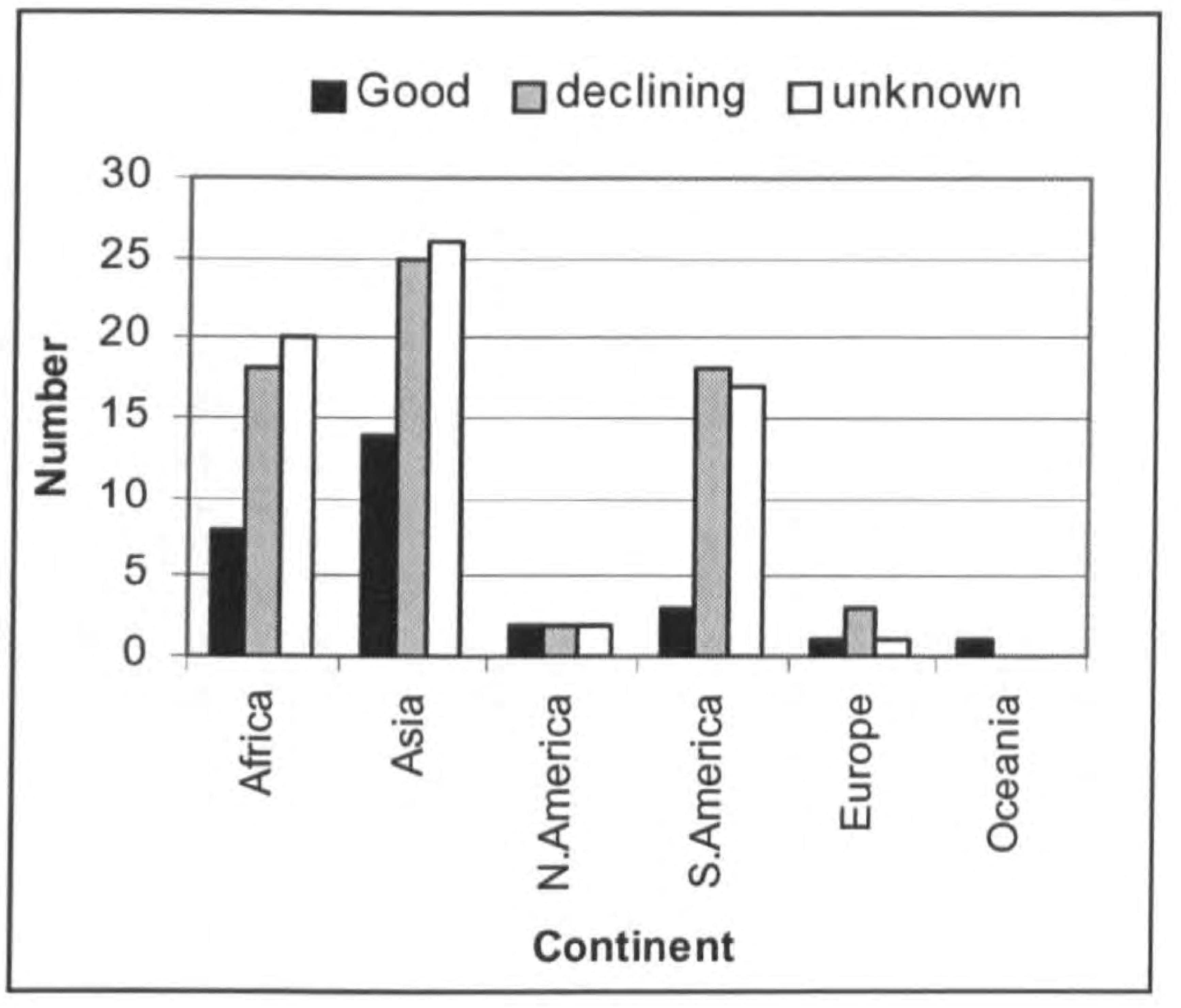


Figure 2.3: Continental trends
Species trend (good = increasing or stable) split by continent.

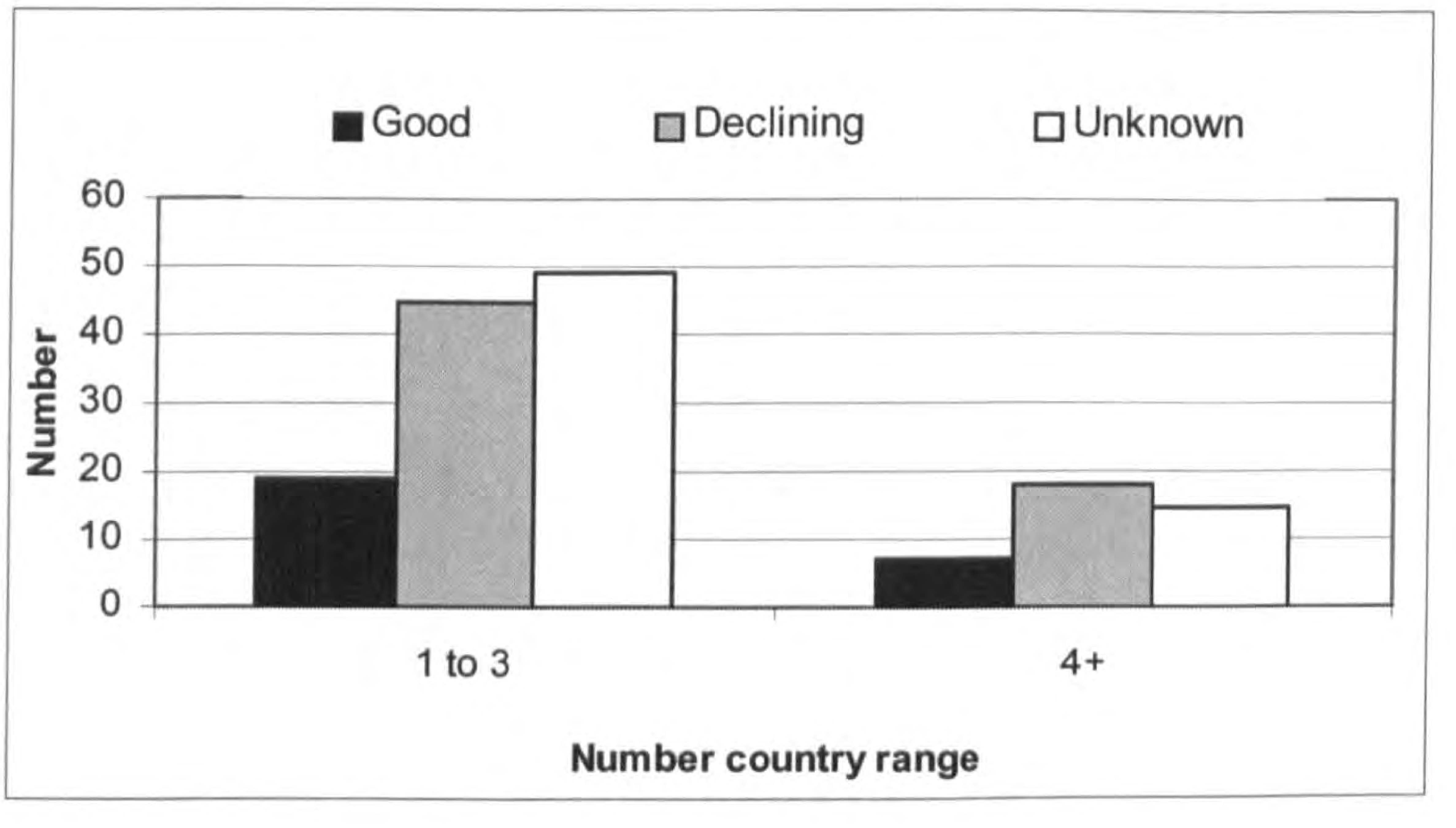


Figure 2.4: Range and trend
Trend split by the number of countries within which each species is found.

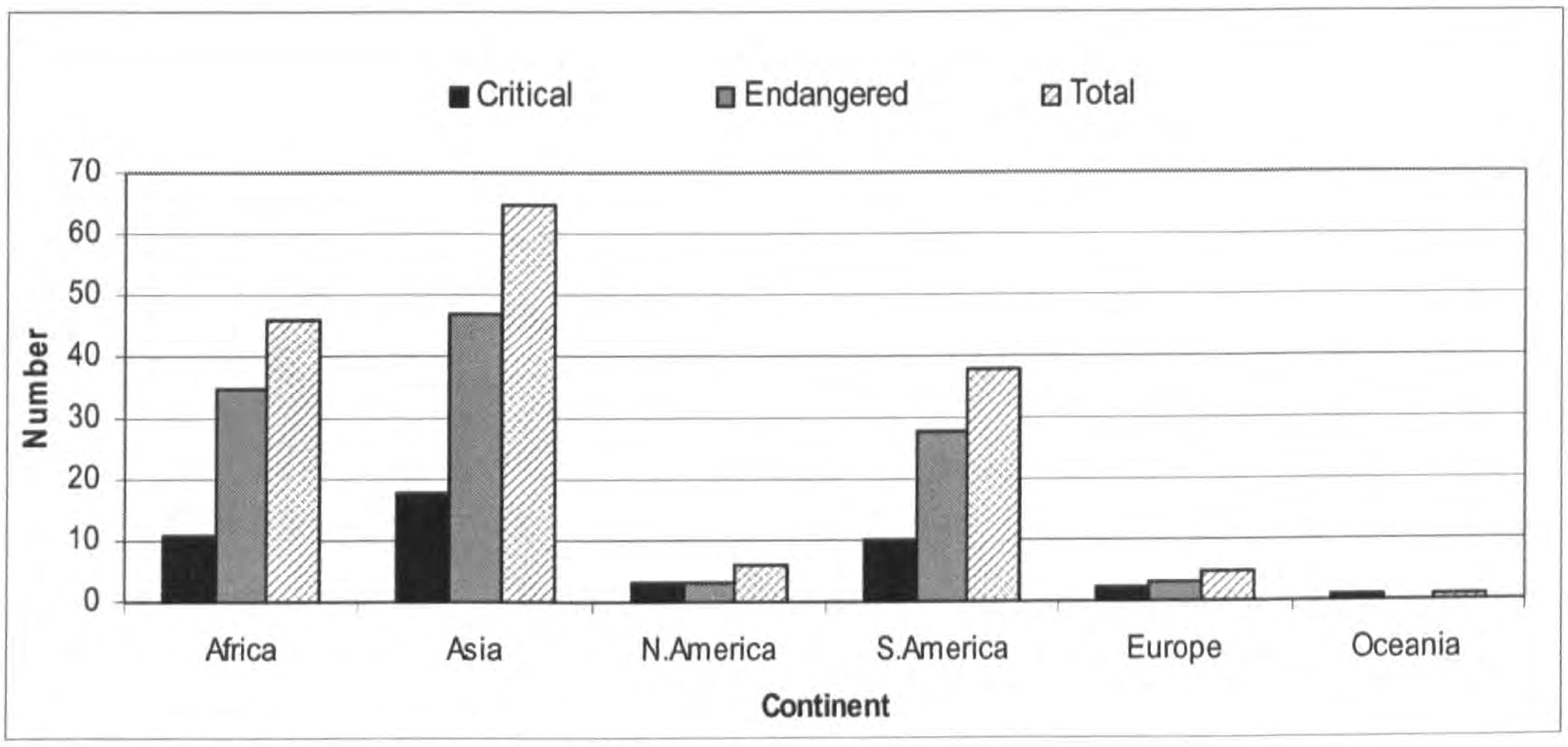


Figure 2.5: Geography of endangerment
Number of critically endangered and endangered species by continent.

	Number of range countries									
	1	2	3	4	5	6	7	8	9	10+
Critical	25	8	0	2	0	0	1	0	1	5
Endangered	55	10	15	8	2	6	0	2	0	13

Table 2.3: Species range
Total number of species in each category of range countries

	Africa	Asia	N.America	S.America	Europe	Oceania
Critical	5	10	1	9	0	0
Endangered	17	22	1	15	0	0

Table 2.4: Species of limited range
Distribution of species with a range of one country

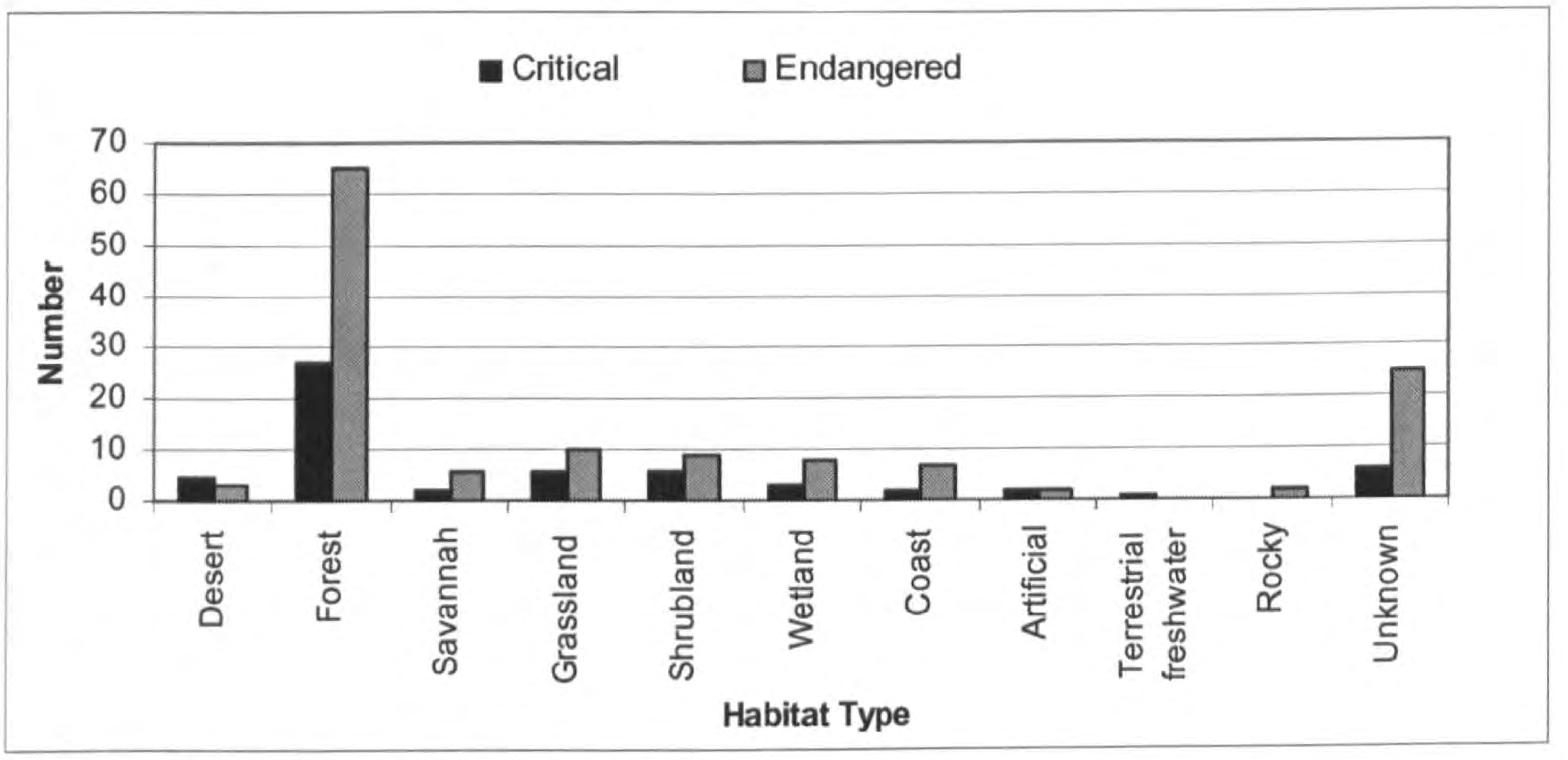


Figure 2.6: Status and habitat type
Habitat type for both critically endangered and endangered species

Threat	Critical	%	Endangered	%
Habitat loss & destruction	35	83.3	97	87.4
Harvesting	29	69.0	73	65.8
Accidental mortality	4	9.5	9	8.1
Change to native species dynamics	7	16.7	14	12.6
Human disturbance	4	9.5	6	5.4
Alien species	6	14.3	21	18.9
Natural disaster	4	9.5	4	3.6
Persecution	2	4.8	11	9.9
Pollution	0	0.0	5	4.5
(IF) - range restriction	6	14.3	16	14.4
(IF) - low density	1	2.4	6	5.4
(IF) - high infant mortality	1	2.4	3	2.7
(IF) - low reproductive success	0	0.0	0	0.0
(IF) - inbreeding	1	2.4	4	3.6
(IF) - skewed sex ratio	1	2.4	0	0.0
(IF) - limited dispersal	1	2.4	1	0.9
(IF) - poor recruitment	0	0.0	4	3.6
Unknown	3	7.1	8	7.2

Table 2.5: Status and threats
Threats suffered by the critically endangered and endangered species as number and percentage of total

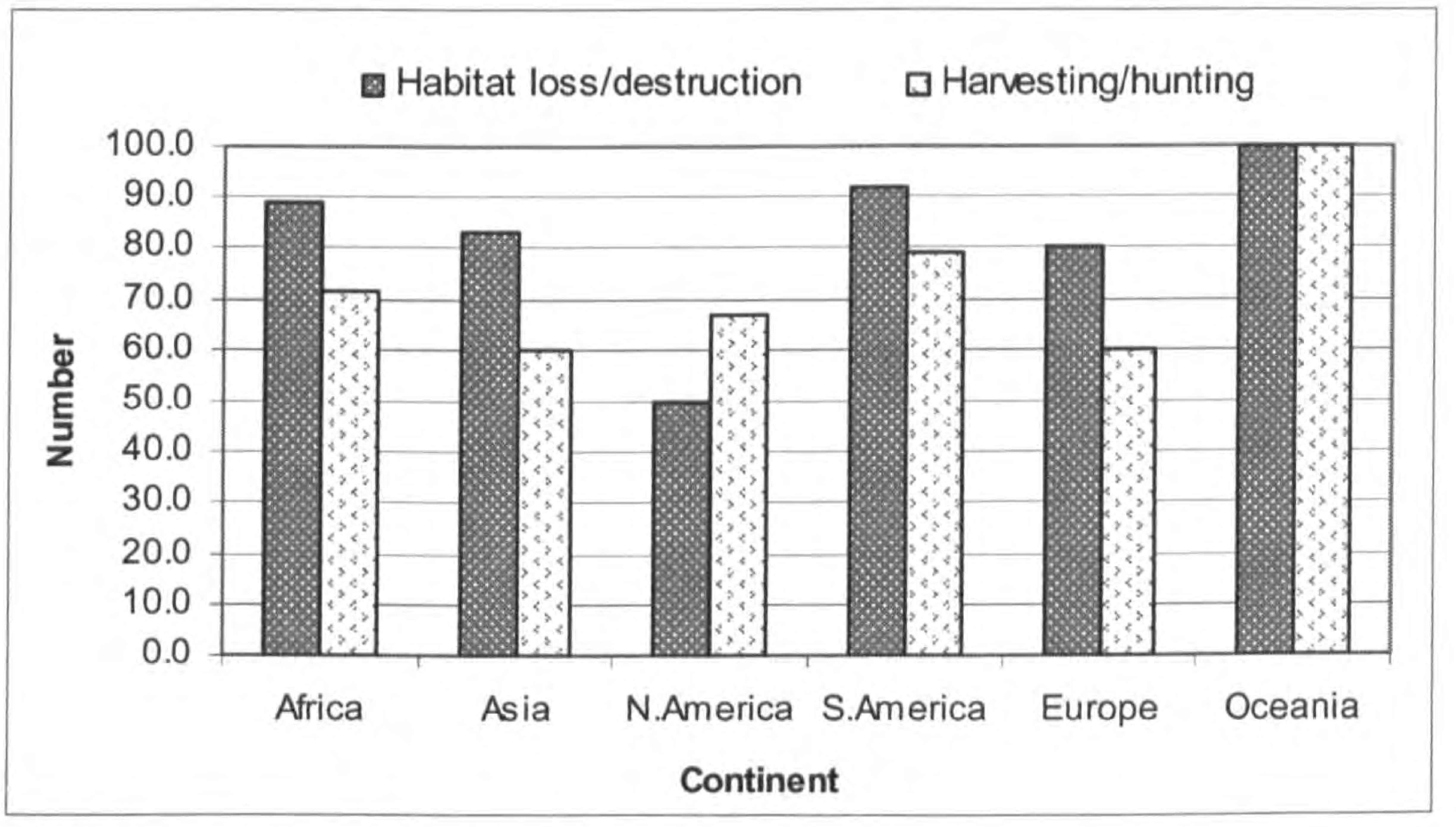


Figure 2.7: Significant threats
Geographic distribution of the 'most significant' threats

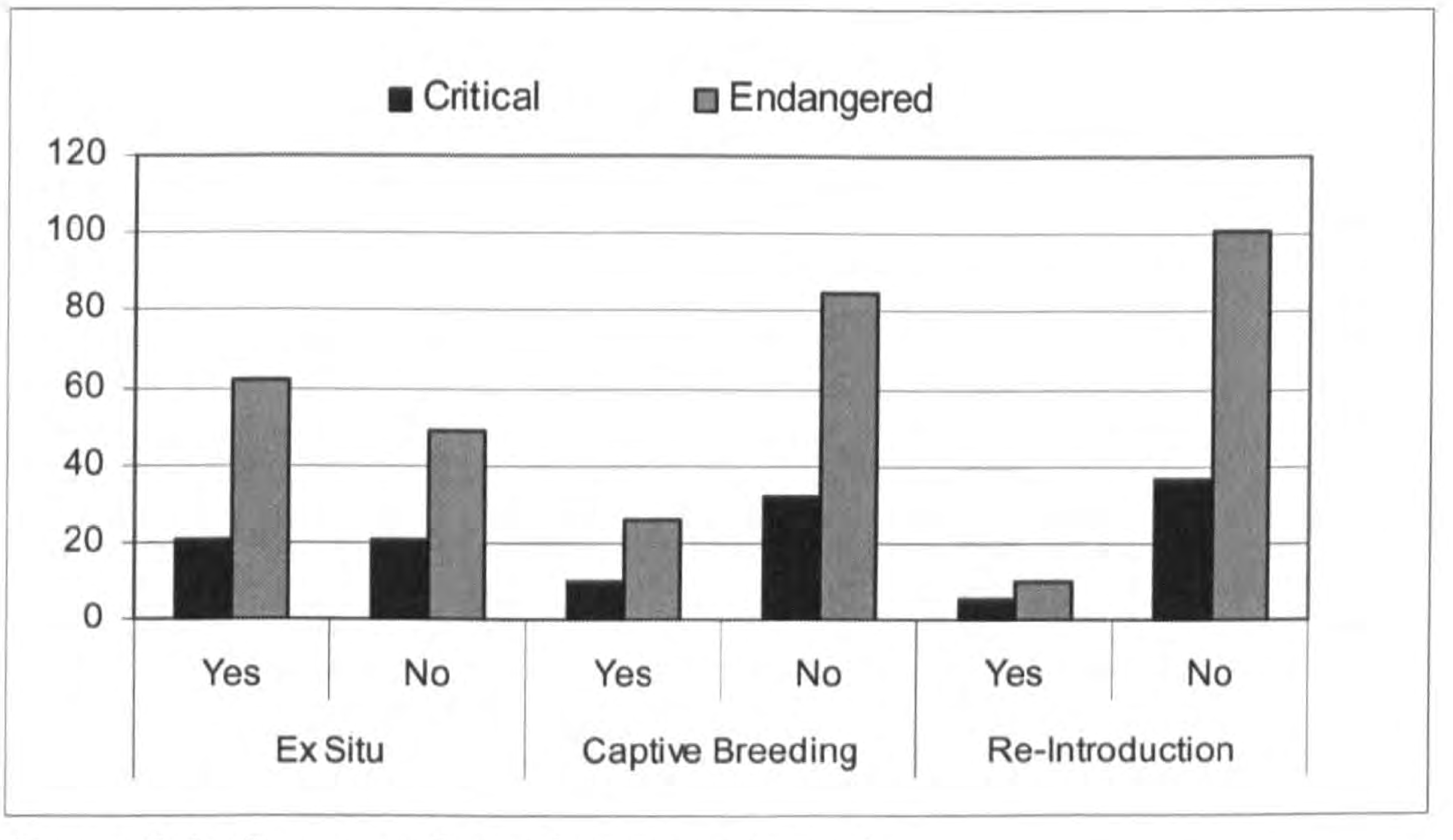


Figure 2.8: Status and species management
Number of species identified as having an ex situ population, captive breeding and a re-introduction programmes ('species management').

	Species Management Grade (SMG)			
	0	1	2	3
Critical	18	15	6	3
Endangered	47	39	16	9

Table 2.6: Status and SMG

Species Management Grades (SMG) (0-3) for the critically endangered and endangered species.

	Research and Monitoring Grade (RMG)					
	0	1	2	3	4	5
Critical	23	5	6	4	1	3
Endangered	63	1	23	14	5	5

Table 2.7: Status and RMG

Research and Monitoring Grade (RMG) (0-5) for the critically endangered and endangered species.

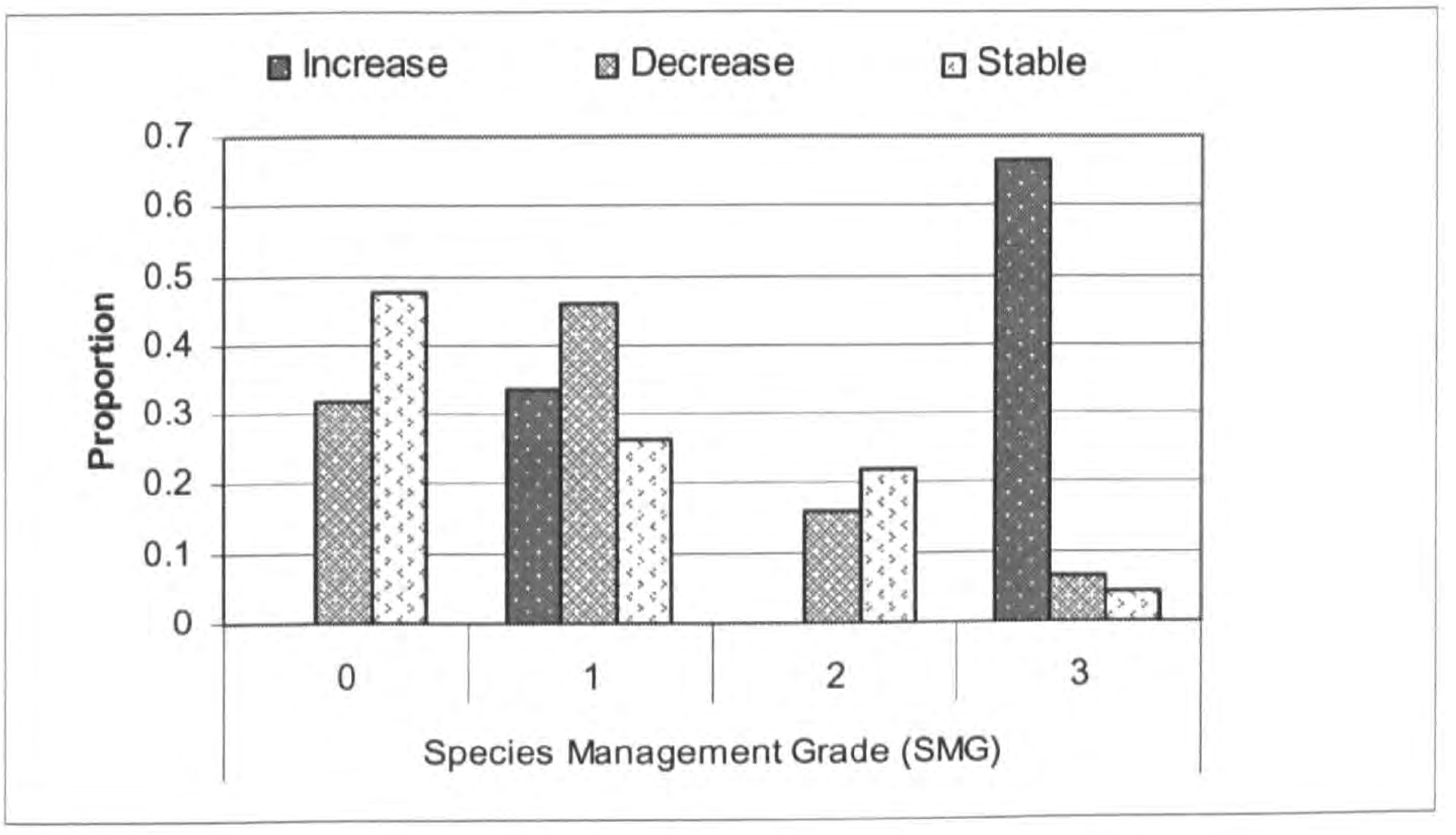


Figure 2.9a: Species and SMG

Proportion of species with each Species Management Grade (SMG) (0-3) with an increasing, decreasing and stable trend.

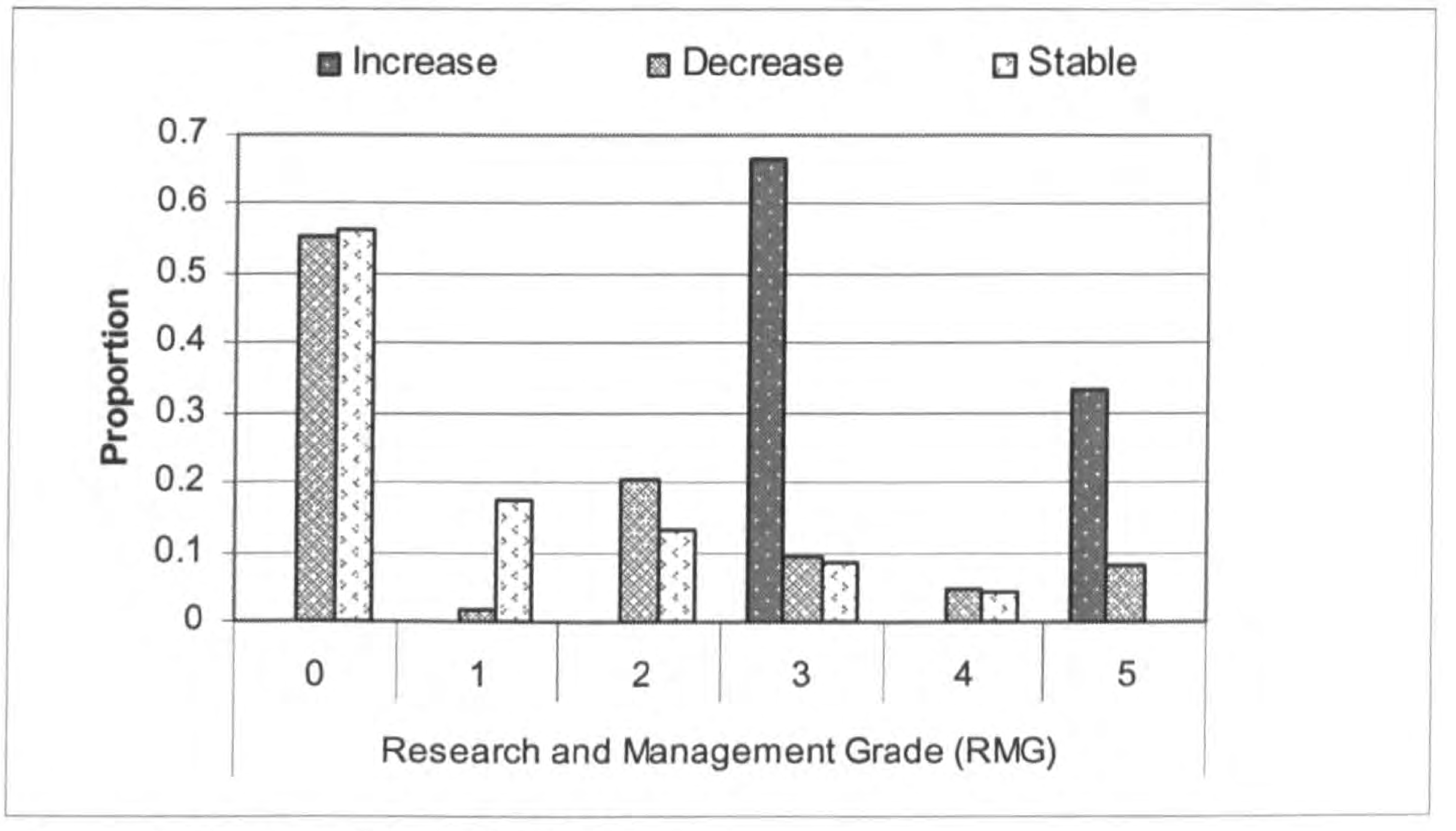


Figure 2.9b: Species and RMG
Proportion of species with each Research and Monitoring Grade (RMG) (0-3) with an increasing, decreasing and stable trend.

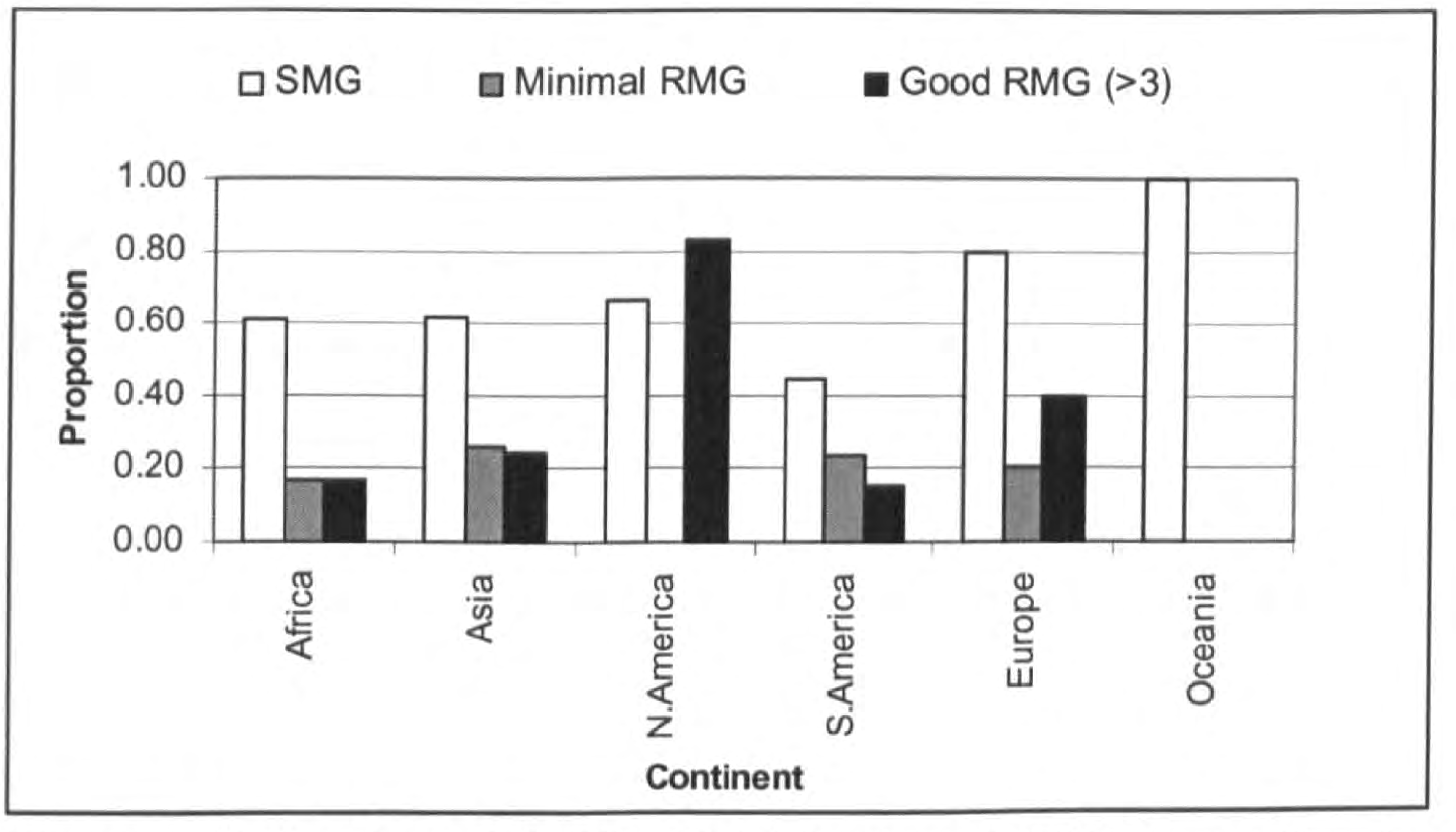


Figure 2.10: Species and SMG with/without good RMG by continent
Distribution of species with species management in place (SMG) and with minimal versus good research and monitoring (RMG)

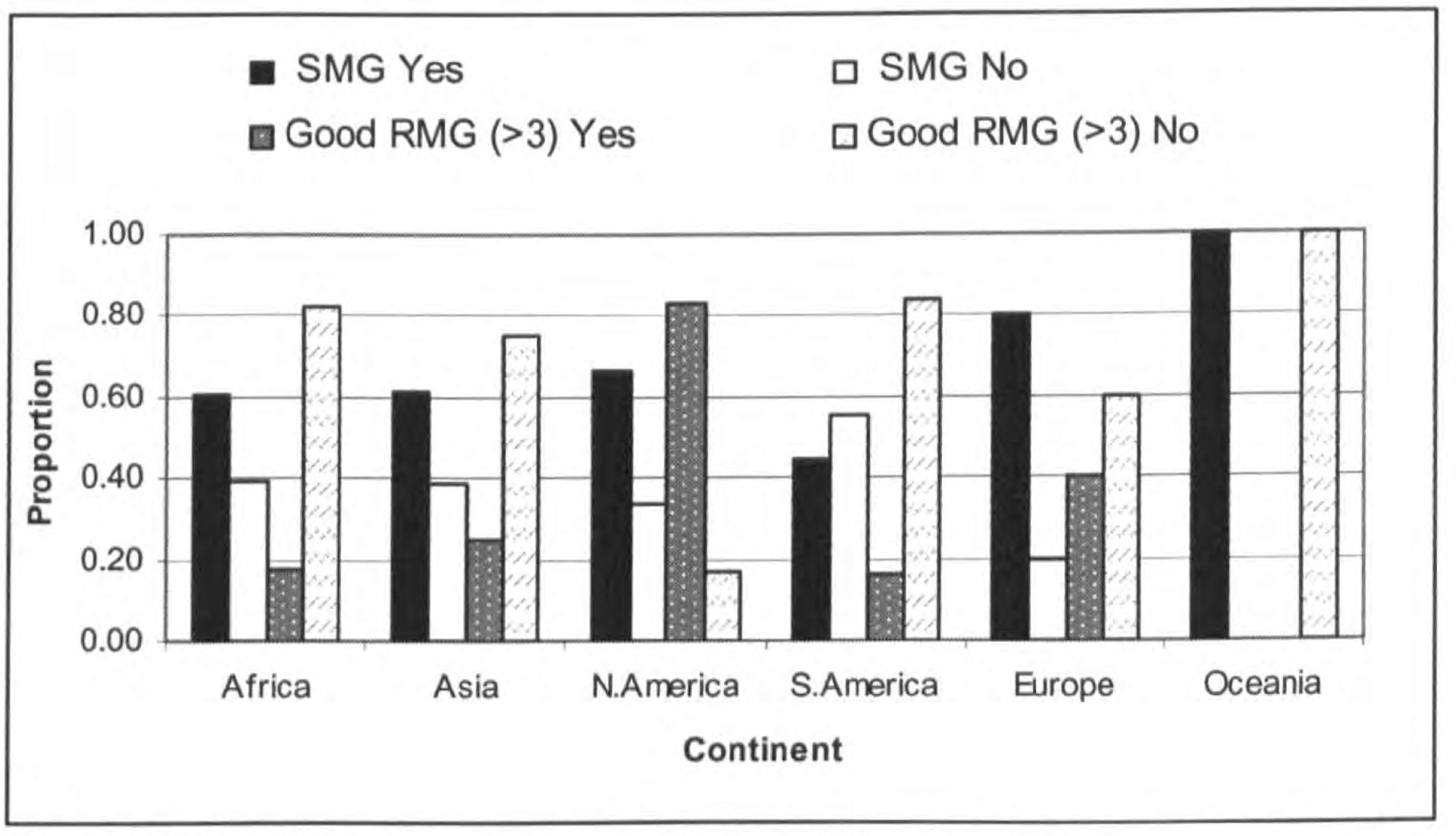


Figure 2.11: presence/ absence of SMG and good RMG
Distribution of species with and without species management programmes (SMG) and good research and monitoring (RMG)

Order	Common Name	Scientific Name	Score	Charisma rank	Trend	SMG	RMG
Artiodactyla	Addax	*Addax nasomaculatus*	57	26	2	3	0
	Aders duiker	*Cephalophus adersi*	61	18	3	1	0
	Bactrian camel	*Camelus bactrianus*	53	29	3	1	0
	Grey ox	*Bos Sauveli*	43	38	3	0	3
	Hirola	*Damaliscus hunteri*	53	29	3	1	0
	Pere Davids Deer	*Elaphurus davidianus*	67	7	2	2	0
	Prezewalskis gazelle	*Procapra przewalskii*	62	16	2	0	0
	Pygmy hog	*Sus salvanius*	40	39	2	1	1
	Saiga antelope	*Saiga tatarica*	54	28	3	1	0
	Tamaraw	*Bubalus mindorensis*	45	36	3	1	0
	Visayan warty pig	*Sus cebifrons*	45	36	2	2	1
	Walia Ibex	*Capra walie*	64	12	2	1	0
Perrisodactyla	African ass	*Equus africanus*	70	5	2	2	0
	Black Rhino	*Diceros bicornis*	67	7	1	1	5
	Javan rhino	*Rhinoceros sondaicus*	60	20	2	0	3
	Sumatran Rhino	*Dicerorhinus sumatrensis*	62	16	2	2	3
Primate	Black faced lion tamarin	*Leontopithecus caissara*	58	25	3	0	2
	Black lion tamarin	*Leontopithecus chrysopygus*	51	33	3	1	2
	Brazilian bare faced tamarin	*Saguinus bicolor*	49	35	3	1	0
	Broad nosed gentle lemur	*Hapalemur simus*	64	12	3	1	0
	Eastern black crested gibbon	*Nomascus nasutus*	56	27	2	0	1
	Golden bamboo Lemur	*Hapalemur aureus*	60	20	3	1	0
	golden crowned sifaka	*Propithecus tattersalli*	51	33	2	1	0
	Javan Gibbon	*Hylobates moloch*	66	10	2	1	2
	Mentawai macaque	*Macaca pagensis*	61	18	2	0	0
	Northern Murqui	*Brachyteles hypoxanthus*	53	29	3	0	2
	Sumatran Orangutan	*Pongo abelii*	77	3	2	2	2
	Tonkin snub nosed monkey	*Rhinopithecus avunculus*	67	7	2	0	0
	Variegated spider monkey	*Ateles hybridus*	65	11	3	0	0
	White headed langur	*Trachypithecus poliocephalus*	59	22	2	0	1
	White rumped black leafed monkey	*Trachypithecus delacouri*	59	22	3	0	0
	Yellow breasted capuchin	*Cebus xanthosternos*	64	12	2	0	2
	Yellow tailed woolly monkey	*Oreonax flavicauda*	53	29	2	0	0
Carnivora	Californian channel island fox	*Urocyon littoralis*	69	6	3	3	5
	Darwins fox	*Pseudalopex fulvipes*	63	15	3	0	1
	Iberian Lynx	*Lynx pardinus*	83	1	3	2	5
	Malabar Civet	*Viverra civettina*	59	22	2	1	0
	Mediterranean monk seal	*Monachus monachus*	73	4	2	0	4
	Red Wolf	*Canis rufus*	82	2	1	3	3

Table 2.8: Charismatic species survey results

Critically endangered species orders, common and scientific names are listed against the total survey score achieved and ranking, with their corresponding trend and Species Management (SMG) and Research and Monitoring (RMG) grades.

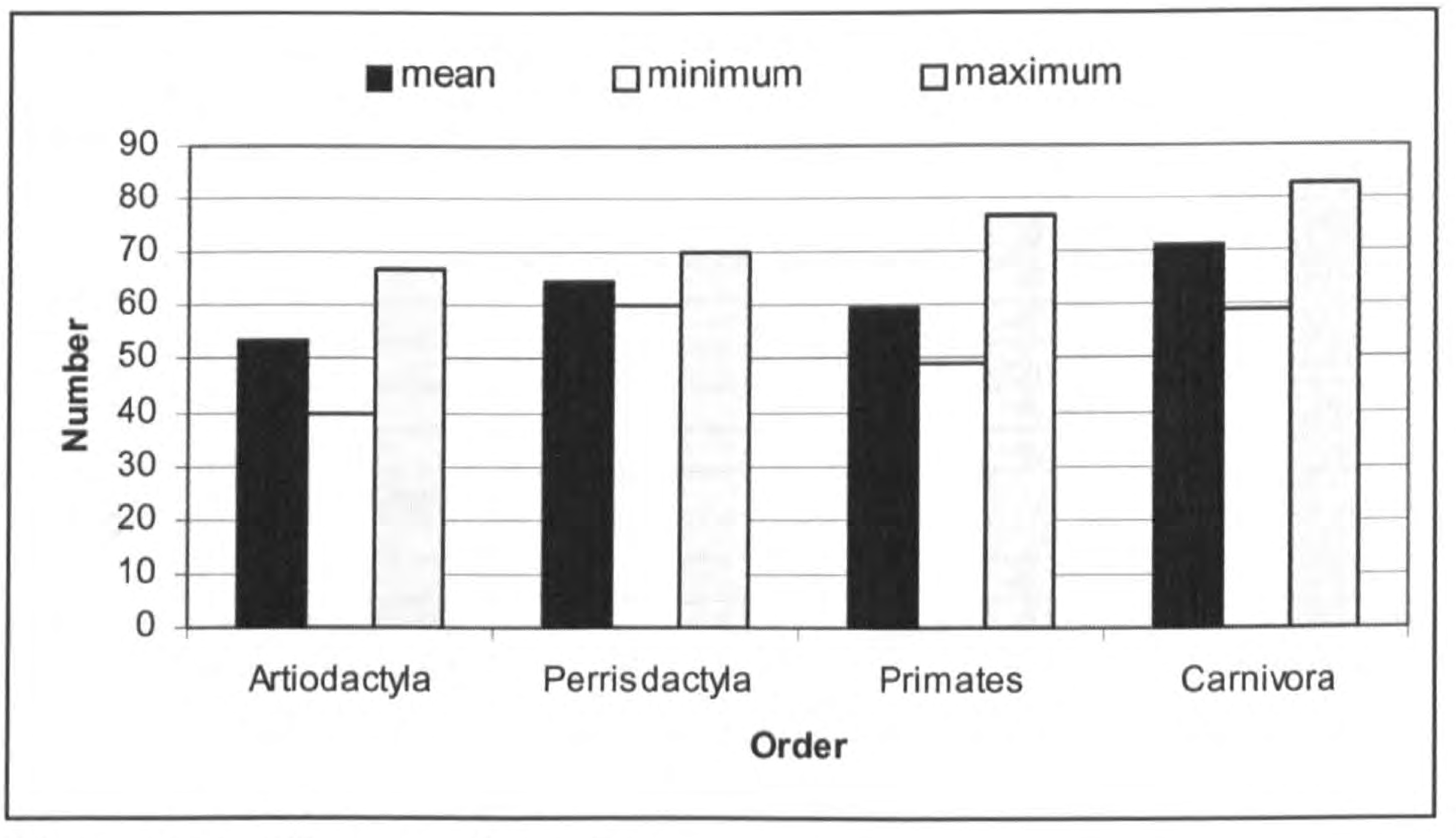


Figure 2.12: Charisma by order
Mean, minimum and maximum charisma scores achieved by each order.

	Classification	Status		
	Variable	Critical	Endangered	MDA
	Status			
	Trend	6.334	3.579	3.325
Continent	Africa	1.465	1.154	1.151
	Asia	0.15	0.452	0.354
	North America	0.346	0.47	0.412
	South America	1.973	0.491	1.025
	Europe	0.16	-0.129	-0.025
	Oceania	0	0	0
Range	Number of countries	2.423	-0.14	0.718
Habitat	Desert	0.358	0.46	0.395
	Forest	0.141	-0.079	-0.02
	Savannah	-0.49	-0.225	-0.327
	Grassland	-0.02	0.305	0.207
	Shrub land	-0.033	0.223	0.148
	Wetland	-0.408	-0.047	-0.153
	Coast	-0.344	-0.06	-0.128
	artificial	-0.587	0.216	-0.002
	Terrestrial freshwater	0	0	0
	Rocky	0	0.277	0.233
	Unknown	-0.793	0.303	-0.011
Threat	habitat loss and degradation	-0.319	0.005	-0.097
	harvesting/hunting	-0.217	-0.047	-0.107
	accidental mortality	-0.867	0.309	-0.047
	change to native species dynamics	-0.559	0.563	0.243
	human disturbance	-0.659	0.065	-0.202
	alien species	-0.118	0.054	-0.033
	natural disaster	-0.251	-0.053	-0.097
	persecution	0.037	0.496	0.336
	pollution	0.832	0.036	0.214
	Intrinsic Factors (IF) - range restriction	-1.553	-0.175	-0.646
	IF - low density	-0.496	-0.169	-0.245
	IF - infant mortality	0.21	0.247	0.234
	IF - low reproductive success	0	0	0
	IF - inbreeding	-0.944	-0.06	-0.358
	IF - skewed sex ratio	0	0	0
	IF - limited dispersal	-0.316	-0.071	-0.17
	IF - poor recruitment	0.687	0.304	0.381
	Unknown	-0.314	-0.38	-0.375
protection	CITES	1.229	0.527	0.752
	Protected Area	-0.221	0.418	0.205
	Legal protection	-0.547	1.105	0.602
management	Ex Situ	-0.022	1.35	0.984
	Captive breeding	-0.168	0.399	0.23
	Re-Introduction	-0.483	0.162	-0.061
research	Population & Range	-0.977	0.306	-0.083
	Biology & Ecology	-1.126	1.202	0.697
	Trends	-0.161	-0.068	-0.109
	Threats	0.563	0.575	0.568
monitoring	Monitoring	0.899	-0.525	-0.136
grades	SMG	0.33	0.972	0.849
	RMG	-0.032	0.799	0.615

Table 2.9: Random forest analysis: MDA scores for status

Random forest analysis figures for predicting status, including calculated predictors for 'critical' and 'endangered' status and Mean Decrease Accuracy (MDA) values for each variable.

Species (common Name)	Votes'	
	Critical	*Endangered*
White-whiskered spider monkey	0.53	0.47
Nubian ibex	0.55	0.44
Sclater's geunon/monkey	0.52	0.48
bearded Saki	0.52	0.48
Arabian tahr	0.63	0.37
Microcebus myoxinus	0.65	0.35
Arabian/white oryx	0.58	0.42
saola	0.51	0.49
Critical		
Addax	0.405	0.595
Grey Ox	0.268	**0.732**
Tamaraw/Tamarou	0.21	**0.789**
Bactrian Camel	0.263	**0.737**
Red Wolf	0.304	0.696
Walia ibex	0.438	0.562
Ader's duiker	0.415	0.585
Hirola/Hunters antelope/hartebeest	0.356	0.643
Sumatran rhinoceros	0.313	0.687
Black rhinoceros	0.238	**0.762**
Pere david's deer	0.359	0.641
African ass	0.44	0.56
Golden bamboo lemur	0.315	0.684
Broad-nosed gentle lemur	0.222	**0.778**
Black lion tamarin	0.292	**0.71**
Iberian lynx	0.24	**0.76**
Mediterranean monk seal	0.312	0.688
Sumatran Orang utan	0.363	0.637
Prezewalski's Gazelle	0.479	0.521
Eastern red colobus	0.421	0.578
Golden Crowned Sifaka/Tattersall's Sifaka	0.456	0.544
Darwins fox	0.333	0.667
Javan rhinoceros	0.494	0.506
Brazilian bare-faced tamarin	0.211	**0.789**
Saiga antelope	0.295	**0.705**
Visayan Warty Pig	0.35	0.65
Pygmy hog	0.435	0.565
White-rumped black leaf monkey	0.473	0.528
California channel island fox	0.35	0.65
Malabar civet	0.468	0.532

Table 2.10: Random forest analysis: confusion matrix votes for status
'Votes' for predicting status calculated by the Random Forest Analysis for each species.

	Classification	Trend				
	Variable	unknown	Increase	decrease	stable	MDA
	Status					
	Trend					
Continent	Africa	0.473	0	-0.404	-0.956	-0.236
	Asia	1.93	1.416	0.393	0.679	1.224
	North America	0.013	0	-0.832	-0.351	-0.267
	South America	2.159	0	0.331	1.233	1.511
	Europe	0.349	0	0.094	-0.293	0.055
	Oceania	0	0	0	0	0
Range	Number of countries	1.184	0.577	0.574	-0.333	0.431
Habitat	Desert	1.56	0	-0.961	0.189	0.499
	Forest	1.283	1.226	0.286	1.417	1.204
	Savannah	0.436	-0.707	0.614	0.189	0.248
	Grassland	1.318	0	-0.458	1.106	0.915
	Shrub land	-0.009	1.226	-0.537	-0.279	-0.204
	Wetland	0.038	-1.416	-0.173	-0.215	-0.12
	Coast	0.222	0	-0.387	-0.416	-0.076
	artificial	-0.317	-1.735	-0.707	1.082	0.216
	Terrestrial freshwater	0	0	0	0	0
	Rocky	0.192	0	0	0.39	0.257
	Unknown	2.939	0	-1.515	2.824	2.141
Threat	habitat loss and degradation	-0.007	-1.226	-1.138	-0.452	-0.348
	harvesting/hunting	1.766	-1.735	-0.764	0.004	0.876
	accidental mortality	0.163	0	-0.474	-0.357	-0.147
	change to native species dynamics	1.268	-1.226	-1.39	1.416	1.063
	human disturbance	-0.179	-0.707	0.316	-0.418	-0.15
	alien species	0.458	0	-2.103	1.109	0.417
	natural disaster	2.047	0	1.479	2.186	1.602
	persecution	-0.024	-0.707	-0.912	-0.465	-0.274
	pollution	0.643	0	0.316	-0.331	0.069
	Intrinsic Factors (IF) - range restriction	0.779	0	0.492	-0.181	0.392
	IF - low density	1.506	0	-0.554	1.033	1.033
	IF - infant mortality	-0.182	0	0	-0.62	-0.311
	IF - low reproductive success	0	0	0	0	0
	IF - inbreeding	0.06	0	0	-0.679	-0.289
	IF - skewed sex ratio	0	0	0	0	0
	IF - limited dispersal	0.295	0	0	0.31	0.221
	IF - poor recruitment	0.598	0	0.289	-0.89	-0.102
	Unknown	-0.708	0	-0.787	-0.699	-0.682
protection	CITES	1.512	-1.416	0.513	1.586	1.357
	Protected Area	1.29	2.352	-0.041	0.85	0.929
	Legal protection	2.352	-3.836	-0.702	1.957	1.716
management	Ex Situ	1.57	0.707	-0.996	-0.149	0.585
	Captive breeding	0.076	1.735	-0.226	-0.771	-0.327
	Re-Introduction	0.526	2.558	-1.335	0.432	0.301
research	Population & Range	0.711	0.316	-0.863	1.526	0.95
	Biology & Ecology	1.62	-2.0047	-1.218	-0.18	0.599
	Trends	-0.087	0	0.839	0.144	0.114
	Threats	0.523	-2.457	1.187	0.734	0.589
monitoring	Monitoring	0.327	1.874	0.359	0.251	0.302
grades	SMG	1.744	3.014	-0.883	-0.143	0.742
	RMG	0.268	2.352	-0.472	0.692	0.391

Table 2.11: Random forest analysis: MDA values for trend

Random forest analysis figures for predicting trend, including calculated predictors for 'unknown', 'increasing', 'decreasing' and 'stable' trends, and Mean Decrease Accuracy (MDA) values for each variable.

	Classification	RMG						
	Variable	**0**	**1**	**2**	**3**	**4**	**5**	**MDA**
	Status	-0.085	2.384	2.377	-0.167	-0.583	-0.821	0.471
	Trend	-0.719	2.32	0.608	-0.915	0.593	2.407	-0.282
Continent	Africa	-0.529	2.154	1.619	1.075	0.735	-1.1	0.053
	Asia	-0.279	1.813	1.38	1.217	1.619	-0.665	0.256
	North America	1.285	0	1.1	3.557	0	-2.113	1.249
	South America	0.247	0.969	2.613	-1.928	1.583	1.226	0.598
	Europe	-0.12	0	-0.658	0.408	-0.885	-0.751	-0.248
	Oceania	0	0	0	0	0	0	0
Range	Number of countries	0.7	0.058	-0.539	1.041	4.073	-0.946	0.521
Habitat	Desert	0.088	0	0.793	-1.478	0	-1.041	-0.04
	Forest	-0.436	-1.858	0.744	0.721	-0.882	0.304	-0.141
	Savannah	-0.083	0.707	1.542	-1.14	-0.913	-1.901	-0.159
	Grassland	0.399	0	-1.668	-0.896	-1.606	4.101	0.149
	Shrub land	-0.419	0.707	1.567	1.535	4.156	2.816	0.538
	Wetland	-0.078	0	0.711	-0.376	0	-0.628	0.037
	Coast	1.512	1.155	1.037	2.88	-2.26	-1.538	1.241
	artificial	0.09	0	-0.534	-0.655	0	-0.913	-0.143
	Terrestrial freshwater	0	0	0	0	0	0	0
	Rocky	0.713	0	-0.417	0	0	-0.817	0.344
	Unknown	-0.85	2.186	0.576	1.643	-2.764	1.191	-0.355
Threat	habitat loss and degradation	-0.906	-2.186	0.784	0.593	0.289	-0.192	-0.525
	harvesting/hunting	0.215	-2.469	1.464	-0.565	2.591	3.148	0.534
	accidental mortality	2.462	0	-0.012	1.46	4.306	-1.328	1.658
	change to native species dynamics	0.163	0.707	-0.137	-1.37	2.629	2.26	0.179
	human disturbance	-0.136	0	0.795	0.83	1.502	1.085	0.26
	alien species	-0.573	-1.148	-0.199	-0.27	-0.199	3.111	-0.303
	natural disaster	1.166	1.001	1.216	-0.618	0.577	0.5	0.878
	persecution	1.023	-1.767	-0.912	0.996	-2.878	2.642	0.615
	pollution	-0.097	0	-0.06	-0.431	0	0	-0.146
	Intrinsic Factors (IF) - range restriction	1.262	0.866	0.443	-0.572	-0.713	-0.189	0.869
	IF - low density	-0.255	0	0.674	-0.567	-1.119	0	-0.186
	IF - infant mortality	0.101	0	-0.127	-1.053	0	-0.5	-0.165
	IF - low reproduction	0	0	0	0	0	0	0
	IF - inbreeding	0.52	0	0.797	-0.237	0	-1.119	0.396
	IF - skewed sex ratio	0	0	0	0	0	0	0
	IF - limited dispersal	0.507	0	0	0	0	2.545	0.519
	IF - poor recruitment	0.501	0	-0.0353	-0.919	-0.5	0.5	0.081
	Unknown	-1.199	-1.366	0.16	1.465	1.001	0	-0.751
protection	CITES	-0.707	-2.542	1.569	0.002	2.855	-2.373	-0.255
	Protected Area	1.266	1.348	2.661	2.254	0.857	-0.021	1.391
	Legal protection	2.569	-3.728	0.968	-2.294	0.788	2.964	1.655
management	Ex Situ	-0.157	-1.693	-0.111	0.891	1.355	-0.658	-0.08
	Captive breeding	0.522	-1.715	-0.363	3.242	1.833	1.524	0.678
	Re-Introduction	0.211	-1.759	-0.909	-1.245	1.001	-1.558	-0.302
research	Population & Range							
	Biology & Ecology							
	Trends							
	Threats							
monitoring	Monitoring							
grades	SMG	0.642	-1.677	-1.859	0.862	-0.026	0.657	0.173
	RMG							

Table 2.12: Random forest analysis: MDA values for RMG

Random forest analysis figures for predicting RMG, including calculated predictors for RMG 0-5, and Mean Decrease Accuracy (MDA) values for each variable.

Variable	Status	Number	Mean	Median
Trend	Critical	42	2.4048	2
	Endangered	111	1.234	0
Africa	Critical	42	0.2619	0
	Endangered	111	0.3153	0
South America	Critical	42	0.2381	0
	Endangered	111	0.2523	0

Table 2.13: Status means and medians
Mean and median predictor variable values for distinguishing status

Variable	Trend	Number	Mean	Median
Unknown habitat	Unknown	64	0.34	0.00
	Increasing	3	0.00	0.00
	Decreasing	23	0.2609	0.00
	Stable	63	0.0476	0.00
Legal protection	Unknown	64	2.72	3.00
	Increasing	3	1.67	1.00
	Decreasing	23	2.44	3.00
	Stable	63	2.13	2.00
Natural disaster	Unknown	64	0.00	0.00
	Increasing	3	0.00	0.00
	Decreasing	23	0.00	0.00
	Stable	63	0.13	0.00

Table 2.14: Trend means and medians
Mean and median predictor variable values for distinguishing trend

Variable	RMG	Number	Mean	Median
Accidental death	0	86	0.01	0.00
	1	6	0.00	0.00
	2	29	0.07	0.00
	3	18	0.22	0.00
	4	6	0.50	0.50
	5	8	0.38	0.00
Legal protection	0	86	2.67	3.00
	1	6	2.50	3.00
	2	29	2.28	3.00
	3	18	1.89	1.50
	4	6	1.67	1.00
	5	8	1.75	2.00
Protected area	0	86	2.31	3.00
	1	6	2.67	3.00
	2	29	1.76	1.00
	3	18	1.50	1.00
	4	6	1.17	1.00
	5	8	1.50	1.00

Table 2.15: RMG means and medians
Mean and median predictor variable values for distinguishing RMG

Dependent Variable	Important predictor variable/group	Interpretation
Status	**Trend** (Critical)	Species with declining or stable trends are more likely to be critically endangered rather than endangered *(in this data set: trend 0 = unknown, 1 = increasing, 2 = stable, 3 = declining)*
	Africa (Endangered)	African species are more likely to be endangered rather than critically endangered
	South America (Endangered)	South American species are more likely to be endangered than critically endangered
Trend	**Unknown habitat** (Unknown)	Species with an unknown habitat type are likely to have an unknown population trend
	Legal protection (Unknown)	Species with needed, or only some, legal protection are more likely to have an unknown population trend. *(in this data set: legal 0 = none, 1 = yes, 2 = some, 3 = needed)*
	Natural Disaster (Stable)	Species which are threatened by natural disaster are more likely to have a stable population trend
RMG	**Accidental death** (≥3)	Species with higher RMG's (≥3) are those which are threatened by accidental death
	Legal protection (≤3)	Species with lower RMG's (≤3) are those which do not have, or which have little legal protection
	Protected area (≤2)	Species with a low RMG (≤2) are those which are not found within a protected area, or are only partly protected. *(in this data set: protected area 1 = yes, 2 = some, 3 = no/needed)*

Table 2.16: Interpretation of important predictor variables
The 3 most important predictor variables for status, trend and RMG as identified by them achieving the highest predictor scores in the analysis compared to all the variables included. Calculated mean values (tables 2.13 – 2.15) for status, trend and RMG revealed the 'direction' of the prediction, the results of which are interpreted.

<u>CHAPTER THREE: SPECIES MANAGEMENT AND MONITORING</u>

3.1 Pre-amble

With endangered species facing a plethora of threats and with the prevalent threats of habitat loss and harvesting or hunting set to increase with increasing human population, effective management and monitoring of already threatened species is increasingly important. From the 153 species studied in chapter 2, only 24 (16%) were identified as having a monitoring programme in place, and 90 (59%) as having some form of species management (mostly an ex situ population). There is also an identified need for quantification of species population trend, particularly for the endangered species included chapter 2. The importance of distributing conservation action in accordance with need and not just based upon 'hotspot' geography has also been highlighted. Analysis revealed certain habitat types, threats, known trend and the presence of legal protection to be good predictors of the best level of research and monitoring, however at this point, the practical application and effectiveness of such monitoring strategies, and indeed species management, has not been explored.

By increasing understanding of management and monitoring techniques across a sample of species it may be possible to determine their effectiveness, identify techniques which could be shared and establish if there is a good standard of monitoring which could then be applied to the development of future monitoring programmes. Such research is important as the effective monitoring of species status must be a fundamental management priority, which is becoming increasingly needed particularly as the urgency to protect species from extinction is potentially outweighing the resources available to do so.

3.2 Introduction

3.21 How are priorities for management and monitoring set?

One of the major challenges in conservation is the setting of priorities and measuring the success of the actions (Mills, 2004). IUCN action plans assess the conservation status of species and their habitats, and specify conservation priorities (IUCN, 2003). These documents are available to natural resource managers, conservationists and government officials around the world (IUCN, 2003). Species status, as determined by the IUCN categories and criteria, is an important criterion when prioritising species for conservation action and while all threatened species deserve to be the focus of concerted conservation efforts, Critically Endangered and Endangered species should receive immediate attention, and separate and unique action plans (Mills, 2004)

Sillero-Zubiri et al (2004) list projects and actions believed to be of priority for canid conservation. These included status surveys, particularly short surveys of data deficient species, the development of both a standardised and a non-invasive survey and monitoring methodology. The action plan details projects around the world. In the Americas, projects range from finding new populations of Darwins fox (*Pseudalopex fulvipes*), surveying the population status of bush dogs (*Speothos venaticus*), a population survey and habitat assessment of maned wolves (*Chrysocyon brachyurus*), hybridisation reduction in red wolves (*Canis rufus*), monitoring and reintroduction of the swift fox (*Vulpes velox*) into Canada and Montana, and gray wolf (*Canis lupus*) restoration projects. In Europe, Africa and Asia, projects include the conservation of artic foxes (*Alopex lagopus*), Ethiopian wolf (*Canis simensis*) and African wild dog (*Lycaon pictus*) monitoring, and surveys, monitoring and protection of dholes (*Cuon alpinus*) and their habitat. For all canid species, priorities include the implementation of the action plan, development of a canid project database, status surveys and monitoring (Sillero-Zubiri et al, 2004).

For antelopes, their action plan states that over-hunting has been primarily or wholly responsible for the regional extinction of several species, and the depletion of most others (Mallon and Kingswood, 2001). In the action plan, Mallon and Kingswood (2001) describe three measures which need to be undertaken. These are full enforcement of existing laws, a review of legislation followed by new or stronger law enactment, and vitally, effective protection in the field. Governmental action needed to conserve antelopes is described as protective legislation, strategies, a wildlife administrative infrastructure and a comprehensive protected areas system. Intergovernmental co-operation is also important where populations cross borders. Protected areas are described as essential, and in the plan are described as needing clear objectives, professional management and need to provide rigorous protection on the ground. Captive breeding and reintroduction, and translocations are stated as the only way of establishing free-ranging populations of now impoverished populations of some antelope species. However it is recognised that it is preferable to concentrate efforts on in situ measures to conserve existing wild populations. A clear first priority is to carry out field surveys determining distribution, numbers and status of antelope species where they are currently unknown, and to research the ecology of most species. Training in techniques for rangers is important and the status of antelopes on the whole should be monitored (Mallon and Kingswood, 2001).

Like the antelope action plan, the deer action plan (Wemmer,1998) also recognises that with limited conservation resources, priority should be given to in situ deer conservation and that captive breeding programmes for deer species should only be initiated if wild populations are low, when threats cannot be mitigated and when there is a clear and high risk of extinction in the near future (Wemmer, 1998). The species should also have a written recovery plan with allocated funds and commitment and there should be appropriate, well managed captive facilities in place (Wemmer, 1998). Objectives stated in the deer action plan include status determination as a priority for data deficient species in particular, species conservation priority setting for each country, according to population demographics inside and outside protected areas, adequacy of protection, and nature of threats to species (Wemmer, 1998).

The wild cat action plan is designed to promote the conservation of all the wild cats in their natural surroundings (Nowell and Jackson, 1996). Priority projects listed among many others include the establishment of a cat conservation data centre, map database development to overlay cat distribution survey data, global survey of methods to alleviate human conflicts (e.g. livestock losses) with cats, a survey of diseases in wild cats and development of an understanding of the demand for cat parts in trade. Surveys and monitoring are the backbone of much priority action listed by the cat action plan. Specific projects stated include the long term monitoring for reintroduced species (e.g. Eurasian lynx (*Lynx lynx*) and bobcat (*Lynx rufus*)), severely threatened species (e.g. Iberian Lynx (*Lynx pardinus*)), and distribution surveys of many cat species around the world (e.g. African golden cat (*Profelis aurata*), cheetah (*Acinonyx jubatus*), lion (*Panthera leo*), tiger (*Panthera tigris*), leopard (*Panthera pardus*) and sand cat (*Felis margarita*)) (Nowell and Jackson, 1996).

For species of bear, priority actions include status surveys (particularly for Asian bears), establishment of managers and management plans (particularly in countries with unknown bear populations), enhancement of cross-border efforts, documentation of illegal trade and support for research into basic ecology, status and survey methodology (Servheen et al, 1999).

Some of the key management actions stated in these action plans include greater law enforcement and protection, particularly in the form of protected areas. Management of *in situ* populations is clearly the priority. Captive breeding, re-introduction and translocation programmes become more important when wild populations are impoverished, threats are not mitigated and where there is a high risk of extinction. The IUCN has a captive breeding specialist group who set guidelines for captive breeding and reintroduction programmes, there may not be equivalent guidelines for monitoring in situ. What is clear from a cross section of action plans is that distribution surveys and population monitoring are of a priority to many threatened species around the world, and that such critical work then forms the basis for conservation action. Action Plans themselves do not conserve biodiversity, only action does, and implementation is the key to achievement of this goal (Mallon and Kingswood, 2001)

3.22 Monitoring threatened species

Monitoring is essential for effective management, and the effective detection of population trend is important for managing threatened species (Joseph et al, 2006, Harris and Yalden, 2004). Animal populations may change in distribution and abundance over time for a wide variety of reasons, the monitoring of such changes and identification of the causes, forms the core of conservation research (Evans and Hammond, 2004, Battersby and Greenwood, 2004). Monitoring involves the collection of identical data types, multiple times, over decadal time scales and such data from species populations are required for reasons such as managing problem species, measuring conservation management impacts, measuring the effects of human activities, monitoring sustainable use and the setting of conservation priorities (Battersby and Greenwood, 2004, Watson and Novelly, 2004).

Monitoring is a critical process in the prevention of species extinction and in an ideal world all threatened species would be continuously, consistently and accurately monitored. It must be recognised however that monitoring programmes will always have limitations, such as cost. Before embarking on a monitoring programme, it would be wise to consider what information can be gained and the limitations which exist, then to conduct a cost benefit analysis and consider the various options available before identifying the most appropriate option (Evans and Hammond, 2004). Clearly identifying costs and benefits will help to prioritise the programmes focus and ultimately, for a monitoring programme to be a success, its benefits, although difficult to quantify, must justify the cost (Caughlan and Oakley, 2001).

Monitoring and management often require more resources and commitment than are usually acknowledged at the planning stage (Regan et al, 2008). Smyth and James (2004) describe a multifaceted process to monitoring design development, involving conception, planning and delivery. Factors to consider in development include method evaluation, with respect to relevance, logistics, robustness and power, and in particular that statistical power is considered when setting objectives, of which the importance of setting appropriate and clear objectives cannot be overemphasised. (Schwartz et al, 2006, Caughlan and Oakley, 2001). It is clear that no monitoring programme could satisfy all purposes (Smyth and James, 2004). Instead a selection of minimum necessary attributes is required, thus prioritising the purposes for monitoring (Smyth and James, 2004). Regan et al (2008) regard the basing of prioritisation decisions on sound science and directly relating them to the goals and objectives of the conservation plan as important in the first step of structuring a monitoring programme.

Watson and Novelly (2004) describe some of the elements of good monitoring as understanding natural variability in the attribute of interest, the importance of timescale, the need for adequate coverage and resolution, and the linkages between change, trend and threatening processes. Other important requirements for a good monitoring programme include achievability, well considered techniques, good and user friendly data management, data interpretation with reporting and feedback, and ultimately the system must be sustainable (Watson and Novelly, 2004).

General attributes of a good monitoring programme are hard to establish as each programme will be set to achieve different goals and collect different information. Also, success can only be determined after a long time scale, with results successfully detecting true trends which either indicate the need for management action, or the stability of the subject, therefore requiring no further action at that time. It may also be necessary to monitor and evaluate additional components of biodiversity, such as communities or ecosystems, to determine if the objectives of the conservation plan are being met (Regan et al, 2008). A good species monitoring programme therefore may be one which encompasses data collection not just on the target species but also on elements of its ecosystem on which it relies to survive. Of course there may be situations where a monitoring programme is not appropriate, either due to costs, lack of resources, or even constraints such as inhospitable areas. In this case, there may be other options for providing information to help make policy decisions, however these methods will need to capture some elements of good monitoring (Watson and Novelly, 2004). Roberts et al (2007) describes the urgent need to develop simple and inexpensive methods for monitoring wildlife populations in countries which are resource-poor. List based monitoring schemes are suggested as a way of achieving large sample sizes, with minimal resources in an easy to establish way, even though compromises may be made with reliability and precision (Roberts et al, 2007). Such a simple system however has ultimate flexibility. List based monitoring schemes might incorporate many sources of data currently collected outside dedicated monitoring schemes (Roberts et al, 2007). At the very least, such information could form and add to baseline information for many species, particularly those for which data is deficient and for which knowledge of their status is critical, particularly in regions in which species may be suffering acute threats.

3.23 Techniques to monitor species

Joseph et al (2006) recognised the increasing interest in monitoring to determine the best management decision to make. However, the development of field-sampling methods lags behind associated statistical theory and computational design for analysing data (Roberts and Schnell, 2006). One issue is how to choose among alternative monitoring methods, and whether to monitor trends in population size (abundance estimates) or to track changes in occupancy or distribution (presence-absence). There are firstly choices to be made about the type of data required and the type of information such data will provide. In exploring the monitoring of Cetaceans, Evans and Hammond (2004) describe the usefulness of different types of information gathered from monitoring. Trends in abundance are useful for identifying populations in which there is concern and for monitoring the impact of conservation actions. Absolute abundance information, particularly in conjunction with population structure data, can identify populations for which management action is required. Geographical and temporal distribution data can determine concentration areas and times, and significant life cycle stages (mating and/or calving) for which conservation action can then be focused (Evans and Hammond, 2004). Survey type will depend upon species abundance and distribution to begin with, the difficulty of detection, and the level of resources available (Joseph et al, 2006).

There have been countless individual research projects attempting to quantify variables such as species population, range, ecology, biology, trends and threats, all using a variety of techniques. In all wildlife management and conservation projects, reliable population size estimates are of crucial, for example to establish priorities and monitor management activities (Carbonel et al, 2002, Gussett and Burgener, 2005). However some species can be difficult to study particularly with often expensive and timely direct methods, therefore indirect census techniques can be cost effective, repeatable and objective (Gussett and Burgener, 2005, Stander, 1998). Indirect sampling can provide comparable information at lower cost, and is used mostly in areas where direct methods are practically or financially constrained (Gussett and Burgener, 2005). Many studies rely on the evidence a species leaves behind of its presence such as spoor and dung, and these are used for example as an indirect way of recording a species' presence. Others attempt to bridge to problem of relying on regular direct sightings by using remote photography or radio and satellite tracking technology. Some studies do use techniques such as distance sampling which rely on sightings. There are many possible techniques which can be incorporated to study species, some of which will be introduced.

3.23.1 Tracks and signs

The use of tracks and signs for species population estimation is arguably one of the simplest techniques to sample a population in a given area. Such a technique is particularly useful for sampling cryptic species, or those in dense habitats (Plumptre, 2000). Two techniques which have been used extensively are dung and spoor counts.

3.23.11 Dung

Many studies have used dung as a tool for surveying species. Dung counts have been used to estimate numbers of vertebrates ranging from lizards to elephants (Barnes, 2001). Such studies have attempted to quantify species density and distributions (e.g. elephants, elusive species, species in dense habitats) and dung has also been used as a non-invasive way of extracting DNA for analysis and to examine species diet (e.g. Eggert, 2003, Ellis and Bernard, 2005, Rasmussen et al, 2005, Komers and Brotherton, 1997, Marques et al, 2001, Reilly, 2002, Steinheim et al 2005, Tuyttens et al, 2001, Van Vliet et al, 2007). Dung counts can give estimates similar (as accurate or inaccurate) to those from other methods for a wide range of vertebrate groups, and therefore are a valid and respectable means of estimating vertebrate populations (Barnes, 2001).

Dung counting has been an effective way of surveying many species around the world. Examples include the estimation of Kirk dik dik population densities (Kenya), kudu abundance (South Africa), woodland deer populations (Scotland), badger group size and population density (UK), and for the study of forest elephants in both Asia and Africa (Barnes, 2001, 2002, Ellis and Bernard, 2005, Komers and Brotherton, 1997, Marques et al, 2001, Rasmussen et al, 2005, Tuyttens et al, 2001). Such studies have found dung count techniques to be reliable and accurate in estimating populations. Barnes (2002) found dung counts to be more reliable and precise than aerial surveys, and Ellis and Bernard (2005) found them to be particularly advantageous in thick vegetation where other methods would be ineffective. They can also be used to count animals in specific areas, or which are using certain resources, for example by counting elephant dung and wells in dry season riverbeds to determine elephant densities (Rasmussen et al, 2005)

There are however potential sources of error to consider with dung counting to count animals. The efficiency of using dung as a tool has been reviewed, and variables such as decay and the effect of rainfall have been considered (e.g Barnes, 2002, Barnes, 2001, Barnes et al, 1997, Nchanjii and Plumptre, 2001, Vanleeuwe, 2008, Van Vliet et al, 2008). Factors such as high rainfall have been found to affect dung decay, although less so in lower temperatures, and dung beetle activity could cause underestimations (Barnes et al, 1997, Vanleeuwe, 2008, Van Vliet et al, 2008). Dung decay rate can be variable between sites and seasons, and a multitude of environmental factors can affect it (Nchanjii and Plumptre, 2001).Therefore, to be reliable, dung counts should be combined with decay estimates and defecation rate to get an accurate estimation of density (Barnes, 2001).

There are, however, other advantages in using dung as a tool. Not only can dung be used to ascertain population densities or species presence, but it can also gain important insights of conservation benefit, such as into species diet, group structure, and genetic information. For example, ascertaining similarities in the dry season diets of Asian elephants and Indian rhinos, predicting elephant age from dung bolus diameter (advantageous in dense habitats) (Steinheim et al, 2005, Reilly, 2002). Genetic information has been harnessed to estimate the population size of forest elephants and to distinguish different duiker species, both studies found such analysis to be detailed, reliable and precise compared to dung counts alone (Eggert et al, 2003, Van Vliet et al, 2007).

3.23.12 Spoor

Spoor identification by tracking is another indirect technique, which is age-old and still practised by many indigenous peoples for hunting and interpreting animal behaviour (Jewell et al, 2001). Track counts were used to assess numbers of 6 large carnivore species by Gussett and Burgener (2005). Their results found the technique could provide reliable and cost effective estimates of abundance with large carnivore species. The relationship between true density and the distribution of spoor was explored by Stander (1998), who compared direct counting data of leopards, African wild dogs and lions to spoor counts along roads. Stander (1998) found successful monitoring relied upon thorough sampling design, and an understanding of the relationship between true density and spoor frequency was of primary importance. It was recognised that spoor frequency on roads may be a function of range or road use, however, both range and road use could be expected to increase with higher population densities (Stander, 1998). Therefore spoor counts could be an index of true density, and in this study, that proved to be the case for all three carnivore species.

Jewell et al (2001) believe that the use of spoor in censusing and monitoring will play an increasingly important part in the conservation of certain endangered species. In their study, a system was developed where digital photographs were taken of rhino prints, which were then analysed and points set up on each image to identify individuals from their spoor (Jewell et al, 2001). The technique was found to promising but with limitations, such as the quality of substrate and the lack of spoor for some of the rhinos in the study (Jewell et al, 2001).

3.23.2 Waves and Vibrations

Wood et al (2005) tested a new detection technique which could be used to census and monitor large mammals. Seismic sensors were used to record the vibrations caused by footfalls of large mammal species, and interestingly, the technique was found discriminate between species with 82% accuracy (Wood et al, 2005). Only a single geophone was used in this study. It was suggested that by increasing the number of geophones (using an array), greater accuracy could be gained in estimating the number of an individual species passing by. A limiting factor would be how far footfalls could travel, however it was suggested that the technique could be useful in monitoring resource use, such as waterholes (Wood et al, 2005).

A technique which uses sound to monitor populations of mammals, is used off the coastline of the UK to monitor cetaceans, and is becoming increasing useful and accurate with advances in technology, to monitoring behaviour, socialisations, and population density of a range of species over continuous timescales (Evans pers.comm, 2008).

3.23.3 Photography

3.23.31 Total counts

Aerial photography has proved useful in censusing species, particularly those which congregate in large numbers. Aerial photography was used to census flamingos on nine Tanzanian lakes, in order to document the distribution and abundance of flamingos in the rift valley, and to continue with the development of a needed long term survey technique (Woodworth et al, 1997). The survey found most flamingos to be concentrated on Lake Natron, with a total estimate of more than 500,000 in groups of 150 to 10,000. Importantly, the study found visual estimation techniques unsuitable as a long term method due to subjectivity in recorders (Woodworth et al, 1997). Photographic censusing proved to be a good methodology, particularly with the large area size and numbers which required surveying (Woodworth et al, 1997). Snyder et al (2001) used photography to census Steller sea lion pups in Alaska. The results and precision were found to be similar to current disruptive drive counts, and photographic censusing was suggested as an alternative, with the added advantage of being able to survey large areas during good weather, with minimal manpower (Snyder et al, 2001).

3.23.32 Camera traps

Photography has also been adapted for use as camera traps, and to carry out mark-re sight surveys, particularly for elusive species which would otherwise be difficult to see for example the tiger, snow leopard and Iberian lynx (Azlan and Sharma, 2003, Karanth, 1995, McCarthy et al, 2007, Smith et al, 2007, Ward, 2006e). This method has proved to be an important monitoring tool, however, this type of survey, when good, is expensive, if done cheaply it is unreliable and the whole technique is dependent on expertise, the quality of equipment, survey effort, and robust analysis with challenging data (Karanth, 2007). Jackson et al (2005) describe the many factors to be considered before starting a camera trap survey. Factors include area size, reliable identification of travel paths, orientation of equipment, if sufficient number of captures for a reliable population estimate can be achieved and are other resources in place such as logistical support, trained staff and facilities for data analysis (Jackson et al, 2005)

3.23.4 Remote tracking

Remote tracking provides a survey technique which requires initial direct contact, but then allows surveying from a distance, or further direct sightings. It has been well used and now incorporates using radio tags and collars (Avenanti and Nel, 1998, Broomhall et al, 2003, Hoffmann and Klingel, 2001, Mills and Gorman, 1997, Osborn and Parker, 2003, Somers et al, 2004), and satellite tags and collars (Lagerquist et al, 2000, Markham and Altmann, 2008, Watkins et al, 1999, Watkins et al, 2002) to monitor a wide range of species.

3.23.41 Radio tracking

Radio tags can provide continuous tracking, which is advantageous for species where sightings are limited, providing greater ecological insights, and advantageous information for conservation. For example, Watkins et al (1999) attached a radio tag to a sperm whale in the Caribbean. This allowed continuous tracking over several days, providing a profile of each dive and surface behaviour. The study found deep dives accounted for 54% of activity, with surface activity and shallow dives accounting for 22.6%, 23.4% of activity respectively (Watkins et al, 1999).

Avenanti and Nel (1998) used radio tracking to monitor 5 caracals in South Africa, in order to determine space and prey use in a conservation area. Caracals were found to be positively correlated with rodent biomass, active during the day and night, males had larger territories and moved twice the distance of females during an active period. Radio tracking revealed a preference for open savannah habitat for cheetahs within Kruger National Park South Africa, with females using dense woodland more often than males, possibly influenced by habitat preferences of their main prey, impala (Broomhall et al, 2003). Hoffmann and Klingel (2001) used radio tracking to monitor a species of rodent in Queen Elizabeth National Park, Uganda. Nine individuals were tracked, to reveal home range size and utilisation, and activity patterns, to form part of a large study of mammal populations in that area. Radio collars were implemented in a study of African Wild dogs to help in determining factors affecting their density and distribution within Kruger National Park, South Africa (Mills and Gorman, 1997). The outcome of this project showed their main prey to be impala, and that wild dog populations may be more successful in areas with low to moderate densities of lions and spotted hyenas (Mills and Gorman, 1997). Habitat selection of the Cape clawless otter in South Africa was studied through radio tracking seven individuals (Somers et al, 2004). A greater proportion of the otters time was spent in habitats with reed beds, boulders, and overhanging vegetation, and they appeared to be selecting the habitats with high prey density (Somers et al, 2004). Combining radio tracking and GIS has helped to identify a wildlife corridor for elephant migration in Zimbabwe, where habitat conservation would also cause the least cost to local residents (Osborn and Parker, 2003).

3.23.42 Satellite tracking

Markham and Altmann (2008) used an automated tracking GPS system to track a single baboon. This was a pilot project to test the effectiveness of the technology with primates using open habitats. Results showed that the collar reliably captured location and other types of data, such as temperature, thus allowing behavioural and physical monitoring of their study primate. There is considerable potential for such use of GPS collars with primates, even with species for which direct observation is already possible and successful (Markham and Altmann, 2008).

Satellite tags have been used to monitor dive characteristics of blue whales, and surface and dive characteristics of sperm whales (Lagerquist et al, 2000, Watkins et al, 1999, Watkins et al, 2002). A small sample consisting of four blue whales were tagged to monitor movements and dive habits. Limitations in this study were short term tag attachment possibly due to drag from observed high swimming speeds, and limited transmission rates due to the whales spending more than 90% of their time underwater (Lagerquist et al, 2000). Radio and satellite tags were attached to three sperm whales (one radio tag, two satellite tags) in the South-East Caribbean in order to follow their surfacing patterns and movements (Watkins et al, 1999). Results revealed most social and rest surfacing to occur in daylight hours, with breathing surfacing during both day and night. Advantages of the technology were that there were no apparent effects on the whales by the presence of the tags and instant identification of each whale was provided on surfacing, regardless of visibility. This study emphasises the potential in observing individual whale activity and providing increased understanding of their behaviour and social interactions (Watkins et al, 1999).

3.23.5 Distance sampling

Distance sampling is a widely used tool for monitoring animal population abundance, used when the detectability of an object varies with the distance of the object and the observer, thus allowing detected animals from a line or point to be modelled (Barry and Welsh, 2001, Buckland et al, 2006). Many studies have used distance sampling from line transects (e.g. Jensen, 1996, Ogutu et al, 2006, Southwell et al, 2004), for point counts (e.g. Kubel and Yahner, 2007, Marsden, 1999), or both (e.g. Ruette et al, 2003), and also in comparison to other methods such as mark re-sight (e.g. Calambokidis and Barlow, 2004, Focardi et al, 2002, Hounsome et al, 2005).

3.23.51 Line transects

The line transect method is widely applied for estimation of abundance because it is simple, economical, and relatively precise (Jensen, 1996). The technique has been thoroughly used tested and evaluated in a variety of studies. Examples of such studies include the estimation numbers of red squirrel nests, African mammal herd size, abundance of hauled out crab eater seals from on ship surveys, estimation of blue and humpback whale populations, estimating forest deer populations, and badger abundance (Jensen, 1996, Ogutu et al, 2006, Southwell et al, 2004, Calambokidis and Barlow, 2004, Focardi et al, 2002, Hounsome et al, 2005).

Most of these studies assessed the effectiveness of line transects and also used them in collaboration with other techniques. Jensen (1996) found a large number of short transects to be preferable than a few long transects to survey red squirrel nests. Ogutu et al (2006), in comparing line and strip transects to estimate African mammal abundance, found precision to increase with both sample size and strip width, but that a combination of methods would best suit the multi species assemblage of the African savannah. In their study to assess the abundance of crab eater seals using line transects from on board a ship, Southwell et al (2004) recommended modifications to data collection after identifying bias toward a number of environmental features known to be associated with seals after difficulties with getting through the ice. Calambokidis and Barlow (2004) used line transects in collaboration with photographic identification to estimate blue and humpback whale abundance off the West coast of America and Mexico. Line transects were found to be effective for offshore estimates of humpback and blue whales, whereas photographic censuses were more effective for humpback whales inshore (Calambokidis and Barlow, 2004). When compared to mark re-sight techniques, line transects were found to be equally useful for assessing the population of fallow deer, roe deer and wild boar in Mediterranean forests (Focardi et al, 2002). Line transects were also found to have potential for estimating the abundance of medium to high density badger populations in fairly open landscapes, and that an abundance estimate was comparable to mark-re sight but with considerably less effort (Hounsome et al, 2005). All of these studies demonstrated the flexibility of using line transects to estimate species population abundance, either singularly or combined with complimentary techniques.

3.23.52 Point counting

Point counting works well for some species, particularly birds, but others are insufficiently noisy or visible for a method which involves recording the distance from the point to all animals detected within some truncation distance (Buckland et al, 2006). Kubel and Yahner (2007) assessed the detection probability of golden winged warblers in Pennsylvania, USA, using 3 minute point counts both with and without call playbacks. With this species, play backs were found to be a valuable supplement to point count surveys, and for investigators wishing to determine local population sizes and densities, playback use could be of benefit. Marsden (1999) assessed the suitability of using point count methods to estimate tropical parrot and hornbill densities in Indonesia. A number of recommendations were made, including a lengthy field season, a short pilot study to determine sampling effort, minimising distance between sample plots, assessing periods of high and low bird activity to identify the optimal, concentrate detection effort at a close distance, maximise the period of count length, be well trained in distance estimation, and exclude aerial birds at the time of the survey (Marsden, 1999).

Ruette et al (2003) evaluated the use of distance sampling for spotlight counts of red foxes along roads and trails in France. Despite a low sighting frequency of foxes near the centre line, good estimates of density were achieved. In comparing point counts to line counts, similar density estimates were made, but point counts only recorded a small number of foxes, resulting in greater variation and they were more time consuming. Overall, line transects were found to have a higher encounter rate (more precise) and were less time consuming (more efficient) (Ruette et al, 2003).

3.23.6 Comparing techniques

Choosing the appropriate method for counting a species will depend upon many environmental and biological factors. There have been studies which have compared some of the techniques introduced here with the aim of identifying the best for their target species. In Scotland, numbers of red deer have been counted since the 1960s, originally with walked transect lines, and more recently using helicopters equipped with digital cameras (Daniels, 2006). Other techniques such as regular counts of tagged deer and dung counts have also been employed (Daniels, 2006). Daniels (2006) aimed to quantify the variation from repeat counts of red deer using the same and different methods, as well as assessing their cost effectiveness. Ground, helicopter and dung counting (in the absence of sheep) were found to be valid methods, but it was recognised due to logistics, methods which minimised time and manpower would be favourable. Each method was found to be good for different things – dung counts for area occupancy over a set time period, direct ground or helicopter counts with photography gave a instant estimation of population size and structure, and infrared cameras, just population size (Daniels, 2006). The chosen method would then rely on the aims of the particular study. Overall, helicopter counts were found to be the quickest and least labour intensive, with accuracy increased by photography and with efficiency reliant upon the size of the area covered (Daniels, 2006).

Following declines in brown hare numbers across Europe, Langbein et al (1999) reviewed methods to assess live abundance of hares and assessed their suitability and limitations, with the aim of deciding on an appropriate methodology to use for a national survey within the UK. Total clearance, wide belt and line transect counts (inactive hares), spotlight circular plots and twilight counts (active hares) and dung pellet counts (indirect method) were tested. All had advantages and disadvantages under certain circumstances, for example some surveys were found to be labour intensive (total clearance), subjective (twilight counts), difficult to apply over a large area or a range of habitats (spotlight counts, dung counts, total clearance, wide belts), although accurate or achieving total counts (spotlight counts, total clearance) (Langbein et al, 1999). Line transects were found to be the most practical method for a nationwide survey, being easy to implement, efficient in terms of minimal manpower and equipment, causing minimal disturbance and providing a reliable estimate of abundance, but would require stratification to cover the range of habitat types effectively (Langbein et al, 1999).

As found by both Daniels (2006) and Langbein et al (1999), there are invariably advantages and disadvantages with each method chosen for a survey. Techniques such as dung and spoor counts do not rely on seeing the animal under study, which is particularly advantageous for cryptic species, or those that live in dense habitats (e.g. Ellis and Bernard, 2005). Dung can also be used gain other biological information such as species diet and genetics (e.g. Eggert et al, 2003, Steinheim et al, 2005, Reilly, 2002, Van Vliet et al, 2007). Disadvantages include the cost, time taken, reliance on good substrate for spoor counts, and expertise needed to analyse the dietary and genetic information from dung. Also, there may be potential errors impacting upon count estimates due to a variety of environmental factors such as rainfall and temperature (Barnes et al, 1997, Nchanjii and Plumptre, 2001, Vanleeuwe, 2008, Van Vliet et al, 2008). Reliable estimates have to use correction factors to combat such influences (Barnes, 2001). Using dung and spoor to count animals is also reliant upon a good survey technique.

Sighting the animals under study may be considered the ultimate way of surveying a species, particularly if a permanent record can be made such as that provided by photographic techniques. Other advantages of photographic total counts include reduced disturbance of animals, the ability to survey a large area in good conditions with minimal manpower (Snyder et al, 2001), as well as developing the potential for individual identification with a database of images which would grow over time. The same photograph(s) could be used multiple times, by different people, to perform repeat counts and increase accuracy compared to visual estimation techniques

(Woodworth et al, 1997). Camera traps provide similar advantages but most likely for photographing individuals. This technique is advantageous within dense habitats to confirm the presence of a species, and over time to monitor individuals (e.g. Azlan and Sharma, 2003, Karanth, 1995, McCarthy et al, 2007, Smith et al, 2007, Ward, 2006e). Disadvantages include cost and quality of equipment, feasibility and maintenance of the study and a reliance upon expertise to understand the study site, set up the equipment, maintain it and analyse the data (Jackson et al, 2005, Karanth, 2007)

Distance sampling techniques also rely on sightings which are reliable enough to collect accurate data required for the analysis. This technique can be advantageous where a photographic census may be less reliable, and is particularly effective in good weather conditions to monitor cetaceans (e.g. Calambokidis and Barlow, 2004). The technique can be economical and precise and there is some flexibility with distance sampling, in that the length of a transect can be tailored to site conditions and the survey is repeatable if transects are properly set (e.g. Focardi et al, 2002, Hounsome et al, 2005, Jensen, 1996, Ogutu et al, 2006) For some species there is the option of point counting, particularly suitable for some bird species (e.g. Marsden, 1999). Distance sampling does rely on a clear view and a good surveyor, and the avoidance of disturbing the target species, the data required (a large enough sample size) may also take a long time to collect.

To bridge the gap between direct and indirect methods, the use of remote tracking has great potential in the conservation of species. A disadvantage is that it relies on initial contact, disturbance and stress to the animal when it is collared/tagged. That animal then has to adapt to wearing a tag or collar, potentially indefinitely if it fails to fall off, or contact is lost before it is removed. Another disadvantage is the cost of equipment, installation and maintenance. When such tagging is successful however, the main advantage is a potentially constant insight into the movements and behaviour of that animal over possibly long time scales. Radio telemetry does require skill and time in tracking the animal down, satellite tags and collars however can send signals straight to a database to allow for instant analysis and ultimate remote tracking. Radio and satellite tracking has already been used successfully for a range of species (e.g. Avenanti and Nel, 1998, Broomhall et al, 2003, Hoffmann and Klingel, 2001, Lagerquist et al, 2000, Markham and Altmann, 2008, Mills and Gorman, 1997, Osborn and Parker, 2003, Somers et al, 2004, Watkins et al, 1999, Watkins et al, 2002)

3.24 Justification

Against the background of economic and social restrictions, there is an increasing urgency for us to set up successful species conservation and management programmes. Species management techniques (ex situ populations, captive breeding and reintroductions) play a large part in this and in situ management and the monitoring of natural populations is imperative to their future existence. What has also been established is that good monitoring requires great design, and particularly, precise aims and objectives. Does a good monitoring system exist, if so, can its attributes be identified and applied to other species? There seems to be few studies focusing on comparing long term monitoring schemes to assess their effectiveness, particularly for threatened species, therefore it is difficult to set out the requirements for a good monitoring system. In the field of conservation, such requirements are important in making sure progress is made with the contribution that monitoring makes in protecting the most vulnerable species from extinction.

The goal of this chapter is to identify what constitutes effective management and monitoring for endangered mammals. In chapter 2, a number of species were identified as being well managed and having monitoring programmes in place. A sample of twenty of those species, representing the four orders of Artiodactyla, Carnivora, Perissodactyla and Primates, will be explored in more detail. These twenty monitored species will be reviewed in available scientific and public literature to identify management and monitoring techniques, conservation action that has been undertaken and key issues which are specific to each species. Techniques will be identified which have the potential for use in monitoring across the different species. Contact with scientists and conservationists will be achieved to gain greater insights and develop case studies into practical management and monitoring for four of the twenty monitored species. A set of criteria and actions for a well managed and monitored species, based on the review and case studies, will be developed. The criteria will then be applied to the original twenty monitored species, including the four case study species, and an assessment made of the condition of their management and monitoring programmes. Suggestions will also be made for their improvement. Further contact with scientists involved with the case studies, and additional managers and scientists, will be used to develop a list of best practice in monitoring for an endangered species. The information from the review, the case studies and list of best practise will then be used to develop a flow diagram which could be followed to design an effective monitoring system.

3.25 Aims and Objectives

3.25.1 Aims:

1. To increase understanding of practical management and monitoring strategies employed for threatened land mammals.
2. To examine if there is a gold standard of monitoring practice
3. To judge the effectiveness of management and monitoring programmes for conserving the threatened land mammals

3.25.2 Objectives:

- To collate data from published sources on the 20 species identified as having monitoring programmes
- Through direct contact with conservation professionals to develop case studies on 4 key species and identify criteria and actions common to their management and monitoring.
- To identify requirements for a good monitoring system and assess the 20 species against those criteria.
- To suggest which monitoring techniques could be adopted in other species
- To develop a simple monitoring system design model based on the study findings and recommendations put forward in scientific literature.

3.3 Methods

3.31 Review of Twenty Monitored Species

The global analysis in chapter 2 brought together information on 153 critically endangered and endangered species. Consequently, 24 species were identified as having a good level of research, and more specifically, established monitoring programmes. Scientific and public literature was reviewed for twenty of these species. Little information in the literature existed for the other four species. The monitored species which were reviewed are:

1. Arabian or white oryx (*Oryx leucoryx*) (endangered (EN))
2. Mediterranean monk seal (*Monochus monochus*) (critically endangered (CR))
3. Hawaiian monk seal (*Monochus schauinslandi*) (EN)
4. Iberian lynx (*Lynx pardinus*) (CR)
5. Tiger (*Panthera tigris*) (EN)
6. Snow leopard (*Uncia uncia*) (EN)
7. Red wolf (*Canis rufus*) (CR)
8. Californian Channel Island fox (*Urocyon litteralis*) (CR)
9. Ethiopian wolf (*Canis simensis*) (EN)
10. African wild dog (*Lycaon pictus*) (EN)
11. Northern steller sea lion (*Eumetopias jubatus*) (EN)
12. Giant panda (*Ailuropoda melanoleuca*) (EN)
13. Black rhino (*Diceros bicornis*) (CR)
14. Sumatran rhino (*Dicerorhinus sumatrensis*) (CR)
15. Greater Indian one horned rhino (*Rhinoceros unicornis*) (EN)
16. Javan rhino (*Rhinoceros sondaicus*) (CR)
17. Grevy's zebra (*Equus grevyi*) (EN)
18. Eastern mountain gorilla (*Gorilla beringei*) (EN)
19. Western lowland gorilla (*Gorilla gorilla*) (EN)
20. Golden lion tamarin (*Leontopithecus rosalia*) (EN)

To outline each species, summary tables (Tables 3.1-3.4) detail geographic location, species range and typical habitat type, alongside CITES listing, existence within a protected area, provision of legal protection and the grades assigned in chapter 2 for information on the type of species management and research underway.

Appendix 2 contains the full written reviews for each species: here, the research and monitoring grade (RMG), species management grade (SMG) assigned in chapter 2, and IUCN categorisation are outlined in order to put each animal in context. A literature review for each species explores current research, management and monitoring techniques. Each review explores the background to each species current status, specific threats, conservation action, monitoring techniques used during research projects and summarises the information on research and monitoring, with a focus on identifying key issues specific to that species.

Information from these reviews is used to develop tables which define key issues, priority action and monitoring techniques used for each of the twenty monitored species. This information is compared and a number of techniques identified which could be adopted by other species within the twenty under review.

3.32 Management and monitoring Case Studies

Managers and scientists involved in conservation work for four of the twenty monitored species were contacted and questionnaire was distributed in order to provide first hand information and behind the scenes action involved in practical management, research and monitoring work. The managers or scientists had to have had practical experience with monitoring the target species, and having been involved with, or have good knowledge of, the conception of the management actions and monitoring techniques in place for the species. They did not have to be in charge of the species conservation programme, but strongly involved. As the development of these studies relied upon contact, ultimately the chosen species were not only those whose scientists involved had the required experience, but who also responded to my interest. The four case study species are:

- Iberian lynx (*Lynx pardinus*), Spain
- Black rhino (*Diceros bicornis*), Kenya
- Giant panda (*Ailuropoda melanoleuca*), China
- Channel Island fox (*Urocyon litteralis*), California, USA

The four species are from contrasting geographical locations (Figure 3.1) with two species from developed regions and two from developing areas. They are also representative of four different families: the Iberian lynx, Channel Island fox and Giant Panda are all from the Carnivora order but from respective families of Felidae, Canidae and Ursidae. The black rhino is in the order Perissodactyla and the family Rhinocerotidae. All are isolated to some degree, one literally inhabiting islands, another maintained within man made islands of fenced reserves, all are restricted by habitat loss and increasing genetic isolation. Threats to these species are therefore both comparable and contrasting, the major threats to each differ, with one primarily threatened by poaching (black rhino), one more threatened by habitat loss and slow recruitment (giant panda), one by alien or non native species (Channel Island fox) and finally one suffering more from genetic isolation and disease (Iberian lynx). All four species were judged in chapter 2 to have an RMG of 4 or 5, which is higher than what was predicted by the random forest analysis. Therefore, it can be said that these four species have already been identified as having a 'good level' of research and monitoring, potentially better than the level predicted.

In order to generate the case study information from scientists involved in conservation work for the four species, twenty broad questions were developed which it was hoped would prompt discussion type answers. All scientists met the requirements of being practically involved in the monitoring work, two have been involved long term with their species and were involved in the design of monitoring strategies, and play a role in decision making (Iberian lynx and Channel Island fox). Both of these scientists are also well published in their field. The two remaining scientists are involved in more limited aspects for part of the range of the target species, but still involved with monitoring work as part of a larger system (giant panda and black rhino). The twenty questions put to each scientist were identical, and were as follows:

1. How do you monitor the changes in population numbers and what is the current population thought to be?
2. How often is monitoring carried out?
3. Who does the surveying? Are they employed and reliable? Are results standardised?
4. How were the survey techniques used originally developed?
5. Has there been any DNA analysis on X populations?
6. Is there any evidence for a genetic bottleneck/decrease in genetic diversity/signs of inbreeding?
7. How is the research/ monitoring programme funded? Do you receive financial support from government/ academic bodies? Is it a fight every year?
8. What is the level of support from local and national government?
9. Where is the main support from?

10. What co-ordination is there between researchers and interested parties working in active X conservation?

11. What is the legal situation? How are those responsible for possibly killing a X dealt with?

12. Is there a captive breeding programme running or planned? If so, are there plans to re-introduce and supplement the wild population?

13. Is the X considered a flagship species?

14. How high profile is the X? Is it pushed as an attraction to the area on a global basis? Is it used on logos or products? Is the X an emblem in its range?

15. Does the X function as an umbrella species? What would be the ecological knock on effects should it become extinct in the wild?

16. Is there an economic benefit from protecting and ensuring the X's survival?

17. Is it detrimental in any way for their population to increase, in terms of the environment and local people? Are there conflicts?

18. With an increased population would the X be in danger of persecution?

19. Is the X confined solely to protected areas? Is there any means of dispersal between the known populations?

20. What are your realistic hopes for the future – is extinction in the wild inevitable?

In addition to the questionnaire, site visits would enable greater understanding of the challenges faced in managing and monitoring the species under study. These sites were Doñaña National Park, Spain for the Iberian lynx study, and Ol Pejeta Conservancy (OPC), Kenya for the black rhino study. San Diego Zoo in California was visited for the giant panda study, and finally, the National Park head quarters in Ventura, and Santa Cruz Island, Channel Islands National Park, California was visited for the Channel Island fox case study.

3.33 Requirements for good monitoring

Contributors to the case studies, and additional conservation scientists, practitioners and wildlife managers were asked to identify ten requirements for an endangered species monitoring programme. From their responses, a top ten list of best practise could be formulated. This list is not exhaustive and is not a list in order of importance. All contributors are involved in theory and practice of monitoring a range of species including the Channel Island fox, Iberian lynx, and five of the contributors are directly linked to conservation work for the black rhino alongside other African species such as Grevys zebra, elephant and a range of predators. The contributors to the top ten are:

- Dr Martin Jones, Manchester Metropolitan University, UK
- Tim Coonan, National Park Service (NPS), USA
- Dr Francisco Palomares, CSIC, Spain
- Ian Craig, Lewa Wildlife Conservancy, Kenya
- Batian Craig, Ol Pejeta Conservancy (OPC), Kenya
- Anthony Wandera, Kenya Wildlife Service (KWS), Kenya
- Nathan Gichohi, OPC, Kenya

3.4 Results

3.41 The Twenty Monitored Species

Summary information from the global analysis of species undertaken in chapter 2 is shown in tables 3.1 – 3.4. These tables highlight key species information such as location and protection (continent, range, habitat type, year first listed as endangered/critically endangered, occurrence within a protected area, and occurrence of legal protection), and conservation action (species management in the form of an ex situ population, captive breeding and re-introduction programme, research, monitoring and the research and monitoring grade (RMG) and species management grade (SMG) achieved in chapter 2.

Of the twenty species, half are critically endangered, and half endangered. Almost three quarters (70%) are listed on CITES appendix 1. Only one species (5%) is on appendix 2, and five (25%) are not listed. Of the 15 species listed on CITES, 2 (13%) have an increasing trend, 3 (20%) are stable, 5 (33%) are in decline and 5 (33%) have an unknown population trend. Of the 5 species not listed, 1 (20%) has an increasing trend, 3 (60%) are in decline and 1 (20%) has an unknown trend. Also, of the species not CITES listed, 3 (60%) achieved the top RMG of 5 and the top SMG of 3, compared to 3 (20%) and 2 (13%) respectively of the 15 species that are listed. Regardless of the percentages, there is no significant difference in the RMG's or SMG's achieved between species that are or are not CITES listed (Mann-Whitney U test: RMG: $U = 43.5$, $n = 20$, $p = 0.910$ SMG: $U = 37.5$, $n = 20$, $p = 0.569$). Therefore, it is possible that CITES listing is beneficial to species in terms of species trend, with 33% of species listed having a good population trend (increasing or stable), compared to 20% of unlisted species. Also, proportionally less listed species (33%) are in decline compared to unlisted species (60%). Although, proportionally more unlisted species achieved the top RMG and SMG scores (60%) than did listed species. However, none of these differences are significant.

All but one of the species (Northern steller sea lion) can be found in a protected area and 12 (60%) also have legal protection. Of all the species found in a protected area, 16% have an increasing or stable trend and 42% are declining. The Northern steller sea lion has a declining trend. Analysis reveals there to be no significant difference in a species RMG or SMG if found within a protected area or not (Mann-Whitney U test: RMG: $U = 3.5$, $n = 20$, $p = 0.057$, SMG: $U = 10$, $n = 20$, $p = 0.343$).

Of the 12 species that have legal protection, 17% have an increasing trend, 8% are stable and 58% are declining. There are 8 species with no, or needed, legal protection. Of these 13% are increasing, 25% stable and 13% are declining. Also, of these 8 species, only 1 (13%) achieved the top RMG of 5, and 2 (25%) the top SMG of 3, compared to 5 (42%) and 3 (25%) species respectively, that do have legal protection. Analysis reveals there to be no significant difference in SMG's and RMG's for species that do and do not have legal protection (Mann-Whitney U test: RMG: $U = 27$, $n = 20$, $p = 0.058$ SMG: $U= 40.5$, $n= 20$, $p= 0.345$). In comparing species with and without legal protection, in terms of trend, proportionally more species (38%) with no or needed legal protection have a good trend (increasing or stable) compared to those who have it (25%). The same proportion of species (13%) that have, or do not have legal protection have a declining population. Also proportionally more species with legal protection achieved the highest RMG and SMG scores available, compared to species without legal protection. All of these differences are however statistically not significant.

When considering species management, 5 species scored a SMG of 0, where there is no ex situ population, captive breeding or re-introduction programme. For these 5 species, none have an increasing trend, 2 (40%) are stable and 1 (20%) is in decline. Of the remaining species, 6 (30%) achieved a SMG of 1, 4 (20%) a score of 2 and 5

(25%) achieved the highest SMG of 3 (Arabian Oryx, red wolf, African wild dog, Californian channel island fox, golden lion tamarin). For those species that achieved the highest SMG, 2 (40%) have an increasing trend and 3 (60%) are in decline. Of all the twenty species, 15 (75%) have an ex situ population, 9 (45%) have a captive breeding programme for the purpose of potential re-introduction, and only 5 (25%) have a re-introduction programme in place. Of all the species with an ex situ population 3 have an increasing trend (20%), 1 (7%) is stable but 7 (47%) are in decline. For the 5 species that do not have an ex situ population, 2 (40%) are stable and 1 (20%) is in decline, the remaining 3 have an unknown trend. For the 5 species with a re-introduction programme, 2 (40%) are increasing and 3 (60%) are in decline. There are 10 species who have an ex situ population and a captive breeding programme but no reintroduction, for these species 1 (10%) is either increasing or stable, and 4 (40%) are in decline, the rest have an unknown trend. Therefore, proportionally, the same number of species with a SMG of 0 and a SMG of 3, also have a good trend (increasing or stable), however more species with the highest SMG have a declining population. More species without (40%) than with (27%) an ex situ population have a good trend (increasing or stable), however none of the species without an ex situ population has an increasing trend, only stable. When considering re-introduction, 40% of re-introduced species have a good trend and 60% are in decline. This compares to 20% of species with only an ex situ population and captive breeding that also have a good trend in the wild, and 40% which are in decline. Therefore, where species management is having a positive effect on species trend, it is the management which includes re-introduction which is most effective. However, where trend continues to decline for those species, it does so regardless of species management.

For research, all twenty have a monitoring programme in place, as this was the basis for the further study. Of all the species, 80% have evidence of research into their population and range, and 70% have evidence of research into their biology and ecology. All twenty species achieved a RMG of 3 or more, indicating a good level of research. Only 6 (30%) of the species achieved the top RMG of 5 (Iberian lynx, Californian channel island fox, Ethiopian wolf, African wild dog, black rhino, Eastern mountain gorilla). Of these 6 species, 1 (17%) has an increasing trend, 4 (67%) are in decline and 1 (17%) has an unknown trend. This compares to 8 species who achieved a RMG of 3, of these 2 (25%) are increasing, 2 (25%) are stable, 1 (13%) is in decline and the remaining 3 species (38%) have an unknown population trend. Therefore, more species with a RMG of 3 (50%) have a good population trend (increasing or stable), compared to species with the best RMG of 5 (17%). The same is true for a declining trend, with more species with the best RMG score (67%) in decline compared to species with a RMG of 3 (13%) There are however proportionally more species with a RMG of 3 that have an unknown trend (38%) than species with RMG of 5 (17%).

Analysis reveals that for both RMG and SMG, there is no significant difference between the grade achieved and the species population trend (Kruskal Wallis test RMG: $H = 5.08$, $df = 3$, $p = 0.166$, SMG: $H = 5.36$, $df = 3$, $p = 0.147$). There may be no significant differences as sample sizes are small. When considering the mean rank scores for RMG and SMG per trend, there is an indication that trend 3 (declining) has the highest RMG. Trends 1 and 3 (increasing and declining) achieve the highest mean rank for SMG. Therefore, there are indications that species with a declining trend may receive more research, and both increasing and declining species may receive more species management, but the differences in this sample of 20 species are not significant.

Overall, the mean RMG for the twenty species is 3.9, and the mean SMG is 1.5. In comparing species orders, the scores for the Artiodactyla order are for one species, therefore the mean cannot be calculated. The Arabian Oryx did however achieve a RMG of 3 and a SMG of 3 which is above the SMG average, but below the RMG average calculated for the whole group of species. For carnivores, their mean RMG is 4.1 and SMG is 1.5, above, and the same as the group average respectively. The Perissodactyles achieved a mean RMG of 3.6 and SMG of 1.2 both slightly below the average scores for the full group. The primates achieved an above average score of 4 for RMG, but were below average with their SMG of 1.3. Therefore the carnivores seem to be the group with the best levels of management and research, whereas the perissodactyles seem to be lacking in comparison.

3.42 Management action and monitoring techniques

Information from the twenty monitored species literature review (appendix 2) was extracted which focused on the key issues affecting each species, priority action required and underway, and the monitoring techniques currently implemented (Table 3.5).

3.42.1 Priority management

When considering the key issues for each species, the most common, affecting 45% of the twenty species was poaching. The next most common issue was food depletion, affecting 35% of the species, followed by habitat loss (25%), disease (25%) and small population (20%). Affecting 10% of species were the key issues of persecution (snow leopard, African wild dog), hybridisation (red wolf, Ethiopian wolf) and entanglement (Mediterranean and Hawaiian monk seals). Other threats affecting single species were inbreeding and drought (Arabian oryx), road fatalities (Iberian lynx), restricted range and slow recruitment (giant panda), flooding (greater Indian one horned rhino) and the pet trade (golden lion tamarin). This is not to say that these species do not suffer from the other threats listed, indeed they form part of the calculated percentages, but out of the key issues identified for the twenty species, they are threats which are acute and specific to each of them. Therefore there are common threats requiring similar management actions across species, but alongside these there are the specific threats requiring targeted management.

There have been many positive management actions identified to tackle the key issues affecting the study species. Priority management for poaching (e.g. Arabian oryx, tiger, snow leopard, all 4 rhino species, the Eastern mountain and Western lowland gorillas) includes clear demarcation of reserve boundaries, greater protection and law enforcement with appropriate punishment for illegal hunting and use of animal parts. Focused management to tackle food depletion (e.g. Grevys zebra, Arabian oryx, both Mediterranean and Hawaiian monk seals, Northern steller sea lion, Iberian lynx, Ethiopian wolf, Snow leopard and African wild dog) includes clear demarcation of reserves, reduction of human settlement, greater research into resource conflicts and schemes such as zonation. The need for more focus on prey species conservation programmes was also identified as a priority action for many predator species. Habitat protection is of course critical for all species. For 9 (45%) of the 20 species, the extension of habitat protection with increased reserve area and creation of habitat corridors is particularly important for their future viability (e.g. Iberian lynx, tiger, African wild dog, giant panda, black and Javan rhinos, both the mountain and lowland gorilla and the golden lion tamarin). Not only this, but priority sites for species need to be identified and protected, such as key feeding and breeding grounds (e.g. Mediterranean and Hawaiian monk seals). To manage disease (e.g. Eastern mountain gorilla, Ethiopian wolf, African wild dog and the Iberian lynx) more research is needed and development of vaccination programmes where they are possible, and outreach programmes where contact with local communities (e.g poor sanitation, dogs) creates a disease risk for the endangered species. Where the threat of a small population is acute (e.g. Javan rhino, Eastern mountain gorilla, red wolf, Iberian lynx), positive management includes improved habitat protection and expansion of available area, and protecting populations from specific threats such as hybridisation (red wolf) and road fatalities (Iberian lynx).

There is clear evidence of some success from management actions, particularly with the Californian Channel Island fox, with its successful captive breeding and re-introduction programme. Priority management is continued removal of threats (e.g. alien species: golden eagles fuelled by the presence of feral pigs) and a focus on monitoring fox recovery and re-introduction of the native bald eagle to prevent re-colonisation of golden eagles. The successful re-introduction of captive bred African wild dog and red wolf pups into wild dens for fostering is also a management option which could continue for these species. Also, following population increases for both the black rhino and golden lion tamarin, key biological management for these species includes using translocations to prevent inbreeding in the near future.

3.42.2 Species monitoring

For all of the twenty monitored species, all have many ways in which they can be monitored, and no species has one monitoring technique in use without others also incorporated, or used independently. For most species, monitoring involves the use of simple techniques such as sightings, or sign surveys (spoor, dung, scrapes/scratching) to estimate a population.

The monitoring techniques listed were split into direct, indirect and other monitoring techniques. A score of 1 was applied to techniques already in use for each species, and a score of 2 indicates a technique which could potentially be implemented into a monitoring programme based on its use for other species (Tables 3.6-3.8).

Of the twenty species, 75% have direct techniques incorporated into their monitoring. Direct count censuses are used for 65% of the species, and for 61% of those species, count censuses are the only direct method used. Capture – recapture (trapping) techniques are used for 2 species (10%), the Californian channel island fox and the golden lion tamarin. Distance sampling is only used for 1 species, the Arabian oryx. Tagging or marking is used for 6 (30%) species, but was identified as having potential use for four similar species. Mark re-sight monitoring techniques were used for 3 species (15%) and identified as being a potential technique for 5 other species.

Indirect monitoring techniques are incorporated into the monitoring of 95% of the twenty species. Sign surveys are the most commonly used technique, employed for 13 (65%) species, and identified as a potential technique for a further 4. Photographic work in the form of census/database records, camera traps and mark re-sight (using a species' markings from a picture) is used for 5 (25%), 4 (20%) and 4 (20%) species respectively. The use of photographic censuses or databases were identified as having potential for 6 other species, and the use of camera traps for one other. Video monitoring in the form of remote cameras and mounted cameras are used for 1 species, the Mediterranean monk seal and the Hawaiian monk seal respectively. Remote video was considered viable for 2 further species, and mounted cameras for 1. Radio collars are used in monitoring 9 (45%) of the twenty species, and considered as having potential for 1 other species, whereas currently GPS collars or tags are used for 6 (30%) of species but were considered as having potential for monitoring 100% of the species.

Other monitoring techniques are employed for 95% of the species, with genetic monitoring being the most commonly used technique - for 15 (75%) of the twenty species. Genetic techniques were considered as having potential for the monitoring of 100% of the species under study. Analysis of faecal, blood and tissue for toxins or dietary purposes, is used for 7 (35%) species, with potential for use for 6 others. GIS modelling is currently incorporated into the monitoring of 9 (45%) species, but has potential for 100% of species. Monitoring of threats and resources is undertaken for 3 (15%), and 5 (25%) species respectively, but again may be applicable to 100% of the species understudy. Finally, the use of public sightings and interviews with local people are used for 5 (25%) species, but was considered viable for a further 6.

Figures 3.2 and 3.3 display results of points scored for each monitoring technique in use per species, and those which could be incorporated respectively. There are 6 points available for direct monitoring techniques, 9 points for indirect techniques and 6 points for the other techniques, making a total score of 21.

Species with the least number of techniques in place include the Californian channel island fox, the Sumatran rhino and the Javan rhino, all with 3 monitoring techniques. More than half the species have 6 or more monitoring techniques used. The Mediterranean monk seal has the most with 11. Monitoring of the Arabian oryx and the golden lion tamarin incorporates, as a majority, direct techniques. Most species have direct, indirect and other techniques employed for their monitoring. The golden lion tamarin however does not have indirect techniques used and for 5 species, the Iberian lynx, tiger, snow leopard, African wild dog and Javan rhino, no direct techniques are used. For all 5 of these species, more than one indirect technique is used to monitor their populations, and all in particular have track and sign surveys.

When the techniques considered as having the potential for inclusion in the monitoring of the twenty species are added to those already in use (figure 3.3), the number of species with ten or more techniques increase from 1 to 12 (Arabian oryx, Mediterranean monk seal, Hawaiian monk seal, Iberian lynx, tiger, snow leopard, red wolf, African wild dog, Northern steller sea lion, Sumatran rhino, Javan rhino, golden lion tamarin). Some species have an increase of 100% or more of techniques which could be available (Arabian oryx, Iberian lynx, Californian channel island fox, African wild dog, Northern steller sea lion, Sumatran rhino, greater Indian one horned rhino, Javan rhino and Western lowland gorilla).

3.43 Questionnaire responses

From the 20 monitored species, 4 were selected, and information from conservation professionals directly involved with their conservation was used to develop case studies. The four species are the Iberian lynx (*Lynx pardinus*), black rhinoceros (*Diceros bicornis*), Californian channel island fox (*Urocyon litteralis*), and the giant panda (*Ailuropoda melanoleuca*). The main points from the case study reports (Appendix 3) have been extracted and summarised in table 3.9.

3.43.1 Surrogate species

All case study species are considered as flagships, with varying profile status. Globally, the giant panda (GP) has a high status being a conservation emblem in the form of the World Wildlife Fund logo. The black rhino (BR) also has an international status but probably a lower profile that that of the GP. In Kenya, the BR has a good national status and is one of the 'Big Five'. The Iberian lynx (IL) has a good national status, being used locally as a logo for different products, and internationally its status is growing, aided by conservation campaigns. All species have been used as logos, and 3 in particular have 'ambassadors' for raising awareness (Finnegan a hand reared Channel Island fox raising awareness at Santa Barbara Zoo in California, Morani the placid BR, recently deceased, but who helped raise the profile of BR in Kenya, and the GPs of San Diego Zoo and Captive breeding centres in China which are open to the public). Currently the IL can be seen at Jerez zoo, Spain, but the captive breeding centre is not open to the public therefore raising awareness through using an ambassador may be limited.

It is possible that all four species may function as an umbrella species, as for the IL, BR and GP in particular, large areas of land and habitat which many other species rely on, are needed for them to survive. Also, the area under current protection for these species may become of lower conservation value should they be lost. It was noted that when the Californian Channel Island fox (CCIF) was absent from the islands, there were fluctuations in deer mouse populations. It was therefore suggested that foxes may control deer mouse populations.

3.43.2 Support and legal protection

Provision of conservation funding comes from NGO's for all species, and some also benefit from governmental support. The IL receives most of its funding from the EU Life Programme. Most funding for BR conservation comes from tourism, with governmental support for security and veterinary requirements. Yearly funding is provided by central government for the GP. The CCIF seems to have the most secure funding in place with its conservation work supported by National Park Service and Nature Conservancy allocations, and there is no need to fight for funding every year.

Official and legal protection is in place and well understood for 3 of the 4 case study species, with an official court process followed by fines and jail sentences for people attempting to, or guilty of killing a BR, IL, and GP. The CCIF does not require such protection as it is not persecuted or poached.

3.43.3 Practical Management

All case study species are isolated to some degree. Only a few IL and BR occur outside protected areas, all CCIF are on protected islands with unlimited dispersal on each island, but obviously not in between. The GP is not confined to protected areas but dispersal is becoming increasingly limited by human developments. The future for the GP may then become a translocation strategy, similar to that in place for the BR in Kenya

Captive breeding is in place for the IL (in situ), the CCIF (in situ) and the GP (most in situ, some based at San Diego Zoo with return of sub adults to China). For the CCIF, the programme was so successful that it has been halted following the release of the last captive foxes back into the wild in 2007. Both the IL and GP need to develop re-introduction programmes. Policy for the BR is in situ conservation, involving high protection within reserves allowing natural breeding, with prevention of inbreeding through a programme of translocations.

3.43.4 Monitoring practicalities

For two of the case study species, the IL and GP, sign surveys are relied upon to monitor their populations. Camera traps are supplementary to the sign census work for the IL. Both BR and CCIF monitoring programmes rely on direct sightings or contact, with rhino patrol sightings used for the BR, and capture re-capture techniques used for the CCIF, alongside radio tracking of some foxes. The intensity of monitoring is different for each species, with monitoring carried out a minimum of once a year plus individual projects for the IL, four censuses a year for the GP, twice yearly capture for the CCIF supported by twice weekly radio tracking, with intense daily patrol monitoring for the BR.

For all of the case study species, monitoring staff were fully trained and techniques were standardised. All techniques had also been based on pilots studies – either accidentally (i.e. results from past work were used as pilot like studies), or purposefully, with initial surveys taking place, followed by large workshops. Such workshops, particularly for the BR, GP and CCIF, developed a standardised system for monitoring. The BR case study, although limited to one rhino population, follows a nationally standardised monitoring system. The level of co-ordination between involved parties for each species is high, particularly for BR and CCIF, with regular internal and international meetings, and dedicated teams. It seems co-ordination between different parties involved with the IL has been more problematic, but with meetings and conferences this situation has, and continues to be improved.

All species have genetic projects underway, particularly using dung as the source for IL and BR genetic work, and is being used more for captive GP's than in the wild. A bottleneck scenario was described as possible for 3 of the case study species, with results currently unknown for the GP. There were concerns recorded regarding inbreeding within the BR, and evidence for genetic similarity in IL. There were also concerns about a bottleneck and reduced variability in CCIF, with some island populations affected more than others.

3.43.5 Consequences of protection

A population increase may put pressure on the habitat as suggested for BR and GP, and it may cause a potential increase in poaching of the BR, and persecution for the IL (if they begin impacting on the rabbit population which is also relied upon by human rabbit hunters). The potential to increase the threat of persecution is considered as low for the GP and CCIF.

An economic benefit of protecting these species is tourism, particularly for the IL, BR and GP. Some land owners also receive an economic benefit if they conserve suitable IL habitat on their land. An economic incentive was not considered a priority for CCIF conservation.

3.43.6 The future

There are optimistic hopes for the future for all four species. An increase in population has been seen to varying degrees for the BR, GP and in particular for the CCIF. The lynx population is described as stable, but it certainly seems more precarious than for the other case study species. Hopes for the IL seem to focus on supplementing the remaining wild population with captive bred individuals. Hopefully there will be increased optimism in the future for this species.

3.44 Criteria for a well managed and monitored species

Common themes within the questionnaire responses were extrapolated and a number of broad criteria were developed based on these responses. The goal is to identify a potentially well managed and monitored species based on minimal information, which may be widely available. Each part of the criteria is equally weighted, i.e. A1 is not designed to be more important or more effective than A2. If an animal has one part of each criteria it qualifies as having that criteria, it does not need to achieve every part. The criteria (A – J) are as follows:

A. Population numbers are monitored
   1. (i) continuously
      (ii) regularly
      (iii) at least yearly
   2. Using one or two standardised techniques
   3. Using techniques which were developed through collaborative workshops

B. Genetic analysis
   1. Has been carried out
   2. Is beginning to be carried out

C. Financial support
   1. National financial support
   2. International financial support
   3. and/or there are minimal funding issues

D. There are official legalities in place to protect species

E. Focus on in situ conservation with population management or
   1. A captive breeding programme in place with re-introduction preparation
   2. A captive breeding programme in place with a re-introduction programme

F. Emblematic species with
   1. A National profile
   2. An International profile

G. Species has potential to function as an umbrella species

H. A population increase would create
   1. Minimal conflicts
   2. Only habitat management issues

I. Population range is
   1. Not confined within protected areas
   2. Confined within protected areas
   3. Confined within protected areas but with good management
   4. As with I3 but has the potential for natural dispersion between areas

J. Population has shown a positive response to management efforts

3.45 Assigning the criteria

Criteria A – J were applied to the information collected for the twenty monitored species in order to generate a code for each animal (Table 3.10). Some of the coding is subjective, such as if the species has the potential to be a good umbrella species, if it is a nationally or internationally emblematic species, and if it receives international funding (as data collection did not have the benefit of direct contact with scientists for 16/20 species).

If a species achieved 5 or more of the criteria, then it could be considered as a well managed and monitored species. Out of the 20 species, 18 (90%) achieved this status. The Hawaiian monk seal and Northern steller sea lion qualified for only 4 criteria. There were 5 species which achieved part of every criteria, 4 of which were the case study species (for which more information was available), the fifth was the greater Indian one horned rhino.

3.46 Best Practice in Monitoring

The 20 monitored species reviews and 4 case studies have highlighted different management and monitoring practices which have often developed within conservation programmes and may be subject to funding and training capacity. Therefore, what standard should be targeted? As part of developing a 'gold standard' of monitoring in particular, conservation scientists and managers were asked to identify key requirements for the successful monitoring of an endangered species. Their responses were combined to form a top ten list of best practise. These responses state that a successful monitoring system must:

- **Be well informed** – by incorporating historical knowledge to fully understand the problem, identifying the appropriate target for monitoring and possibly priority indicators which can act as an early warning sign, appreciating seasonality and where appropriate identifying threats and incorporating analysis and control (i.e. disease). Also by thinking outside of the box and having an ecosystem approach, for example incorporating habitat monitoring within a species monitoring program, to better understand trends.

- **Be well planned, tried and tested** – through being regularly evaluated and planned strategically with clear goals which are guided by specific, measurable, achievable, realistic and time bound objectives and by including a pilot study.

- **Be statistically robust** – by assigning fixed sample sizes (for example through using power analysis) to identify true levels of change.

- **Be cost effective** – by using basic equipment and being sustainable with funding in place and adequate resources so as not to be reliant on external funding.

- **Be user friendly** – by having a documented strategy of data collection, and a set and easy system for data storage, analysis and retrieval, with rigorous training if required, allowing for continuity and standardisation, and for new people to continue using the technique, improving standards over time but importantly, using the same core methods even if additions are made later.

- **Collect key baseline information** – such as periodical appropriate estimates of population parameters such as density, growth rate, age and sex ratios, key breeders, breeding intervals, mortality rates and causes and where appropriate genetic variability and structure

- **Plan for the future** – by specifying possible management options and responses to cover any foreseen eventuality

- **Put the monitored species first** – by having little or no impact on individual members of the species, thus indirect methods may be of higher priority.

- **Incorporate co-ordination** – by placing high emphasis on communication with timely dissemination of findings and involvement of relevant stakeholders and interested parties

- **Be continued!** – By being implemented over a long time period to identify true trends.

3.5 Discussion

3.51 Management and monitoring strategies

3.51.1 Management of the 20 species.

For the 20 monitored species under study there was found to be no significant relationship between SMG and the variables 'trend', 'CITES' listing, 'legal protection' and 'protected area'. Although these factors do not seem to impact upon the level of management in place for the 20 species, the insignificant results may also be due to small sample size. One indication from the results (although not statistically significant) was that within the 20 species, those with re-introduction programmes are proportionately more likely to have an increasing trend than those with just an ex situ population and captive breeding. This suggests that re-introduction may be an important part of species management. The study has also clearly identified threats which are common to a number of species as well as some which are unique to individual species and which present particular management problems. These require specific alleviation measures, as it is these threats which may have most influence on the short and long term survival of some of the species. The most common threat within the 20 species was poaching, followed by food depletion, habitat loss and disease.

Tighter protection and control of reserve boundaries is recognised as a common management priority for many of the 20 species including the tiger (Linkie et al, 2006), Eastern and western lowland gorillas (Oates, 1996), Iberian lynx (Aerts and Van Heijnsbergen, 2006) and all four rhino species (African Rhino Specialist Group, 2003, Asian rhino specialist group, 1996, Amin et al, 2006). Requirements include a concerted effort to clearly demarcate and improve the management of reserve boundaries, and to improve connectivity between reserves. Such action goes hand in hand with general habitat protection whether within reserves or not. Many species are increasingly threatened by habitat loss and fragmentation, which is affecting their opportunity to disperse and breed (e.g. Javan rhino, (Khan et al, 2002)), and is bringing them into closer contact with humans (e.g. Eastern mountain gorilla (Guerrara et al, 2003)). As well as habitat protection as a whole, key resources need to be identified, with focused protection put in place as part of habitat protection schemes (e.g. feeding, rest, breeding sites and debris clearance for Mediterranean and Hawaiian monk seals (Gucu et al, 2003, Marine Mammal Commission, 2002)).

Other common actions across the 20 species to combat the threat of poaching include visible law enforcement on the ground (e.g. rhino protection units (Amin et al, 2006, Foose and Van Strein, 1998), coupled with greater punishments for wildlife crime. Crucially, there needs to be more action targeted at trade routes, with increased efforts to curb demand for wildlife products, particularly for traditional Chinese medicine (TCM) (Ellis, 2005). Only when demand is cut and the incentive to supply wildlife products removed, can this constant threat of poaching be managed effectively.

Common actions to alleviate food depletion include conservation work targeting prey species and more research into resource conflicts and plans for zonation schemes. For example, the Grevys zebra could benefit from a land zonation scheme, in a similar way to the marine protected area set up for the Mediterranean monk seal (Durant and Harwood, 1992). This management technique employed for the latter species could also be applicable to the Hawaiian monk seal and the Northern steller sea lion. Predatory species in particular are affected by resource depletion making prey resource conservation a common priority management action. Specific examples include the protection and restoration of rabbits for the Iberian lynx (Aerts and Van Heijnsbergen, 2006), protection of the giant mole rat for the Ethiopian wolf (Sillero-Zubiri et al, 1993, Sillero-Zubiri and Macdonald, 1997), and protection of wild prey for the tiger, snow leopard and African wild dog (Nowell and Jackson, 1996, Woodroffe et al, 2005, Woodroffe et al, 2004).

Where species have a small population, restricted range and/or are in increasing contact with humans and their domesticated animals, disease becomes a major threat, particularly so for species such as the Eastern mountain gorilla (Guerrara et al, 2003), Ethiopian wolf (Sillero-Zubiri and Macdonald, 1997, Haydon et al, 2002), African wild dog (Woodroffe et al, 2004) and Iberian lynx (Aerts and Heijnsbergen, 2006). Common management actions include increased research into the presence and affects of diseases on the species, development of vaccinations and management of contact with the human population and their domesticated animals. Some species specific actions include restricting gorilla contact with tourists and implementing education programmes to improve sanitation, also improving domestic animal husbandry within areas inhabited by the Ethiopian wolf and African wild dog.

As well as common issues affecting species there are species specific threats which have the capability of undermining conservation work, with drastic implications for remaining populations, and these require specific management action. Of the 20 study species, 5 species were affected in this way. The Iberian lynx suffers road fatalities, particularly within the vicinity of Doñana National Park. Recently, new road signs and road markings warn drivers about the presence of lynx (pers.obs), but the road continues to be a fast road right through lynx habitat. There were 10 lynx killed by traffic between 2004 and 2006 alone (Ward, 2008b) and plans to close the road (which was illegally constructed) were met with threats against the lynx and potential withdrawal from hunting agreements (Ward, 2008b). Road speed could be reduced by more effective speed humps and even speed cameras (the proceeds from fines could be put back into conservation work), and could be coupled with greater lynx access to over or under passes. This is one threat which seems wholly manageable, yet continues to produce many lynx casualties in a very small population (35 lynx, 17 of which are adults (Ward, 2008b)), already under severe risk of extinction.

For the Arabian oryx specific actions include better management of the captive breeding programme to prevent inbreeding, and the provision of resources during drought conditions coupled with better resource management and selection of re-introduction sites (Marshall and Spalton, 2000, Seddon and Ismail, 2002, Van Heezik et al, 2003). Alongside expanding the availability of habitat, the giant panda requires the proposed development of a reintroduction programme (Durnin et al, 2004) to become reality. There has been great success in breeding pandas in captivity (Swaisgood et al, 2003, Swaisgood, 2007, Zhang et al, 2004), but while they remain there, aside from financial gains from tourism, they play no part in supporting populations in the wild. For the Greater Indian one horned rhino, the specific threat of flooding (Foose and Van Strien, 1997) can be mitigated by creating and managing a metapopulation as opposed to having most of the population in one location. Finally for the Golden lion tamarin, a specific action to combat the threat of capture for the pet trade, like the threat of poaching in other species, is to continue targeting and controlling the trade routes.

Many common actions have been identified which are critical to species survival and which are applied globally such as habitat protection and work to combat poaching. On the ground it is the specific management actions which are equally important in maintaining the viability of a species population which has specific and sometimes unique threats acting upon it. The findings here support the key actions identified in many species action plans, which focus on in situ conservation, with greater law enforcement, protection for reserves (Mallon and Kingswood, 2001Nowell and Jackson, 1996, Servheen et al, 1999, Sillero-Zubiri et al, 2004, Wemmer, 1998). They also identify that distribution surveys and monitoring form the basis for much needed conservation action

3.51.2 Monitoring the 20 species.

As with SMG, for the 20 study species there is no significant relationship between RMG and the variables of trend, CITES listing, legal protection and protected area, suggesting research and monitoring has no effect on, or is not dependent upon, these variables. Again, the small sample size is probably the reason why there are not at least some significant associations.

All of the 20 species were monitored using more than 1 technique, with both indirect (e.g. sign surveys) and other techniques (e.g. genetic monitoring) used for 95% of the species, and direct techniques (e.g. direct counting) for 75%. For typically elusive, or difficult to study species, i.e. Iberian lynx, snow leopard, African wild dog and Javan rhino, monitoring methods usually used signs. Track and sign surveys are useful for monitoring species within dense habitats, or which are cryptic (Plumtre, 2000), it is therefore logical that this is a common method across species with those characteristics. Such monitoring may collect the baseline information required, such as relative population estimates which are crucial to establish priorities, and may be desirable due to their cost effective nature, repeatability and technological ease in comparison to direct methods (Carbonel et al, 2002, Gussett and Burgener, 2005, Stander, 1998). Direct techniques are also employed for such species but at a smaller scale, and it is the basic techniques which will continue to form the backbone for monitoring endangered species. This is particularly true where there is a requirement for low cost but effective monitoring to run alongside required management actions, such as combating the threat of poaching and protecting the credibility of reserves. If done well, indirect techniques can be a cost effective, repeatable, objective, valid and respectable means of monitoring vertebrate populations (Barnes, 2001, Gussett and Burgener, 2005, Stander, 1998). It may also be the case that the choice to use indirect techniques for monitoring is based upon the fact that direct methods are practically or financially restricted (Gussett and Burgener, 2005), and that relevant expertise and resources are unavailable.

Where most of the study species had both direct and indirect techniques incorporated into their monitoring, for the Arabian oryx and golden lion tamarin, direct techniques were predominant. A commonality is that both of these species have a re-introduction programme (Keirulf et al, 2002, Spalton et al, 1999). It may be that intense monitoring through direct techniques is a requirement, not only to monitor individuals of a species, but to ensure success of re-introduction, as efforts with captive breeding and reintroduction may have already been potentially costly. There may also be greater funding available to use more expensive monitoring.

More than half the species had more than 6 techniques incorporated into their monitoring. It is not the number of techniques which is important, but the quality of monitoring, with consistent use of one or two effective techniques. Where many techniques are used, this may indicate that the ideal monitoring methodology has not been identified, or that many of the techniques are used peripherally around one or two core techniques (e.g. Mediterranean monk seal). Where few techniques are used, this could mean there is a good, well developed monitoring strategy in place (e.g.

Californian Channel Island fox), or that other techniques have not yet been considered and that the monitoring programme may be in its infancy (e.g. Javan rhino)

It is apparent that most species monitoring incorporates common techniques, but to answer specific management questions. It is also clear that indirect techniques are used over direct ones, whether that be due to cost, lack of expertise or that indirect techniques are more effective, they certainly will impact less on the study species. What is important is that managers investing in monitoring be aware of global advances in technology and expertise available for monitoring species with similar ecology and threats.

3.51.3 Sharing techniques

There were many techniques which were identified as having potential for species based on similarities such as common threats and similar habitat, biology and ecology. When the potential for sharing monitoring techniques across the 20 species was considered, techniques available for some species could be increased by 100% (Arabian oryx, Iberian lynx, Californian Channel Island fox, African wild dog, Northern steller sea lion, Sumatran rhino, Greater Indian one horned rhino, Javan rhino, Western lowland gorilla). Also, the number of species with 10 or more techniques potentially applicable to them increased from 1 to 12. There are a number of techniques which have clear potential across many of the species and which have clear benefits to their conservation should they be employed as part of a large scale monitoring system. These include satellite technology, threat and resource monitoring and GIS in particular, along with photography and video, mark and re-sight, sign surveys, scat detection dogs, community involvement and greater use of laboratory techniques.

3.51.31 Satellite technology

Satellite technology has the capability of improving knowledge into species' ecology beyond what even radio collaring has already achieved. A number of species were identified which would benefit from such increased information. Arabian oryx monitoring can incorporate GPS collars or tags to better locate key herds, to track movements and resource use. Such technology would have a positive impact on monitoring as the automated signal would reduce man hours in the field, as most of the monitoring currently relies on sightings (e.g. Seddon et al 2003). Not only this but the technology could provide an instantaneous way of tracking the need for a certain resource, or can alert the management of a poaching incident.

GPS tagging has already been used successfully with the Hawaiian monk seal to identify habitat use and foraging ecology, including juvenile foraging, alongside seal movements and dive patterns (e.g. Parrish et al, 2005, Stewart, 2004, Parrish et al, 2000). There is potential for the same to be achieved for the Mediterranean monk seal and Northern steller sea lion. For the Mediterranean monk seal, GPS tags could be incorporated to monitor the overlap with human fishing, and to identify key feeding sites for strict protection, as the main threat is conflict with fishermen (Gucu et al, 2003, Panou et al, 1993). The Northern steller sea lion is also threatened by conflicts with fisherman, as well as habitat loss and changes due to climate change (Hare and Mantua, 2000, Holmes and York, 2003, Sease and York, 2003 Seal Special Group, 1996), therefore GPS tagging would give great insights into key habitats and feeding sites for this species. Following successful studies with whales fitted with GPS tags (e.g. Lagerquist et al, 2000, Watkins et al, 1999, Watkins et al, 2002), there is obvious potential to monitor species, such as the monk seals and steller sea lion, for which much of their time is spent off shore, and many aspects of their ecology are unknown.

For species such as the Iberian lynx the use of satellite collars or tags would be highly beneficial. In particular, their use would provide managers with 24 hour monitoring and the possibility of tracking movements precisely and raising the alarm should a key individual (e.g. breeding female or mature male) wander into dangerous areas such as on hunting land or near main roads. It is also more feasible to monitor the majority of the Iberian lynx population with this technology as unfortunately their numbers are currently so few. As well as for the Iberian lynx, the use of GPS collars or tags is viable and would be a beneficial addition to the monitoring of both the Californian Channel Island fox and Ethiopian wolf, having been trialled and used successfully for monitoring the red wolf (USFWS, 2003) and the African wild dog (Mills and Gorman, 1997). Use for the Californian Channel Island fox could reduce or cancel out the need for repeated capture of individuals to monitor them and more questions could be answered about the use of their habitat. For the Ethiopian wolf, as for the Iberian lynx, the technology would be beneficial in providing 24 hour monitoring of key individuals and also analysing key factors such as the level of conflict with people, contact with domestic dogs, and also identifying key sites in need of more protection, especially as all conservation of the Ethiopian wolf is in situ (Sillero-Zubiri and Macdonald, 1997).

The use of GPS collars or tags was also felt to be a potential addition to the monitoring of giant pandas in the wild, further enhancing knowledge of movements, interactions and resource use, and panda response to natural disasters, particularly bamboo die off (Guo, 2002a, Hunter Jr, 1991, Reid et al, 1989, Taylor and Zisheng, 1993, Zhi and Schaller, 2002). They also have great potential as an addition to programmes such as the community monitoring scheme set up for the Grevys zebra (LWC, 2006), in particular to monitor zebra movements in response to human competition in more detail. The use of GPS collars and tags was considered as biologically applicable for the greater Indian one horned rhino, Sumatran rhino and Javan rhino. If viable, the advantages of having consistent location information, particularly for the Sumatran rhino which is under immense poaching pressure, (Foose and Van Strien, 1998), and for the little understood Javan rhinos, are great. However, the affects of thick vegetation on technological performance would reduce its potential significantly, and there are also significant risks associated with immobilising species such as rhino within dense habitats. This is also true for the Western lowland gorilla, Eastern mountain gorilla and golden lion tamarin, where there would be great benefit in receiving fully automated location information without relying on sightings after initial fitting and maintenance. Markham and Altman (2008) agree that there is considerable potential for incorporating satellite technology into primate studies, even as an addition to direct observation, following their success monitoring a baboon with a GPS collar. The application of such technology for animals which are difficult to find, for which little is known, and to complement existing scientific information is certainly appealing, but technological advances are required for it to be effective and safe to use for species residing within thick vegetation. This is something which hopefully could become an option for such species in the future.

3.51.32 Threat and resource monitoring

Monitoring of threats and resources can be an inherent part of management initiatives in place to protect species from extinction. For example monitoring of threats such as the illegal trade in wildlife can inform effective management, particularly for species who could be decimated by poaching. Products such as traditional Chinese medicine and jambiya (dagger) handles (Ellis, 2005) have already been recognised as requiring critical management. Effective monitoring of supply and demand for such products is essential in protecting species susceptible to poaching e.g. the tiger, snow leopard and all four rhino species. As is the monitoring of demand, and preventing live capture of Arabian oryx, to prevent a repeat of the rescue in Oman, 1998, following a dramatic reduction of their re-introduced population, which was possibly due to illegal live capture. (Plowman and Mallon, 2003, Spalton et al 1999).

It has already been discussed that management action targeting specific threats affecting a species is as important as managing the common threats. Monitoring can identify the gravity of specific threats and then help to guide required management. For example, quantification of the specific threats which may be contributing to decline, or impeding the recovery, of the Northern steller sea lion is needed (Burek et al, 2005, Hare and Mantua, 2000, Holmes and York, 2003, Seal Special Group, 1996, Sease and York, 2003). As is monitoring leading to pre-emptive management of drought for the Arabian oryx in both existing oryx sites and in potential reintroduction areas (Seddon and Ismail, 2002, Van Heezik et al, 2003).

Monitoring of threats for Iberian lynx, tiger and snow leopard as part of a long term monitoring programme is vital to their conservation. Specifically, already identified as requiring management, focused monitoring is critically needed of the use and speed of vehicles using roads in Iberian lynx habitat, especially near Doñaña National Park, and also the monitoring and management of unlicensed agriculture such as strawberry farms (Palomares, CSIC, 2005, pers.comm). The inclusion of focused regular monitoring of threats is also of benefit to the red wolf (e.g. hybridisation with coyotes and human-wolf conflicts (Sillero-Zubiri, 2004, Kelly et al, 2004, Miller et al, 2003), Californian Channel Island fox (e.g. predation from golden eagles until bald eagles are re-established (Coonan, NPS, 2007 pers.comm, Roemer et al 2004a, Sillero-zubiri et al 2004, Wilkerson, 2006) and the African wild dog (e.g. range restriction, human-wild dog conflicts (Sillero-Zubiri et al, 2004, Mills and Gorman et al, 1997).

For the giant panda increased monitoring of threats is perhaps of greater importance than the focus on captive breeding. Human action is increasing pressure on their habitat, thus intensifying the potential effect of periodic bamboo die off as available habitat decreases in size and connectivity, and intrinsic threats affecting their population viability also need greater research focus (e.g. small population, increasing isolation, poor reproduction and recruitment) (Hong-wan et al, 2006, Xu et al, 2006, Guo et al, 2002b, Lu et al, 2001, Bear Specialist Group, 1996). Finally, all three primate species which were studied would benefit from greater monitoring of threats, particularly the rate of uncontrolled and/or illegal habitat loss. Monitoring the incidence of retaliation for crop raiding, poaching threats and the incidence of disease transmission from humans and human waste is needed for the mountain gorilla (Guerrara et al, 2003, Harcourt, 1980, Kingdon, 1997, McNeilage, 2006, Webber and Vedder, 1983). The threat of disease also requires monitoring for the lowland gorilla, as does the incident of illegal hunting and capture (Butynski, 2000, Matthew and Matthew, 2004, Poulson and Clark, 2004, Sabater, 1980-81). For the tamarin, continued monitoring and control of the pet trade, and the effects of fragmentation is important (Gravitol et al, 2001, Kleiman and Mallinson, 1998, WWF, 2001).

Monitoring of resources must be part of effective habitat management and particularly prey species protection. Resource depletion affects many of the study species such as the Mediterranean and Hawaiian monk seal, and the Northern steller sea lion due to over fishing and direct conflict resulting in persecution (Craig and Regen, 1999, Geodicke, 1981, Gucu et al, 2004, Marine Mammal commission, 2002, Panou et al, 1993, Sease and York, 2003, Seal Specialist group, 1996). Also the Grevys zebra (competition for grazing and water sources with human livestock (Equid Specialist Group, 1996, Low and Manyibe, 2006, UNEP,2006, Williams, 2002), the snow leopard (prey depletion (Nowell and Jackson, 1996) and tiger (prey depletion and habitat fragmentation (Nowell and Jackson, 1996). For the tiger habitat monitoring and protection has always been recognised as crucial to maintaining the viability of protected areas (Nowell and Jackson, 1996), and is now growing in importance alongside the need to reduce isolation by increasing connectivity between remaining tiger populations (Dinerstein et al, 2007).

Resource monitoring is also essential to the greater Indian, Sumatran and Javan rhino, which are particularly threatened by habitat loss and/or isolation (Amin et al, 2006). This is particularly pressing for the Javan rhino, as its effective global population is restricted to the Ujung Kulon Peninsula, the Western most tip of Java, and appears to be in great need of habitat expansion to increase its population (Thomas and Dee, 1982, Foose and Van Strien, 1998). Monitoring of resources is also needed for the Western lowland gorilla (habitat loss/disturbance due to logging (Matthews and Matthews, 2004)), Californian channel Island fox (changes to native vegetation (Coonan, 2007 pers.comm, Wilkerson, 2006), giant panda (periodic bamboo die off (Bear Specialist Group, 1996), and African wild dog (habitat fragmentation (Woodroffe et al, 2004). All these species would benefit from greater monitoring of resources as part of their long term management and protection. In particular, there needs to be greater monitoring focus on key resources.

3.51.33 GIS

The incorporation of GIS into the long term monitoring of all of the species in this study seems logical. For example, with hoped increases in the population of Arabian oryx, their range would also increase, and mapping seasonal distribution and resource use to identify long term trends and requirements for this species would enable optimal management.

For both the snow leopard and the Iberian lynx, the use of GIS as part of their monitoring would be advantageous as it has been used successfully with tigers (e.g. Linke et al, 2006). Greater emphasis on the use of GIS to monitor movements and key resources was also considered as a beneficial addition to a monitoring programme for both the Californian Channel Island fox and African wild dog. It has already been used to monitor habitat changes for the Ethiopian wolf (EWCP, 2005), and as a method to screen large areas for red wolf hybrids and coyotes (Adams et al, 2003). GIS use could to enhance knowledge of island fox resource use and identify potential differences between each sub species on each island (Roemer et al 2004a, Wilkerson, 2006), and has great potential for monitoring the African wild dog, as they range widely at low densities and are susceptible to competition with other predators such as lions and hyenas, the populations of which could also be mapped (Woodroffe et al, 2004, Creel and Creel 1996).

GIS has potential for monitoring movements of populations and identifying key areas for protection of resources, in particular for the Grevys zebra, but also once populations were better known, for the Sumatran and Javan rhinos. The possible benefit of incorporating GIS into monitoring of both the Western lowland gorilla and Golden lion tamarin is also substantial. For example, in mapping movements and resource use alongside habitat loss and incidents of poaching, thus identifying and increasing monitoring of key sites. It has been used successfully for the Eastern mountain gorilla in assessing home range and frugivory patterns (Robbins and McNeilage, 2003). GIS is growing in its potential to become a key tool in the future conservation of these and many other endangered species.

3.51.34 Photography and recording technology

Photography and recording technology such as mobile video has been widely used but was still identified as being applicable to species where there was no or little evidence of its use, or where it would be complimentary to studies already underway. For example, an aerial photographic census, such as that carried out for flamingos in the rift valley of Kenya (Woodworth et al, 1997), may be effective in covering a large distance in a short amount of time during an annual Arabian oryx count, and would complement other techniques. The use of remote video, as seen for the Mediterranean monk seal (e.g. Gucu et al, 2004), could be directly applied to monitor key land sites of both the Hawaiian monk seal and the Northern steller sea lion. Seal mounted cameras, as used successfully for the Hawaiian monk seal, to identify habitat use and foraging ecology, including juvenile foraging, alongside seal movements and dive patterns (e.g. Parrish et al, 2005, Stewart, 2004, Parrish et al, 2000), could be applied to both the Mediterranean monk seal and Northern steller sea lion to gather the same data.

A photographic database could become a key monitoring tool supplementing other methods, for example using camera traps for the elusive Iberian lynx, tiger and snow leopard. The potential for individual identification of all three species from their pelage marks is high, and has already been achieved to some extent with tigers (e.g. Karanth, 1995). For the tiger and snow leopard, databases could be regional as these species are far ranging. For the Iberian lynx, this resource is considered crucial as the population is so small and each individual should be known. Such a database may also be useful for the African wild dog, particularly for local studies on packs where the identification of individuals would be advantageous. If successful, the database could be expanded on a regional scale.

Camera trapping could become a potential addition for the Sumatran rhino after some success with the Javan rhino (Poleti et al, 1999). The usefulness of this technique would increase if all individuals were identifiable, a photographic database could then become applicable. There has already been some success with camera traps for the tiger, snow leopard and Iberian lynx (Azlan and Sharma, 2003, Karanth, 1995, McCarthy et al, 2007, Smith et al, 2007, Ward, 2006e). However, there are many considerations before carrying out such as survey as the techniques is expensive and requires good technology and expertise (Karanth, 2007, Jackson et al, 2005).

3.51.35 Mark and re-sight

Mark and re-sight techniques are used but may not be considered as optimal techniques for monitoring with other methods proving equally or more efficient (e.g. line transects Focardi et al, 2002, Hounsome et al, 2005), and particularly with advances in new technology. Its applicability to the study species was still considered. The tagging and mark re-sight techniques used for the Mediterranean monk seal (e.g. Forcada, 2000, Gazo et al, 1999) could be directly applied to the Hawaiian monk seal to monitor annual numbers at haul outs and individual longevity. For the Sumatran rhino, greater Indian one horned rhino and Javan rhino it was felt that tagging or marking such as the ear notching system used for the black rhino (Gitchohi, OPC,2005 Pers.com, Adcock et al, 1998) may be beneficial, particularly in recording every individual of Sumatran and Javan rhinos. However, the logistics of accessing each individual would be almost impossible as they both inhabit dense habitats. The limitations of thick vegetation would undoubtedly be a problem but there is a possibility for this method to be applied in collaboration with camera trapping technology, probably most useful for monitoring a known sample of individuals.

3.51.36 Sign Surveys

Even if not used as the main way of estimating populations, sign surveys could still be useful for monitoring species, particularly those which are cryptic or in dense habitats (Plumptre, 2000), or they could be used to complement other methods. Sign surveys were felt to have some use for the red wolf and Californian Channel Island fox, even if not required as the main way of estimating the population as both are well known. Their use would also be a good way of testing the accuracy of the method, and then using it as the populations expand. Sign surveys could also supplement information gained from surveys relying on sightings of greater Indian one horned rhino from elephant back in Nepal (Amin et al, 2006, Choudhury, 2005), and could be incorporated into areas with Indian rhino where censuses are not yet implemented regularly.

The use of sign surveys are used to census both Eastern mountain and Western lowland gorillas (e.g. AWF, 2006, 2007, Blom et al, 2001, Hall et al 1998, Harcourt, 1980-81, Matthews and Matthews, 2004, McNeilage, 2006, 2001, Murnyak, 1981, Poulson and Clark, 2004, Webber and Vedder, 1983, Yamagiwa et al, 1993). It was felt that the methods used for other primates may also be applicable to studies of golden lion tamarin to complement studies currently based on radio tracking and fur dying (e.g. Stoinski and Beck, 2004, Dietz and Baker, 1993).

Although potentially one of the simplest techniques to use to monitor species, it is still of significant benefit, particularly for species which are difficult to monitor directly. Sign surveys have been used successfully for many species (e.g. Barnes, 2001, 2002, Ellis and Bernard, 2005, Fox et al, 1991, Gussett and Burgener, 2005, Komers and Brotherton, 1997, Marques et al, 2001, Rabinowitz, 1993, Rasmussen et al, 2005, Stander, 1998, Tuyttens et al, 2001) and their use will remain important to monitor endangered species (Jewell et al, 2001). Although reliant on particular expertise, techniques relying on sign are continuing to be used and improved such as DNA, dietary analysis, and the identification of individuals (e.g. black rhino) from spoor measurements (e.g. Jewell et al, 2001, Eggert et al, 2003, Steinheim et al, 2005, Reilly, 2002, Van Vliet et al, 2007), and also, scat detection and identification through using specially trained dogs.

3.51.37 Scat detection dogs

The use of scat detection dogs has been successful used for snow leopards and tigers (e.g. Kerley and Salkina, 2007, SLT, 2007). This technique would be a great asset to the monitoring of the Iberian lynx, particularly in the mountain regions where total populations are unknown. The dogs could be used to identify lynx scat from other predators, after being 98% successful in doing so for tigers after repeated trials (Kerley and Salkina, 2007). Such use is also applicable for the red wolf, Ethiopian wolf and African wild dog, although the risks perceived with disease such as rabies would be an important consideration. It is thought that the use of dogs to detect pure scat from that of other predators or even hybrids would be an advantageous tool, particularly for the red wolf as an alternative or an additional method to genetic analysis (e.g. Adams et al, 2003) of scat.

The use of scat detection dogs has potential to census panda populations across their range, for example along line transects as an alternative or in addition to relying on human sightings of pandas and panda signs. Their potential within dense habitat is also promising, for example in surveying the population of Sumatran and Javan rhinos, thus relying upon the sensitivity of a dog along transects in addition to locating tracks and signs.

3.51.38 Community involvement

The recording of sightings and the use of interviews, and/or the potential for the development of a community monitoring system such as that for the Grevys zebra (LWC, 2006) is considered a possible way of extending monitoring information for a number of species. Such a project could be possible for the snow leopard as sightings by managers or researchers may be limited. Also, a community monitoring system would be beneficial to the overall monitoring of the Ethiopian wolf, particularly as the wolves often encounter livestock herders (Sillero-Zubiri and Macdonald, 1997). Sightings and interviews such as those incorporated for the Mediterranean monk seal (e.g. Geodicke, 1981, Güçlüsoy and Savas, 2003), could also be applied to the Hawaiian monk seal and Northern steller sea lion, to collect monitoring information and assessing conflicts. Having a well known data collection system for people to contribute to could also collect valuable information for elusive species such as the Sumatran and Javan rhinos. By incorporating and involving local people in a scientific way would not only create a database of information but would also raise the species' profile, and encourage community involvement in conservation and pride in their wildlife.

3.51.39 Laboratory techniques

Although requiring experienced personnel, for some species the incorporation of laboratory techniques into their population monitoring is becoming essential. For example, the analysis of blood or tissue samples is important for Mediterranean monk seal and Northern steller sea lion, as it has been used successfully for monitoring levels of organochlorines in blubber, and also for genetic analysis of the Hawaiian monk seal (e.g. Wilcox et al, 2004, Kretzman et al, 2007). This would be an important step to monitor the effect of pollution, and in particular, genetic analysis would be beneficial for the Northern steller sea lion to determine genetic diversity amongst the different population locations.

Greater use of genetic analysis was considered as a beneficial expansion of monitoring both African wild dog and Ethiopian wolf populations. It has been used successfully for Californian Channel Island fox (e.g. Roemer et al, 2004b, Coonan, NPS, 2007 pers.comm) and red wolf populations (e.g. Adams et al, 2003) to combat threats of hybridisation in the red wolf and genetic variation in the fox, problems applicable to both the Ethiopian wolf and AWD. The use of faecal, blood and/or tissue for analysis of toxins or disease monitoring, and dietary analysis of scat, are options for the Ethiopian wolf. This was considered particularly to assess diet (as used for the African wild dog e.g. Woodroffe et al, 2005) and as the threat of disease is so acute in its restricted population (Marino et al 2006, Stephens et al 2001, Sillero-Zubiri and Macdonald, 1997).

The use of faecal samples for DNA extraction and to assess diet and incidence of disease is seen as a way of increasing knowledge within monitoring of both the Sumatran and Javan rhinos, with genetic analysis particularly important to the highly restricted population of Javan rhinos (Khan et al, 2002, Poleti et al, 1999).

Genetic analysis was considered as a useful addition to the monitoring of the Eastern mountain gorilla to assess genetic variability, having been used successfully in a study of a population of lowland gorillas, with DNA extracted from hairs left in nests (Morgan et al, 2003). Conversely, the analysis of faecal material, blood or tissue could be incorporated into monitoring populations of lowland gorillas, having been used successfully to assess disease in mountain gorillas (Kalema-Zikusoka, 2005).

3.51.4 Precedents for effective management and monitoring

The four case studies provided a greater insight into the practicalities of successful species management and monitoring. All four species had isolation in common, either within protected areas, isolated geographically, or becoming increasingly restricted due to a growing human population. Managers considered them all to be flagships, with the potential to be umbrella species. Although no quantified evidence for this was generated from the case studies, generally the species require large tracts of undisturbed habitat to survive, and the general consensus was that protecting land for the endangered species undoubtedly provides habitat for others that reside there.

The conservation work currently in place for these species has the potential to set a precedent for other species. A number of key management and monitoring actions common to the success of the case study species conservation work can be identified. Firstly, for all four species, monitoring techniques were developed and standardised through pilots, workshops and collaborations between interested parties. The intensity and method of monitoring varied across the species, but a common theme was co-ordination. This was particularly evident for the Californian Channel Island fox and black rhino, with the occurrence of regular internal and international meetings and dedicated teams. Such co-ordination appears to be crucial to successful management of endangered species and creates effective conservation. As a result, the population of black rhino in Kenya is on the increase, and the captive breeding and reintroduction programme has now been halted for the Island fox, as all foxes have been released and are doing well. One factor which appears to be hampering in situ conservation work for the lynx is problematic co-ordination between interested parties.

Secondly, a crucial management action is a fast response of managers to a critical situation, for example, quick and effective threat removal and population protection. This was evident particularly for the Island fox with rapid removal of the threats which caused the fox populations to crash. The remaining foxes were captured, captive breeding began and, most importantly, the original foxes and first generation offspring were re-introduced. Undoubtedly, rapid re-introduction such as this prevented habituation and a loss of survival skills in the foxes and avoided complications with pre release training (Coonan, pers.com, 2007). The success of Island fox conservation work is testament to how good management coupled with fast action can quickly save a species from extinction. Although a major threat still needs to be managed effectively for the Iberian lynx (road fatalities), its captive breeding is also advancing well. Since the visit to a captive breeding centre in 2005, when there had been no lynx births, there have been more than 20 births, the ex situ programme has expanded with new centres and hopes to be able to provide 20-40 individuals per year for reintroductions from 2010 (Ward, 2008a). There have however been no re-introductions, but the plans are in progress with the first 'soft' releases planned for 2009 (Ward, 2008a). The obvious success of the quick turn around of the Island fox captive breeding and release programme will serve to support the need for speedy release of both Iberian lynx and Giant panda. The rapid response required by management evidently incorporates the first requirement for good co-operation and collaboration between organisations involved. This requirement is evidential from the other case study successes, and is critical to effective management, protection and removal of threats.

Thirdly, finance is important. It is true that the success of the Californian Channel Island fox management may be partly owed to the financial situation appearing to be the most secure, with managers not required to apply for funding from NGO's or other sources in the same way as for the other case study species. Also proving an economic benefit for Island fox conservation was considered a non priority. However, the major threats to the Island fox were potentially more manageable and less costly to remove (e.g. alien species removal) or prevent than for the other species (e.g. poaching, disease). Although not quantified by the case studies, for the Iberian lynx, giant panda and black rhino, tourism was considered an economic benefit of their existence, alongside other land management payment schemes e.g. the incentive scheme for landowners to conserve lynx habitat. It appears that for these three case study species, they are more under threat from human opinion as they potentially impact upon human livelihoods, such as preventing settlements and cultivation. Therefore, although the Island fox can be considered here as a conservation success story, its management may not have had the intensity of problems and the need to provide for and defend its actions as much as for the other species.

All case study species receive funding from governmental or NGO sources. The black rhino situation is more precarious with some conservation reliant upon income from tourism; this can be affected by political unrest and by economic markets, and is seasonal. Governmental support can also change, particularly with a change in elected parties. It does seem that where support is secure in the medium term (e.g. EU life programme, government funding) progress is made. Where support appears short term or insecure (e.g. tourism, NGO project funds) it may be difficult to put effective management and monitoring in place, with much time spent trying to secure future funding. What is evident is that with full support (e.g. financially) and with minimal conflicts, the threat of extinction can certainly be better guarded against. Therefore, financial security has obvious benefits and is imperative for long term effective management and monitoring.

The case studies have provided a snap shot of species management and the problems it faces. It appears that good collaboration, rapid response and secure funding are three common foundation requirements for successful management and monitoring of an endangered species.

3.52 Refining management and monitoring

3.52.1 Identifying a gold standard

From the case study responses, an attempt was made to identify some broad criteria, which could be used to identify species which are well managed and monitored. When assigning the criteria to the 20 monitored species, the criteria (A-J) were considered to be equally weighted, however it is possible to suggest some weighting within the generated criteria to refine and better define good management and monitoring (table 3.11). A number of the criteria are considered to be essential to good management and monitoring practice, whereas others act as indicators that there could potentially be good management and monitoring in place. For example, criteria A, C and J (table 3.11) require that a species is monitored, there is funding in place and that the species has or is showing a positive response to management. These three criteria are considered to be essential for identifying a well managed and monitored species. The remaining 7 criteria require certain information to be known about a species, such as ecological and demographic information, whether the species is highly regarded e.g. it has an important role in its ecosystem or is considered an ambassador species, and whether it is protected in a reserve and/or legally. All of these criteria require information to be available through studies which are carried out by management or people involved in monitoring programmes, therefore acting as an indication that such action is taking place for a species.

It was considered that qualifying for part of 5 or more of the 10 criteria could indicate a species is potentially well managed and monitored. Of the 20 monitored species, 90% achieved this status. All four of the case study species expectedly achieved every criterion, alongside another species, the greater Indian one horned rhino. Such results were expected, as all of the 20 species were chosen for further study on the basis of them having good research. The criteria has the potential however, to be applied to other species for which such in depth information is not necessarily known, as the criteria rely upon broad and accessible information, and can provide an indication of the quality of conservation work in place. Such a scheme can therefore highlight deficiencies but also outline a provisional 'gold' standard of management and monitoring using basic information.

Where the criteria indicate a 'gold' standard for management and monitoring, the top ten list of 'best practice', generated from managers, scientists and conservationists, concentrates on monitoring alone. Monitoring species populations is a priority stated within a variety of species action plans (e.g. Mallon and Kingswood, 2001, Nowell and Jackson, 1996, Servheen et al, 1999, Sillero-Zubiri et al, 2004, Wemmer, 1998). Effective management relies on good monitoring (Joseph et al, 2006) with results from good monitoring forming the backbone to further targeted research and conservation action, the implementation of which ultimately acts to save threatened species.

To better define a 'gold' standard for monitoring, the best practice list can be combined with elements of the criteria developed in this study. Therefore to achieve the best level of monitoring:

≈ Programmes should be thoroughly planned, being based on good and proven theoretical knowledge and practical experience.

≈ The system must be piloted, evaluated and improved before implementation.

≈ Clear goals must be established which are both realistic and quantifiable.

≈ Funding must be in place from the beginning for the duration of at least the first round of any programme, including the pilot study.

≈ The system must be repeated regularly or continuously if required/possible, and should adhere to a time frame, after which results must be evaluated.

≈ The system must be robust: by using a repeatable and user friendly methodology accompanied by a clear data collection, storage and analysis format. It must be consistent and standardised, incorporate training and be statistically powerful enough to answer management questions, as well as being well co-ordinated and communicated.

≈ The system should collect broad raw data which can be refined later to answer many management questions e.g. take an ecosystem approach not limited specifically to the species of interest but also other important ecological parameters which are/may be related.

≈ Any system must be sustainable, i.e. manageable enough to be easily continued over a long time period, and flexible enough for new data to be collected within the methodology to answer new management questions.

Watson and Novelly (2004) support such findings, stating important requirements including the use of well considered techniques in an achievable and sustainable system with a system of feedback and user friendly data management and interpretation. However, limitations are acknowledged (e.g. Caughlan and Oakley, 2001, Evans and Hammond, 2004, Regan et al, 2008, Smyth and James, 2004), with the justification of costs being a major factor. Caughlan and Oakley (2001) recognised the importance of budgeting monitoring programme costs to its longevity, and the necessity for perceived benefits of the information to justify the costs involved. Their study presents a monitoring programme development process incorporating three stages (design, testing and implementation), based upon cost issues and incorporating statistical power. Progression through each stage relies upon proof of feasibility, before resources are committed to the final monitoring programme. Such a decision making system can be developed which builds on the elements of the gold standard for monitoring identified here. The system will assume funding is fundamental to its success, and will be based upon the reviewed literature on managing and monitoring species under threat of extinction, and on feedback from conservation professionals which has been collated within this study.

3.52.2 Monitoring design flow diagram

Information from the twenty monitored species reviews, four case studies and from the top ten best practise list, can be combined to develop a flow diagram (figure 3.4) This flow diagram is therefore based upon species literature and direct contact with managers and scientists, and its goal is to outline a decision making process which could be followed in order to achieve a good monitoring system.

The model is initiated by the identification of a conservation management issue. This could simply be the recognition that a population is in decline, or concern about a specific threat such as poaching, disease or an alien species. Any monitoring programme must be designed alongside threat alleviation measures, particularly measures to combat acute and possibly unique threats to the focus species. Examples include combating poaching, food depletion, disease and road fatalities for species such as rhinos, Arabian oryx, predatory species such as tigers and African wild dogs, and the Iberian lynx. Targeted threat alleviation measures alongside effective monitoring can be very successful, as seen with the Californian Channel Island fox population recovery. Targeting common threats may also aid many species, e.g. targeting the supply and demand of poached wildlife products.

The next stage is fundamental to the success of the monitoring system and involves identification of the appropriate and target species to monitor. The monitored species may not be the species of concern. Instead it could be an emblematic species which would create support, and which may also function as an umbrella species - incorporating the target species under its protection. Alternatively, the target species could be emblematic in its own right, and identifying an umbrella status could also increase its conservation value. In the case of predators, alongside monitoring the target species, it may be just as important to monitor prey populations, particularly for species such as the Iberian lynx, Ethiopian wolf, snow leopard and tiger, among others, who are threatened by prey depletion.

Once the target species has been identified, the next step is to identify the key baseline information required to answer management questions. This may be the most challenging stage but it is crucial, as this is where specific aims and objectives are set and where it is decided if a monitoring system is in fact the best way to answer management questions. Both of these stages incorporate the need for good theoretical knowledge, and recognition of what is achievable and realistic. Both the twenty species reviews and the case studies have demonstrated the benefit of researching conservation work undertaken for other species, learning from successes and failures, particularly with similar species, e.g. many of the techniques used for the Mediterranean monk seal seem directly applicable to the Hawaiian monk seal and vice versa. Co-operation between interested parties and among the global conservation community is imperative to the success of long term conservation goals. Such co-operation and co-ordination in the planning and initiation stages of a large scale, long term monitoring programme would undoubtedly benefit its development.

It is only following this 'initiation' stage that the 'mobilisation' stage can begin. This involves the design of the monitoring system and includes research into funding and equipment available, the incorporation of habitat surveys into the monitoring system and the successful running of a pilot study to test monitoring techniques. These stages are fundamental and crucial to the long-term success of a monitoring programme. So too is the development of a fixed sample size, one that is effective enough to answer specific management questions and meet the aims and objectives set in the initiation stage. Co-ordination between interested parties is again important at this stage and can influence the success of a monitoring programme, success such as that seen for the Californian Channel Island fox, with rapid co-ordination, and timely action. Pilot studies are extremely important as demonstrated with all the case study species. The choice of techniques used must be influenced by their effectiveness, something which can only be measured by testing. Direct techniques may be considered the best way to get information about an individual of a species, but indirect (e.g. sign surveys) and other techniques (e.g. local people surveys) may be the only option to gain population information, particularly for elusive species. One or two techniques can then be refined and used on a regular basis. Finally, securing funding is of course vital. This was in place, from governments and NGO's and tourism, for the case study species.

It is only after such mobilisation, that the design of the monitoring system can move on to the 'implementation' stage. Here is where the detailed strategic planning takes place. This involves the standardisation of the monitoring programme whereby the final technique following analysis of the pilot study is designed, specific aims, objectives or goals are refined, a strict time scale for the system is set, and data storage and analysis techniques are fully prepared. It is only following this stage that the monitoring system can begin. Conversely, following evaluation during strategic planning, it may be the case that a new or improved mobilisation stage is necessary.

The next stage of implementation involves the thorough training of any personnel involved into all aspects of the design from field techniques through to data storage and analysis. For all the case study species, monitoring staff had been fully trained, demonstrating the importance and effectiveness of training in standardising the monitoring system. Such training is fundamental and crucial to the success of the monitoring system under construction.

It is only after all of these stages have been suitably achieved can the 'monitoring cycle' stage be entered into. This is the goal of a monitoring system design: to be within the monitoring cycle with a set procedure incorporating a core methodology of field techniques and data analysis, communicating results and repeating this within a set timescale (e.g. annually). It must be expected however that during initial cycles, evaluation may reveal the need to return to earlier stages in the monitoring design in order to improve the whole process. A set timescale must also be adhered to, following this the monitoring system must be thoroughly evaluated and either adapted to answer new questions, while maintaining continuity, which is essential for long term monitoring. Monitoring must move with the times, and specifically, with management needs, but any system must also remain true to set goals.

3.6 Conclusions

- Reintroduction is a critical part of species management

- Both common and species specific management actions are equally important for the conservation of the 20 monitored species.

- Similar monitoring techniques are used across the 20 species, but are directed towards answering specific management questions.

- Use of basic techniques will continue to form the backbone for monitoring endangered species, with indirect techniques being cost effective and reliable

- It is not the number of techniques used which is important, but the effective use of 1 or 2 effective techniques.

- Satellite technology and GIS has great potential in monitoring endangered species

- Scat detection dogs, photography and/or video and sign surveys have particular potential for monitoring elusive species, and in combination with other techniques.

- Community monitoring can provide valuable information, raise a species' profile and encourage community pride in their wildlife.

- Laboratory techniques require experienced personnel but can be of great benefit for specific threats (pollution, disease, inbreeding)

- Requirements for effective management and monitoring of an endangered species include:
  - Collaboration and co-operation in developing and standardising techniques.
  - A fast response (threat removal, re-introduction)
  - Secure funding

- Indicators of the presence of good management and monitoring from basic information about a species include:
  - A statement that there is consistent monitoring in place
  - Secure funding
  - A positive response of a species to management efforts
  - Availability of ecological and demographic information

- The gold standard of monitoring requires that a system is well planned, tried and tested, with clear goals and secure funding, using techniques which are sustainable, but flexible and robust but easy to use, and which collects broad data for later refinement to answer management questions.

- A flow diagram has been developed which can guide through '*initiation*', '*mobilisation*' and '*implementation*' of a monitoring system, through to the end goal of the '*monitoring cycle*' which incorporates core methodology, analysis and feedback.

Figure 3.1: Case study map

World map (adapted from Baillie et al, 2004) with case study species locations and site visits.

Location and protection								
Species	***Continent***	***Countries***	****Habitat***	***Endangered***	***Critically endangered***	***Cites***	***Protected area***	***Legal Protection***
Bovidae								
The Arabian or White Oryx (*Oryx leucoryx*)	Asia/Africa	11	D	1986	-	1	Yes	Needed
Conservation action								
	Ex Situ	*Captive Breeding*	*Re-introduction*	*Population and range research*	*Biology and ecology research*	*Monitoring programme*	*Research and monitoring grade (RMG)*	*Species management grade (SMG)*
	Yes	Yes	Yes	No	No	Yes	3/5	3/3

Table 3.1: Monitored Artiodactyla Summary
Summary of location, protection and conservation action in place for the monitored Artiodactyla, the Arabian Oryx.
Source: IUCN, 2004, WCMC 2004, CITES 2004
* D = desert

Location and protection								
Species	*Continent*	*Countries*	**Habitat*	*Endangered*	*Critically endangered*	*Cites*	*Protected area*	*Legal Protection*
Phocidae								
Mediterranean Monk Seal (*Monochus monochus*)	Afr/Eur	25	C	1986	1996	1	Yes	No
Hawaiian Monk Seal (*Monochus schauslandi*)	N.America	1	C	1986	-	1	Yes	No
Felidae								
Iberian lynx (*Lynx pardinus*)	Europe	2	F, Sh	1986	2002	1	Yes/Needed	Yes
Tiger (*Panthera tigris*)	Asia	22	F, S	1986	-	1	Yes	Yes
Snow leopard (*Uncia uncia*)	Asia	12	G,Sh	1986	-	1	Yes/more required	Yes
Canidae								
Red Wolf (*Canis rufus*)	N. America	2	F,Sh, W, A	1982	1986	-	Yes	Yes
Californian Channel Island Fox (*Urocyon litteralis*)	N.America	1	F, G, Sh, C	-	2004	-	Yes	Yes/more needed
Ethiopian wolf (*Canis simensis*)	Africa	1	G, Sh, W, R	1986 2004	1996	-	Yes	Yes/more needed
African Wild Dog (*Lycaon pictus*)	Africa	35	F, S, G	1990	-	-	Yes	Yes/more needed
Otariidae								
Northern Steller Sealion (*Eumotopias jubatus*)	Asia N.America S.America	4	C	1996	-	-	No	No
Urcidae								
Giant Panda (*Ailuropoda melanoleuca*)	Asia	1	F	1990	-	1	Yes	Yes

Table 3.2: Monitored Carnivore Summary

Summary of location and protection in place for the monitored Carnivores.

Source: IUCN, 2004, WCMC 2004, CITES 2004

* F = forest, S = savannah, Sh = Shrub land, W = wetland, C = coast, A = artificial, G = grassland

Table 3.2 continued: Monitored Carnivores Summary

Conservation action

Species	*Ex Situ*	*Captive Breeding*	*Re-introduction*	*Population and range research*	*Biology and ecology research*	*Monitoring programme*	*Research and monitoring grade (RMG)*	*Species management grade (SMG)*
Phocidae								
Mediterranean Monk Seal (*Monochus monochus*)	No	needed	No	Yes	Yes	Yes	4/5	0/3
Hawaiian Monk Seal (*Monochus schauinslandi*)	No	No	No	Yes	Yes	Yes	3/5	0/3
Felidae								
Iberian lynx (*Lynx pardinus*)	Yes	Yes	No	Yes	Yes	Yes	5/5	2/3
Tiger (*Panthera tigris*)	Yes	*No	No	Yes	Yes	Yes	4/5	1/3
Snow leopard (*Uncia uncia*)	Yes	*No	No	Yes	Yes	Yes	4/5	1/3
Canidae								
Red Wolf (*Canis rufus*)	Yes	Yes	Yes	*No	Yes	Yes	3/5	3/3
Californian Channel Island Fox (*Urocyon litteralis*)	Yes	Yes	Yes	Yes	Yes	Yes	5/5	3/3
Ethiopian wolf (*Canis simensis*)	No	Needed	No	Needed	Yes	Yes	5/5	0/3
African Wild Dog (*Lycaon pictus*)	Yes	Yes	Yes	Yes	Yes	Yes	5/5	3/3
Otariidae								
Northern Steller Sealion (*Eumotopias jubatus*)	Yes	No	No	Yes	No	Yes	3/5	1/3
Urcidae								
Giant Panda (*Ailuropoda melanoleuca*)	Yes	Yes	*No	Yes	Yes	Yes	4/5	2/3

Location and protection								
Species	***Continent***	***Countries***	****Habitat***	***Endangered***	***Critically endangered***	***Cites***	***Protected area***	***Legal Protection***
Rhinocerotidae								
Black Rhino (*Diceros bicornis*)	Africa	15	D, S, Sh	1986	1996	1	Yes	Yes
Sumatran Rhino (*Dicerorhinus sumatrensis*)	Asia	10	F	1986	1994	1	Yes	No
Greater Indian One Horned Rhino (*Rhinoceros unicornis*)	Asia			1986		1	Yes	Yes
Javan Rhino (*Rhinoceros sondaicus*)	Asia	10	F	1986	1996	1	Yes	Yes
Equidae								
Grevys Zebra (Equus grevyi)	Africa	6	S	1986	1996	1	Yes	Yes
Conservation action								
Species	***Ex Situ***	***Captive Breeding***	***Re-introduction***	***Population and range research***	***Biology and ecology research***	***Monitoring programme***	***Research and monitoring grade (RMG)***	***Species management grade (SMG)***
Rhinocerotidae								
Black Rhino (*Diceros bicornis*)	Yes	*No	*No	Yes	Yes	Yes	5/5	1/3
Sumatran Rhino (*Dicerorhinus sumatrensis*)	Yes	Yes	No	Yes	No	Yes	3/5	2/3
Greater Indian One Horned Rhino (*Rhinoceros unicornis*)	Yes	Yes	No	Yes	Needed	Yes	3/5	2/3
Javan Rhino (*Rhinoceros sondaicus*)	No	No	No	Yes	No	Yes	3/5	0/3
Equidae								
Grevys Zebra (Equus grevyi)**Grevys Zebra**	Yes	No	No	Yes	Yes	Yes	4/5	1/3

Table 3.3: Monitored Perrisodactyla Summary
Summary of location, protection and conservation action in place for the monitored Perrisodactyla
Source: IUCN, 2004, WCMC 2004, CITES 2004
*Habitat: D = desert, S = savannah, Sh = Shrub land, F = forest   *No = not well established, or for the purpose of re-introduction in the case of captive breeding

Location and protection

Species	*Continent*	*Countries*	**Habitat*	*Endangered*	*Critically endangered*	*Cites*	*Protected area*	*Legal Protection*
Homnidae								
Eastern Mountain Gorilla (*Gorilla beringei*)	Africa	3	F	2000		2	Yes	No
Western lowland gorilla (*Gorilla gorilla*)	Africa	8	F	1996		1	Yes	Needed
Callitrichidae								
Golden Lion Tamarin (*Leontopithecus rosalia*)	S.America	1	F	1982		1	Yes	No

Conservation action

Species	*Ex Situ*	*Captive Breeding*	*Re-introduction*	*Population and range research*	*Biology and ecology research*	*Monitoring programme*	*Research and monitoring grade (RMG)*	*Species management grade (SMG)*
Homnidae								
Eastern Mountain Gorilla (*Gorilla beringei*)	No	No	No	Yes	Yes	Yes	5/5	0/3
Western lowland gorilla (*Gorilla gorilla*)	Yes	No	No	Yes	Yes	Yes	4/5	1/3
Callitrichidae								
Golden Lion Tamarin (*Leontopithecus rosalia*)	Yes	Yes	Yes	No	No	Yes	3/5	3/3

Table 3.4: Monitored Primate Summary
Summary of location, protection and conservation action in place for the monitored Primates
Source: IUCN, 2004, WCMC 2004, CITES 2004
*Habitat: F = forest

Table 3.5: Summary of monitored species reviews				
Species	***Population**	**Key Issues**	**Priority action**	**Monitoring Techniques**
Arabian Oryx (*Oryx leucoryx*)	886 (Re-introduced)	Poaching Inbreeding Drought	Captive breeding with greater genetic management to prevent inbreeding. Key resource identification prior to allocating reintroduction sites. Supplementary feeding during prolonged drought conditions. Restricted human settlement within reserves.	Twice Yearly ranger based surveys (derivation of population size from births and deaths). Distance sampling. Mark – re-sight (Tagging). Spoor Tracking. Visual Observations. Genetic analysis.
(Corp et al, 1998, IUCN, 2004, IUCN, 2001, IUCN, 1994, Marshall and Spalton, 2000, Marshall et al, 1999, Ostrowski et al, 1998, Plowman and Mallon, 2003, Saltz.D, 1998, Seddon et al, 2003, Seddon and Ismail, 2002, Spalton et al, 1999, Spalton.J, 1999, Van Heezik et al, 2003)				
Mediterranean Monk Seal (*Monochus monochus*)	-	Competition with humans for fish Entanglement	More anti predator nets. More enforcement of legal protection & effective punishment. Strict fishing quotas. Regular clean ups and fines for irresponsible fishing equipment disposal. Compensation scheme (well managed). Zonation (Marine Protected Area). Greater protection of key sites (caves and rest areas). Abandoned pup/injured rescue & re-release scheme.	Photographic capture-recapture (Individual ID from marks and scars). Flipper tagging. Sign surveys. Direct observation. Infra-red video. Local interviews. Threat analysis (death records). Modelling (predictive). Genetic analysis.
(Durant and Harwood, 1992, Forcada, 2000, Gazo et al, 1999, Goedicke, 1981, Güçlüsoy and Savas, 2003, Güçlüsoy et al, 1999, Gucu et al, 2004, IUCN, 2004, IUCN, 1994, Karamanlidis et al, 2003, Lonnon, 2005, Panou et al, 1993, Pastor et al, 2004, Seal Specialist Group, 1996, Forcada and Aguilar, 2000)				
Hawaiian Monk Seal (*Monochus schauslandi*)	-	Entanglement Reduced food resource	Key habitat protection (foraging sites). Continued removal of fishing debris.	Annual census (repeat haul out counts). Seal mounted cameras. Satellite transmitters. Photography. Direct observation. Toxin analysis (blood and blubber). Threat analysis (transect and plot surveys and debris removal). Genetic analysis.
(Baker and Johanos, 2004, Boland and Donohue, 2003, Craig and Ragen, 1999, IUCN, 2004, IUCN, 1994, Kretzmann et al, 1997, Marine Mammal Commission, 2002, Parrish et al, 2005, Parrish et al, 2000, Seal Specialist Group, 1996, Stewart, 2004, Willcox et al, 2004)				

Table 3.5 continued: Summary of monitored species reviews				
Species	***Population**	**Key Issues**	**Priority action**	**Monitoring Techniques**
Iberian lynx (*Lynx pardinus*)	250 (estimated effective size)	Road fatalities Disease Small population	Prevent road deaths: financial speeding penalties (cameras). Rabbit population supplementation and recovery. Disease management (focused research). Habitat protection/restoration. Rapid development of re-introduction techniques. Translocations. Continue work with landowners.	Radio collars. Touch plate camera traps. Spoor surveys. Den surveys. Sighting records. Genetic analysis.
(Aerts and Van Heijnsbergen, 2006, Cat Specialist Group, 2002, Ferrer and Negro, 2001, Ferreras et al, 2004, Ferreras.P, 2001, Fernandez and Palomares, 2000, IUCN, 2001, IUCN, 2004, Nowell and Jackson, 1996, Palma et al, 1999, Palomares et al, 2005, Palomares.F, 2001, Palomares et al, 2000, Rodriguez and Delibes, 2002, Rodriguez and Delibes, 2003, Rodriguez and Delibes, 2004, Ward, 2007, 2006a, 2006b, 2006c, 2006d, 2006e, 2005a, 2005b, 2005c)				
Tiger (*Panthera tigris*)	<2500	Poaching Habitat loss and fragmentation Loss of prey base Human disturbance	Greater management and control of acute threat of poaching. Effective and international punishment for use of tiger parts to cut supply. Habitat protection and establishment of corridors. Standardisation of monitoring techniques for each population.	Camera traps – mark recapture (Individual ID from stripe patterns). Radio collars. GPS collars. Tracking and transects (spoor, scrapes, scat). Visual observation. Networks and surveys. GIS mapping and modelling. Scat detection dogs. Genetic analysis.
(Azlan and Sharma, 2003, Chunderwat et al, 2007, Dinerstein et al, 2007, Dorji and Santiapillai, 1989, Ellis, 2005, Goodrich et al, 2007, IUCN, 2004, IUCN, 2001, Johnsingh and Negi, 2003, Karanth, 2007, Karanth, 1995, Kawanishi and Sunquist, 2004, Kerley and Salkina, 2007, Kerley et al, 2002, Kinnaird and O'Brien, 2002, Lairweb, 2006, Linke et al, 2006, Miquelle et al, 2007, Mountford, 1974, Nowell and Jackson, 1996, Plowden and Bowles, 1997, Rabinowitz, 1993, Reddy et al, 2004, Sharma et al, 2007, Smith et al, 2007, Smith et al, 1998, Xu et al, 2005, Yu et al, 2006)				
Snow leopard (*Uncia uncia*)	<2500 (effective)	Poaching Retaliatory killing Prey base depletion	Continuation of education and predator proof corral development. Prevention of illegal hunting, greater punishments. Ecosystem approach – protect undisturbed habitat and wild prey resources. Standardised monitoring techniques.	Sign indices (scrapes, scent, scat, claw raking). Photo trap cameras. Radio collars. GPS collars. Scat detection and individual ID using dogs. Genetic analysis.
(Cat Specialist Group, 2002, Chettri, 2003, Fox, 1991, Habib et al, 2007, IUCN, 2004, IUCN, 2001, Jackson et al, 2007, Jackson and Wangchuk, 2001, Jackson, 1979, Jackson et al, undated, Mallon, 1991, McCarthy et al, 2007, McCarthy et al, 2007, McCarthy et al, 2005, NABU, 2001, Nowell and Jackson, 1996, SLT, 2007, 2007b, SLC, 2005)				

Table 3.5 continued: Summary of monitored species reviews				
Species	*Population	Key Issues	Priority action	Monitoring Techniques
Red Wolf (*Canis rufus*)	<150 (Re-introduced)	Hybridisation Small population	Continuation of hybrid monitoring and control. Continuation of pup fostering programme.	Continuous monitoring following re-introduction. Radio collars. GPS collars. Tagging. GIS mapping. Genetic analysis.
(Adams et al, 2003, Kalinowski et al, 1999, Kelly et al, 2004, Miller et al, 2003, Sillero-Zubiri et al, 2004, NCOB, 2005, USFWS, 2004a, 2004b, 2003, 2002, 2002b, 1999)				
Californian Channel Island Fox (*Urocyon litteralis*)	1500 (2002)	Alien species Disease	Continued threat removal and management. Close recovery monitoring. Bald eagle re-introduction.	Transect and grid trapping – capture recapture. Radio collars. Genetic analysis.
(Friends of the Island Fox, 2005, Goldstein et al, 1999, IUCN, 2001, Roemer et al, 2004a, 2004b, Roemer and Wayne, 2003, Roemer et al, 2001, Roemer et al, 2001, Sillero-Zubiri et al, 2004, Wilkerson, 2006)				
Ethiopian wolf (*Canis simensis*)	442 (239 mature)	Disease Hybridisation	Vaccinations. Community conservation programme. Prey resource protection.	Regular transects (field signs). Road and horseback transects. Radio collars. Tracking. Individual identification. GIS mapping. Threat & resource monitoring (grazing, dogs, resource use, persecution, prey (rodent trapping grids)
(Ashenafi et al, 2005, EWCP, 2005, Haydon et al, 2002, IUCN, 2004, IUCN, 2001, Laurenson et al, 1998, Marino et al, 2006, Sillero-Zubiri and Marino, 2004, Silero-Zubiri and Macdonald, 1998, Sillero – Zubiri and Macdonald, 1997, Sillero-Zubiri et al, 1995, Stephens et al, 2001)				
African Wild Dog (*Lycaon pictus*)	3000-5500	Habitat fragmentation Prey depletion Disease Persecution Vaccination risk	Large land area protection Interconnection development/protection. Prey species conservation. Focus on wild population conservation. Continued research into re-introduction/pup removal & reintroduction.	Photography. Individual identification (unique pelage). Call simulation. Spoor counts. Satellite radio tracking. Radio collars and implants. Community reports. Scat analysis.
(Childes, 1988, Creel and Murusha Creel, 1996, Frantzen et al, 2001, Gorman and Mills, 1997, Graf et al, 2006, Lindsey et al, 2005, Maddock, 1999, Maddock and Mills, 1994, Robbins and McCreery, 2003, Stander, 1998, Woodroffe et al, 2005, Woodroffe et al, 2004, Woodroffe, 2001)				

Table 3.5 continued: Summary of monitored species reviews				
Species	***Population**	**Key Issues**	**Priority action**	**Monitoring Techniques**
Northern Steller Sealion (*Eumotopias jubatus*)	-	Insufficient food resource Oceanographic change	Extend monitoring to cover full range. Basic biological studies. Research impact of fishing industry.	Aerial and ground counts. Photography (haul out sites. Presence/absence and re-sighting. Drive counts. Branding. Modelling.
(Burek et al, 2005, Calkins et al, 1999, Calkins et al, 1998, Call and Loughlin, 2005, Cottrel and Trites, 2002, Deagle et al, 2005, DeMaster et al, 2006, Ebhardt et al, 2005, Fadely et al, 2005, Hare and Mantua, 2000, Holmes and York, 2003, IUCN, 2004, IUCN, 1994, Raum-Suryan et al, 2002, Rosen and Trites, 2002, Seal Specialist Group, 1996, Sease and York, 2003, Trites and Donnelly, 2003, Trites and Porter, 2002, Westlake et al, 1997)				
Giant Panda (*Ailuropoda melanoleuca*)	-	Habitat loss – range restriction Slow recruitment	Expand panda habitat. Develop corridors to promote genetic exchange. Focus on wild population protection. Continue developing a reintroduction programme. Monitor habitat alongside the species.	Radio collars. Scat analysis. Habitat monitoring (resource: Bamboo). Census recording sightings and sign. GIS and Modelling. Genetic analysis.
(Bear Specialist Group, 1996, Carter et al, 1999, Durnin et al, 2004, Guo et al, 2002a, Guo et al, 2002b, Hong-Wan et al, 2006, Hunter.Jr, 1991, IUCN, 2004, IUCN, 1994, Liding Chen et al, 2003, Linderman et al, 2005, Liu et al, 1999, Loucks et al, 2003, Lu et al, 2001, Reid et al, 1989, Seidensticker and Eisenberg, 1984, Swaisgood, 2007, Swaisgood, 2003, Taylor and Zisheng, 1993, Wan et al, 2006, Yiming et al, 2003, Zhang.G et al, 2004, Zhang et al, 2000)				
Black Rhino (*Diceros bicornis*)	3100 (2001)	Poaching	Focus on in situ conservation. Continue with translocations between populations (following strict guidelines). Ideally connect populations naturally.	Daily rhino patrols recording sightings. Individual identification (ear notching). Radio implants (into horn). Body scoring. Repeated sightings. Habitat monitoring. Modelling. Digital spoor analysis. Genetic analysis.
(Adcock et al, 1998, African Rhino Specialist Group, 2003, Alibhai and Jewell, 2001, Amin et al, 2006, Ashley et al, 1990, Birkett and Stevens-Wood, 2005, Brett, 1998, Clauss et al, 2006, Conway et al, 1989, Cromsigt et al, 2002, Du Toit, 2002, Emslie, 2004, Foose and Wiese, 2006, Hutchins and Kreger, 2006, IUCN, 2004, IUCN, 2001, Osofsky et al, 2001, Reuter and Adcock, 1998, Rice and Jones, 2006, Rookmaaker, 2005, Zoe et al, 2001)				
Sumatran Rhino (*Dicerorhinus sumatrensis*)	<400	Poaching	High protection of wild populations. Improve viability in the wild. Captive breeding in situ (secondary to programmes for wild rhino).	Rhino Protection Units (RPUs). Transects (sightings and sign). Trail surveys (sign). Genetic analysis.
(Amin et al, 2006, Asian Rhino Specialist Group, 1996, Dee, 2001, Foose and Van Strien, 1998, 1997, IUCN, 2004, IUCN, 1994, Morales et al, 1997, Rabinowitz, 1995, Reilly and Hills Spedding, 1997, Van strien and Maskey, 2006a, 2006b, 2006c, Van Strein, 2005, Zahari et al, 2002)				

Table 3.5 continued: Summary of monitored species reviews				
Species	***Population**	**Key Issues**	**Priority action**	**Monitoring Techniques**
Greater Indian One Horned Rhino (*Rhinoceros unicornis*)	2000	Poaching Natural disaster (flooding)	High protection for wild populations. Natural disaster strategy – many small populations versus one large.	Direct counts (elephant back surveys). Modelling. Photography and sketch records. Genetic analysis.
(Ali et al,, 1999, Amin et al, 2006, Asian Rhino Specialist Group, 1996, Choudhury, 2005, Dinerstein and McCracken, 1990, Foose and Van Strien, 1997, IUCN, 2004, IUCN, 1994, Kapur et al, 2003, Lott et al, 1995, Martin, 2004, Rothley et al, 2004, Seidensticker, 1976, Thapaliya, 2006, Thomas and Dee, 1982, Van strien and Maskey, 2006, Steinheim et al, 2005)				
Javan Rhino (*Rhinoceros sondaicus*)	54-60	Poaching Small population	High priority protection measures. Focus on increasing viability in the wild (breeding sanctuary): - Increase habitat/ number of reserves available. - Avoid captivity due to risks - Once numbers show an increase, create a second/third population. - Use reserve interconnections/translocations to promote breeding	Transects surveys (sign). Tracking. Camera traps. Spoor plaster casts for individual identification.
(Amin et al, 2006, Asian Rhino Specialist Group, 1996, Ellis, 2005, Foose and Van Strien, 1998, Foose and Van Strien, 1997, IUCN, 2004, IUCN, 1994, Khan et al, 2002, Khan et al, 2001, Khan et al, 2000, Poleti et al, 1999, Thomas and Dee, 1982, Van Strien, 2006)				
Grevys Zebra (Equus grevyi)	-	Overgrazing Competition for water points	Continue with community involvement in conservation. Protect existing/ create new water sources. Grazing zonation system during key seasons.	Photographic database. Individual identification from stripe patterns. Radio collars (monthly tracking by air). Community Scout programme. Faecal analysis. Genetic analysis.
(Chege, 2006, Equid Specialist Group, 1996, IUCN, 2004, IUCN, 1994, Kingdon, 1997, Low and Manyibe, 2006, LWC, 2006, Muoria et al, 2007, Mouria et al, 2005, UNEP, 2006, Williams, 2002)				
Eastern Mountain Gorilla (*Gorilla beringei*)	-	Poaching (bush meat and trophies) Human encroachment Disease Small population	Clear and strict demarcation and enforcement of reserve boundaries. Outreach education programme (including sanitation). Continued and improved protection.	Long term surveys (sightings and sign). Transects (sightings and sign). Nest counts. Faeces and hair analysis (demographics). Habitat use. Modelling. Habituated groups (close monitoring).
(AWF, 2007, AWF, 2006, Butynski. & Members of the Primate Specialist Group, 2000, DFGFI, 2006, Ganas and Robbins, 2005, Ganas et al, 2004, Guerrera et al, 2003, Harcourt, 1995, Harcourt, 1980-81, IUCN, 2004, IUCN, 1994, Kalema-Zikusoka et al, 2005, McNeilage et al, 2006, McNeilage et al, 2001, Oates, 1996, Plumptre, 1996, Robbins and McNeilage, 2003, Stokes et al, 2003, Watts, 1998a, 1998b, Weber and Vedder, 1983, Yamagiwa et al, 1993)				

Table 3.5 continued: Summary of monitored species reviews				
Species	***Population**	**Key Issues**	**Priority action**	**Monitoring Techniques**
Western Lowland Gorilla (*Gorilla gorilla*)	-	Poaching (Bush meat and trophies) Habitat loss (legal & illegal logging concessions) Human disturbance	Standardised monitoring to establish true status. Improved demarcation/ creation of reserve areas. Tighter law enforcement and protection.	Strip and transect surveys (gorilla sign and human activity). Direct observation (from tower). Nest counts. Local people surveys. Genetic analysis.
(Blom et al, 2001, Bradley et al, 2004, Butynski & Members of the Primate Specialist Group, 2000, Goldsmith, 1999, Hall et al, 1998, IUCN, 2004, IUCN, 1994, Kingdon, 1997, Matsubara et al, 2005, Matthews and Matthews, 2004, Morgan et al, 2003, Murnyak, 1981, Oates, 1996, Poulson and Clark, 2004, Robbins and McNeilage, 2003, Stokes et al, 2003, Van der Hoeven et al, 2004, Yamagiwa et al, 2003, Zhang et al, 2001)				
Golden Lion Tamarin (*Leontopithecus rosalia*)	>1000	Habitat fragmentation Pet trade (currently managed)	Creation and maintenance of corridors allowing natural dispersal. Continued education and legal protection. Continued translocations (secondary to a campaign to provide corridors).	Long term continuous monitoring following re-introductions. Radio collars. Live trapping and fur dye. Direct observation. Habitat and resource surveys. Faecal analysis. Genetic analysis.
(Beck et al, 2003, Dietz and Baker, 1993, French et al, 2003, GLTCP, 2006, GLTCP, 2000, Grativol et al, 2001, Hankerson et al, 2007, Holst et al, 2006, IUCN, 2004, IUCN, 2001, Kierulff et al, 2002, Kleiman and Mallinson, 1998, Miller and Dietz, 2006, Oliveira et al, 2003, Rambaldi et al, 2006, Rapaport and Ruiz-Miranda, 2006, Ruiz-Miranda et al, 1999, Rylands et al, 2003, Stoinski and Beck, 2004, WWF, 2001)				

Table 3.5: Summary of monitored species reviews

Summary information from monitored species reviews (appendix 2) highlighting key issues, priority action and monitoring techniques used based on information from literature cited for each species.

Species	Census (direct counts)	Capture-recapture (Trapping)	Distance sampling	Tagging/ marking	mark re-sight (M-R) (tagging)
Arabian Oryx	1		1	1	1
Mediterranean monk seal	1			1	1
Hawaiian monk seal	1			2	2
Iberian lynx					
Tiger					
Snow leopard					
Red wolf				1	
Californian channel island fox		1			
Ethiopian wolf	1				
African wild dog					
Northern steller sea lion	1			1	
Giant Panda	1				
Black rhino	1			1	2
Sumatran rhino	1			2	2
Greater indian one horned rhino	1			2	2
Javan rhino				2	2
Grevys Zebra	1				
Eastern mountain gorilla	1				
Western lowland gorilla	1				
Golden lion tamarin	1	1		1	1

Table 3.6: Direct monitoring techniques
Direct monitoring techniques for the twenty monitored species (1) and those which could be employed in the future (2)

Species	sign surveys	Photographic			Video		radio collars	GPS collars/tags	scat detection dogs
		census/ database	traps	M-R (markings)	remote	mounted			
Arabian Oryx	1	2					2	2	
Mediterranean monk seal	1	1		1	1	2		2	
Hawaiian monk seal		1			2	1		1	
Iberian lynx	1	2	1				1	2	2
Tiger	1	2	1	1			1	1	1
Snow leopard	1	2	1				1	1	1
Red wolf	2						1	1	2
Californian channel island fox	2						1	2	
Ethiopian wolf	1						1	2	2
African wild dog	1	2		1			1	1	2
Northern steller sea lion		1			2			2	
Giant Panda	1						1	2	2
Black rhino	1							1	
Sumatran rhino	1	2	2					2	2
Greater indian one horned rhino	2			1				2	
Javan rhino	1	1	1					2	2
Grevys Zebra		1					1	2	
Eastern mountain gorilla	1							2	
Western lowland gorilla	1							2	
Golden lion tamarin	2							2	

Table 3.7: Indirect monitoring methods

Indirect monitoring techniques for the twenty monitored species (1) and those which could be employed in the future (2)

Species	Genetics	Faecal/blood/ Tissue (non genetic e.g. toxins/diet)	GIS/ modelling	Threats	Resources	sightings/ interviews
Arabian Oryx	1		2	2	2	
Mediterranean monk seal	1	2	1	1	2	1
Hawaiian monk seal	1	1	2	1	2	2
Iberian lynx	1	1	2	2	2	1
Tiger	1		1	2	2	1
Snow leopard	1		2	2	2	2
Red wolf	1		1	2	2	
Californian channel island fox	1		2	2	2	
Ethiopian wolf	2	2	1	1	1	2
African wild dog	2	1	2	2	2	1
Northern steller sea lion	2	2	1	2	2	2
Giant Panda	1	1	1	2	1	
Black rhino	1		1	2	1	
Sumatran rhino	1	2	2	2	2	2
Greater indian one horned rhino	1		1	2	2	
Javan rhino	2	2	2	2	2	2
Grevys Zebra	1	1	2	2	2	
Eastern mountain gorilla	2	1	1	2	1	
Western lowland gorilla	1	2	2	2	2	1
Golden lion tamarin	1	1	2	2	1	

Table 3.8: Other monitoring techniques
Other monitoring techniques for the twenty monitored species (1) and those which could be employed in the future (2)

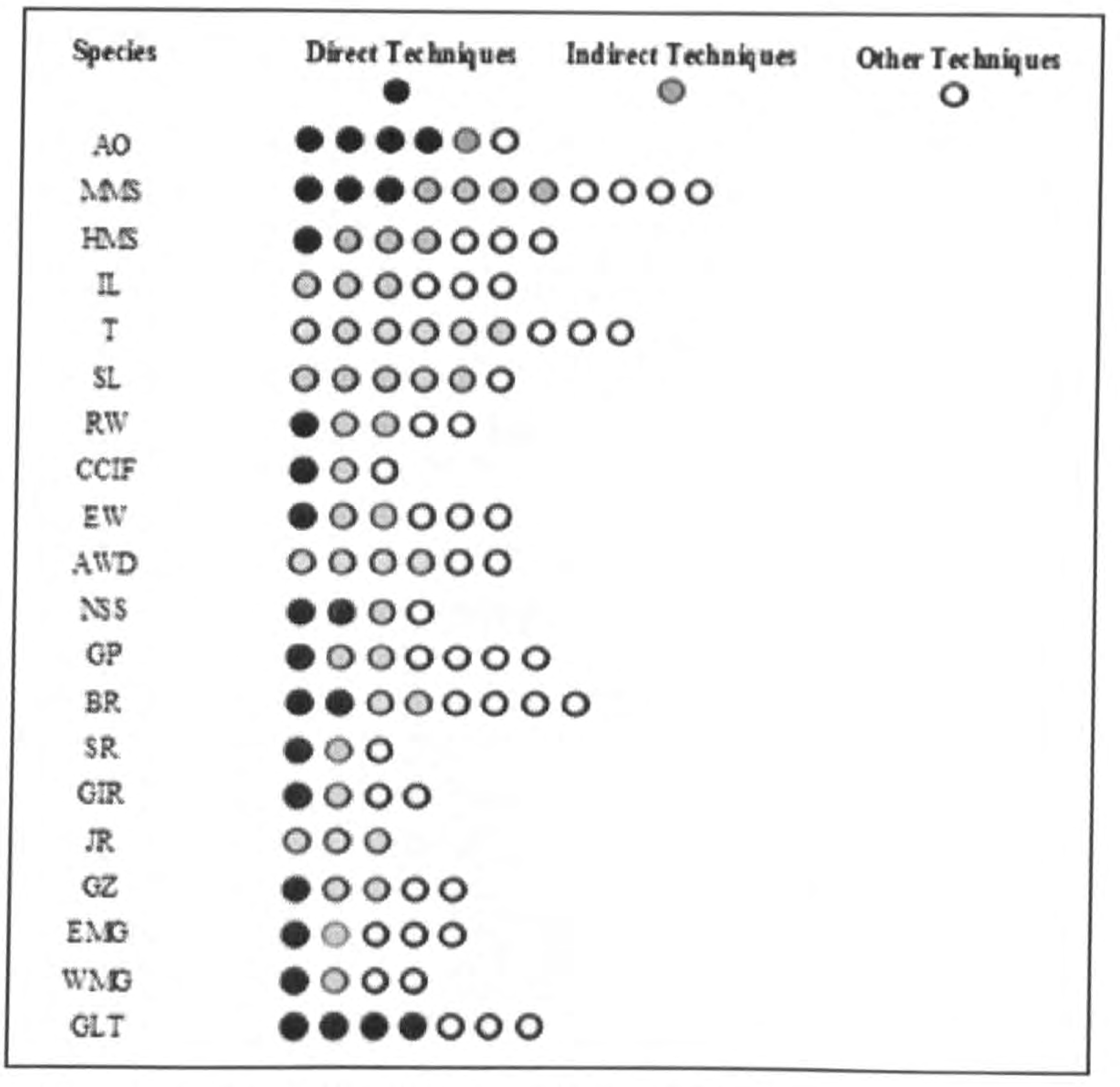


Figure 3.2: Monitoring techniques in use
Scoring system for monitoring techniques currently in use for each species. Score is out of a total of 21 points.

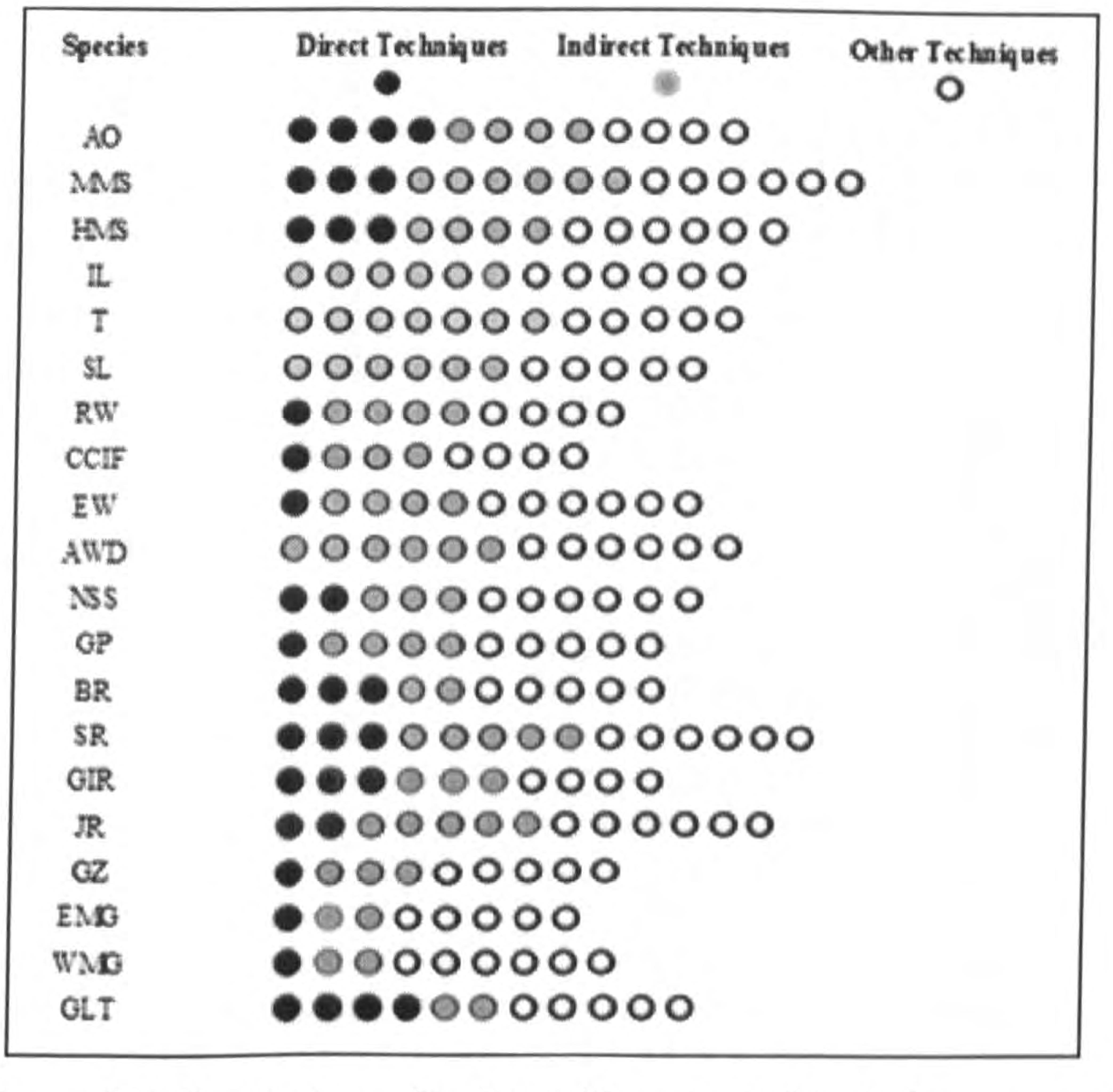


Figure 3.3: Current monitoring with potential techniques scored
Scoring system for monitoring techniques currently and which could be potentially incorporated into monitoring each species. Score is out of a total of 21 points.

Table 3.9: Summary of case study questionnaire responses

Question	Iberian Lynx	Black Rhino	Californian Channel Island Fox	Giant Panda
How do you monitor the changes in population numbers? What is the current population thought to be?	Track Census & Camera Traps Donana C.40 Sierra Morena C.100-150	Each rhino is individually identified. The area is separated into blocks which are assigned to a patrol. Blocks are patrolled daily. If an individual rhino not sighted for 7 days, patrols combined, followed by and aerial survey until found. Patrols collect data on location, activity, body condition, and companions – all information kept in a database. 2006 population: 48 average increase 7.4%pa	High Population: capture recapture on large grids. Low population: radio collaring and tracking.	Standardised transect survey through panda habitat recording droppings, footprints, feeding marks. Bamboo stem diameter and droppings also measured to determine number of pandas. Only carried out in some reserves – still to be expanded. Stable population estimates for the past 10 years.
How often is monitoring carried out?	Minimum yearly plus individual projects.	Daily	Capture-recapture: yearly, 3 grids per island. Radio tracking: twice a week	Four times a year
Who does the surveying? Are they employed and reliable? Are results standardised?	Estacion Biologica de Donana staff and students, Donana National Park. Attempts for agreement between parties & systematic plan from 2006	OPC trained patrols. Data accuracy is high, standardised field books and kit. Body condition assessment carried out by research staff. Monitoring is nationally standardised.	Biologists and technicians employed by the National Park Service (NPS), results are standardised.	Local nature reserve managers who are well trained, reliable and standardised
How were survey techniques originally developed?	Monitoring started when little was known about the Lynx. Preliminary surveys 5x5km grids over 1-2 days to0 ID tracks and collect evidence	Stakeholder's workshops in 2001 (government and private sector involvement) Biological aspects were developed and standardised to work in each sanctuary. Information was shared and individual requirements built in. All information is centralised at KWS headquarters	Capture recapture technique was developed and standardised by fox researchers working on the different islands. Workshops formed a pert of it.	Based on large scale surveys carried out in 1980's and 1990's. Workshops followed to study sample methods and survey techniques – this was funded by the World Wildlife Fund.
Has there been any DNA analysis on populations?	Faeces: to ID lynx in a particular area, distinguish lynx from other species and to attempt individual ID.	Current genetic analysis using dung, blood and tissue. Aims to look at genetic health and population structure.	There has been extensive genetic work to identify population differentiation, demographic history and the level of genetic exchange.	There has been some genetic work done and it is on going. Also some genetic projects with captive pandas.
Is there any evidence for a genetic bottleneck/decrease in genetic diversity/signs of inbreeding?	Evidence for genetic similarity and definite historic bottleneck and possible current bottleneck scenario.	Results are pending. Some concerns about inbreeding so plans to move rhinos through translocation programs to increase gene pool and enhance population growth.	Evidence for a current bottleneck and less genetic variability on San Miguel and Santa Rosa Islands.	Too early to say conclusively that there is or has been a bottleneck or decline in diversity.

Table 3.9 continued: Summary of case study questionnaire responses

Question	Iberian Lynx	Black Rhino	Californian Channel Island Fox	Giant Panda
How is the research/ monitoring programme funded? Do you receive financial support from government/ academic bodies? Is it a fight every year?	EU life program (extended in 2007 to 2011). National and Andalucian government. Corporate support (La Caixa Bank, BP)	Some revenue from tourism although most funding from internal company budget, no external donors. Visiting researchers use own resources. Currently Fauna and Flora International have bought the area and are involved in transition form a sanctuary to a conservancy. USFWS are occasional donors, as are the local community	The northern islands are supported by NPS and the Nature conservancy. NPS provides base money and not soft funding so there is no fight every year.	Current monitoring funding is through WWF which provides yearly funding and salaries. Academic involvement has its own funding.
What is the level of support from local and national government?	Support prompted by EU involvement	Security is assisted by local and national government, KWS support with equipment and technical assistance, policy issues, veterinary and security concerns.	No support from the state of California	Local and National government support includes some funding and support with policies, man power and development of techniques. The panda is the highest conservation priority.
Where is the main support from?	EU Life Project	Internally generated (tourism) and current funds from FFI handover	NPS and Nature Conservancy	Central government which provides large scale yearly funding.
What co-ordination is there between researchers and interested parties working in active species conservation?	Difficulties in co-ordinating many different staff. CSIC involved in advising other parties. Many organisations involved in EU life project, communication now much improved with regular meetings and conferences In each area and including Portugal.	Co-ordination is a key strategic objective of management strategy. There are regular meetings between internal departments and with KWS. The website facilitates open access, plus external newsflashes and letters.	Co-ordination is high between the USFWS island fox recovery team and biologists. 1999 – group of experts gathered by NPS to address issues, this has continued annually. Co-ordination was originally between landowners, conservancies, zoos, non profit organisations and academics (the island fox conservation working group) in 2004; USFWS established the island fox recovery team.	There is co-ordination between reserve staff and researchers to carry out projects, provide training and advice. Decisions are made involving government departments. Specific research funds are sometimes provided. There is also good co-ordination between researchers and both internal and international conservation organisations.
What is the legal situation? How are those responsible for possibly killing the species dealt with?	Can be problems if Lynx found to have killed a lamb. Those who are found to have killed a lynx have big problems with police involvement, court process and fines. No- one in Lynx area is unaware of protection.	Legal action following a poaching incident is through the court system. The ruling is up to the courts and there are some grey areas. Objective is to secure severe penalties in national law. Past problems have been low fines. Now there is also a quick response system.	No-one has it in for the fox	There are strict legalities in place, with any one caught killing a panda serving jail sentences.

Table 3.9 continued: Summary of case study questionnaire responses

Question	Iberian Lynx	Black Rhino	Californian Channel Island Fox	Giant Panda
Is there a captive breeding program running or planned? If so, are there plans to re-introduce and supplement the wild population?	Yes – first purpose is to learn how lynx breed. Program is running with planned expansion and re-introduction program. First lynx born in captivity in 2005. program uses secure and private enclosures with viewing towers and video equipment. Also a rabbit breeding system. The aim is to preserve 90% diversity over 100 years, need 60 lynx in program, hope to have reintroduction programme running by 2010.	Kenyan policy is in situ conservation in managed rhino sanctuaries with management through translocation and not captive breeding.	Captive breeding established in 1999 alongside plans to remove main threat (golden eagle predation) and remove feral pigs and deer. Centres set up on each island. San Miguel: 1999 14 captured, by 2004, 50 foxes in program and first releases. By 2006, wild population C.40, captive 26. Santa Rosa: 2000 all 14 foxes caught, by 2006 56 in captivity. 2007 with release and births, wild population 34, captive, 34. Santa Cruz, 2001 wild population 50-60, 12 captured in 2002. 2006, 61 captive foxes, c.150 wild (recruitment). All foxes released 2007, population c.210 Captive breeding centres now closed due to success, also signs that released foxes were lacking something (increased mortality), wild births more valuable	Currently there are captive breeding programs run by both forestry and city construction management system. The forestry department captive breeding program is based in some nature reserves e.g. Wolong, and some are concentrated in zoos including several international programs e.g. San Diego Zoo (SDZ). Here pandas are on loan, and those born there are returned to China when more than 4 years old. SDZ have a capacity of 6 pandas (2 on show), all housed at the panda research centre . They have successfully had 3 offspring so far, recently returning one, Mei Sheng, to China (2007). With an increasing captive population, there are plans to release and supplement the wild population. Some preparation is underway, including one artificially bred panda being taught to survive, and the testing of radio tracking techniques.
Is this species considered a flagship species?	Yes – very important, wildlife star of Spain with increasing coverage and news.	Very much so, it is a key species with high importance attached to it – highly valued by the government.	Yes – emblematic of the Channel Island National Park, only place where the species occurs.	A definite flagship species, very high profile globally.
How high profile is this species? Is it pushed as an attraction to the area on a global basis? Is it used on logos or products? Is it an emblem in its range?	High profile in Spain. Increasing visitors to the mountains, no access to breeding centre but good visitor centre at Donana NP entrance. Logos include local milk cartons, food produce, real estate and golf courses.	It has been an emblem on stamps and matchboxes. There is a lot of media publicity of rhino issues. International conferences and events. In Kenya rhinos are first.	Good profile – it is the emblem of Friends of the Island Fox, and 'Finnegan', a hand reared fox at Santa Barbara zoo is very popular and is raising awareness.	Very high profile, locally and globally. It is a big attraction within its distribution area and to any zoo holding one. It is the WWF logo, and was the LA Olympic games mascot.
Does this species function as an umbrella species? What would be the ecological knock on effects should it become extinct in the wild?	Cannot be said for sure as there is no evidence or test to prove it although they need a large area of a typical habitat which many other species rely upon. Also, the populations of other carnivores are controlled by lynx presence.	Yes and no, its extinction may not directly affect other species, although rhino sanctuaries are highly protected, therefore if lost other species could be adversely affected.	This is possible, as when foxes were absent, wild swings in deer mouse populations were seen. Fox predation may dampen this.	Yes – by protecting panda, many other species and a large habitat area are protected as well. Although extinction may not have a direct effect – habitat would then have a low conservation value.

Table 3.9 continued: Summary of case study questionnaire responses

Question	Iberian Lynx	Black Rhino	Californian Channel Island Fox	Giant Panda
Is there an economic benefit from protecting and ensuring survival?	Plans to research economic benefit of lynx conservation. Present benefits include income from tourism. Land owners with lynx may also have hunting rights bought by life project in order to conserve habitat for lynx.	Yes. Morani (the friendly rhino) is very famous and a significant tourist attraction. The rhino is one of the big five, and so all black rhino are economically attractive through tourism.	There is minimal economic benefit as there are not many visitors specifically for the island fox.	Little economic value of the panda itself, but its status and rarity have given it a famous reputation and it is of high scientific value.
Is it detrimental in any way for their population to increase, in terms of the environment and local people? Are there conflicts?	Biggest future problem may be impact on rabbit population, possibly causing a reoccurrence of poaching and accidental snaring by rabbit hunters.	Under current management techniques there is no conflict with local people, unlike crop raiding with elephants. An unfortunate consequence of population increase may be habitat degradation.	Not detrimental for the population to increase as there are no conflicts and recovery is occurring on protected islands, no conflicts with land use and development.	Conflicts are unlikely as they have a specialised diet ad elusive behaviour, however a population increase would put more pressure on the habitat.
With an increased population would this species be in danger of persecution?	Some people do not like lynx but dislike consequences of harming one much more.	There may be possible greater temptation for people to increase poaching due to demand for rhino horn in the middle east and for traditional Chinese medicine.	No	There is almost no conflict with local people, and it is unlikely to be in danger of persecution due to high law enforcement.
Is the species confined solely to protected areas? Is there any means of dispersal between the known populations?	Most Donana lynx are found within the National Park, but some occur outside. Some dispersal northwards but limited by natural barrier (water), causing limited mixing of lynx.	A few remnant populations may be hanging on but most are now within reserves with the only way of dispersal being through translocation.	Confined to protected islands with no dispersal in between, only within.	About 50% of panda habitat is outside of protected areas therefore the panda is not confined solely to reserves. There is some evidence of attempts to disperse over large areas. However an increase in human infrastructure has prevented this, therefore translocations may be the only way to promote future genetic exchange
What are your realistic hopes for the future – is extinction in the wild inevitable?	If situation with lynx numbers does not improve then extinction in the wild rests on many different circumstances, must see what happens over the next 10 years. Thoughts must stay optimistic. More is being learned about lynx future and now there is more funding than ever to help. Lynx populations have remained relatively stable for 20 years.	With continued protection, biological management and hard work, extinction is not inevitable. Since 2001 the average rhino population in Kenya has increased by 4.5% and the country holds 85% of the subspecies.	Extinction is not inevitable. There has been a good recovery in response to conservation work, particularly now the main threat has been eradicated (2007) and that the captive breeding and reintroduction was so successful and quick. Continued recovery will ultimately depend upon promoting ecological conditions which dissuade golden eagle use, such as removal of feral pigs and re-introduction of the bald eagle	Extinction is not inevitable as there is fast technological progress and high support - we can keep improving conservation efforts into the future

Table 3.9: case study response summary

Summary of case study response reports (appendix 3) Contributors: For the Iberian lynx, Dr Francisco Palomares (2005, 2008), CSIC, Spain.
For the black rhino, Nathan Gichohi (2006) Research department, Ol Pejeta Conservancy, Kenya. For the Channel Island fox, Tim Coonan (2007) NPS, USA.
For the Giant Panda, Dai Bo (2006) Forestry Commission, China.

Species name	*Criteria code*	*Score*
Arabian or white oryx (*Oryx leucoryx*)	A1(iii), B1, E + E2, F2, I2, J	6
Mediterranean monk seal (*Monochus monochus*)	A1(ii), B1, F1, G, J	5
Hawaiian monk seal (*Monochus schauinslandi*)	A1(iii), B1, E, J	4
Iberian lynx (*Lynx pardinus*)	A1(iii),B1, C1,2, D, E + E1, F1, G, I1, J	10
Tiger (*Panthera tigris*)	A1(ii), B1, C1,2, D, E, F1,2, G, I1	8
Snow leopard (*Uncia uncia*)	A1(ii), 3, B1,2, C2, D,E,F1,2, G, I1	8
Red wolf (*Canis rufus*)	A1(i), B1,2, C1, D, E + E2, I2, J	7
Californian Channel Island fox (*Urocyon litteralis*)	A1(ii)+(iii),2,3,B1,C3,D,E+E2,G,H2,I3,J	10
Ethiopian wolf (*Canis simensis*)	A1(ii), D,E,F1,G, I1, J	7
African wild dog (*Lycaon pictus*)	A1(ii), D, E + E1, F1, G, I1, J	7
Northern steller sea lion (*Eumetopias jubatus*)	A1(iii), 2, E, G, I1	4
Giant panda (*Ailuropoda melanoleuca*)	A1(iii),2,3,B1,2,C1,2,D,E+E1,F1,2,G,H1,2,I1,J	10
Black rhino (*Diceros bicornis*)	A1(i),2,3, B1,C1,2,D,E,F1,G,H2,I3,J	10
Sumatran rhino (*Dicerorhinus sumatrensis*)	A1(ii), B1, C2, D,E,G,H1,2,I2	8
Greater Indian one horned rhino (*Rhinoceros unicornis*)	A1(ii), B1, C2, D, E, F1, G, H1,2, I3, J	10
Javan rhino (*Rhinoceros sondaicus*)	A1(ii), C2,D,E,G,H1,2,I2	7
Grevy's zebra (*Equus grevyi*)	A1(i), B1, C2,E,F1,G,I1,J	8
Eastern mountain gorilla (*Gorilla beringei*)	A1(ii), C2, E, F2,G,H2,I2,J	8
Western lowland gorilla (*Gorilla gorilla*)	A1(ii), B1, C2, E, F2, G,H2,I1	8
Golden lion Tamarin (*Leontopithecus rosalia*)	A1(i), B1, C2, E +E2, F1,2, G, H2, I3,J	9

Table 3.10: Assigning criteria for a well monitored species
Assigning the developed criteria for a well monitored species to derive a monitoring code for each of the twenty monitored species

Criteria			Weighting	Interpretation
A	1	**Population numbers are monitored**	Criteria A is essential for good management and monitoring. A1 is weighted higher than A2 & A3 A1(i) is potentially better than A1(ii) &(iii),	A species graded as A1 (i), 2, 3 is exceptionally well monitored, although may also be considered to be under increased threat. A species achieving any less of the criteria is still well monitored but there may be room for improvement. The minimum requirement is annual monitoring, with the more criteria achieved, the better the quality.A2 & A3 indicate good monitoring practice
	(i)	continuously		
	(ii)	regularly		
	(iii)	at least yearly		
	2	Using one or two standardised techniques	A2 & A3 have equal weight	
	3	Using techniques which were developed through collaborative workshops		
B		**Genetic analysis**	B1 & B2 are equally weighted, but not a requirement of good management & monitoring	Achieving any part of criteria B indicates the presence of high quality research – genetic monitoring is expensive and technical. Criteria B is therefore a potential indicator that good management and monitoring may be established.
	1	has been carried out		
	2	Is beginning to be carried out		
C		**Financial support**	Criteria C is essential for good management and monitoring C1 & C2 are equally weighted	Criteria C is critical to good management and monitoring as without funding and support good programmes can be considered impossible. International support indicates a global value and more funding sources, but national support is important for conservation success The best scenario is for funding not to be considered an issue (C3).
	1	National		
	2	International		
	3	and/or there are minimal funding issues	C3 is the optimal criteria	
D		**Legal protection** is officially in place	Not a requirement but an indicator of good management & monitoring	The presence of legal protection indicates management and monitoring is needed or is a requirement of protection, with potential governmental support and obligation
E		**In situ conservation** focus with population management or	E is the best scenario for a well managed and monitored species	E potentially indicates that captivity is not required and the wild population is effectively managed. Although it could indicate such a programme is not yet underway. E2 indicates an established management system with reintroduction established, whereas E1 is only in the planning stages of re-introduction, or where it is currently not feasible. There is no grade for captive breeding not for the purpose of reintroduction as this is not considered good management.
	1	captive breeding programme in place with re-introduction preparation	E1 is weighted below E2	
	2	captive breeding programme in place with a re-introduction programme	E2 is weighted above E1 but below E	
F		**Emblematic species** with	F, 1, 2 and G are equally weighted, non are essential for good management and monitoring	F and G indicate an ambassador species. The achievement of F &/ or G indicates the species is highly regarded. There may also be studies to support the necessity of their protection. An emblematic species may also garner support and funding for its conservation.
	1	A National profile		
	2	An International profile		
G		Potential **Umbrella species** status		
H		A **population increase** would create	H1 is weighted above H2	Minimal conflicts are an indication that good management is in place. There are no criteria for a species which creates conflicts as these may prevent the best level of management and monitoring
		Minimal conflicts		
		Only habitat management issues		
I		**Population range** is	I1 is weighted above I2, 3,&4	I1 is best but may also indicate a large range which is difficult to manage and monitor. I3 &/or I4 indicate the potential presence of good management and monitoring, with I4 the best of the two for survival of the species. I2 indicates there is possibly good management and monitoring but there is an 'island scenario
	1	Not confined within protected areas (PAs)		
	2	Confined within PAs	I2 is weighted below I1, 2, 3	
	3	Confined within PAs but with good management	I3 & I4 are equally weighted, above I2, below I1	
	4	As with I3 but with potential for natural dispersal		
J		Population has shown a **positive response** to management efforts	Important criteria to achieve	A positive response, i.e. an increasing population, indicates there is effective management and potentially good monitoring in place for a species, as demography is being recorded.

Table 3.11: Weighting of Criteria
The criteria for identifying a well managed and monitored species are weighted in terms of importance and interpreted

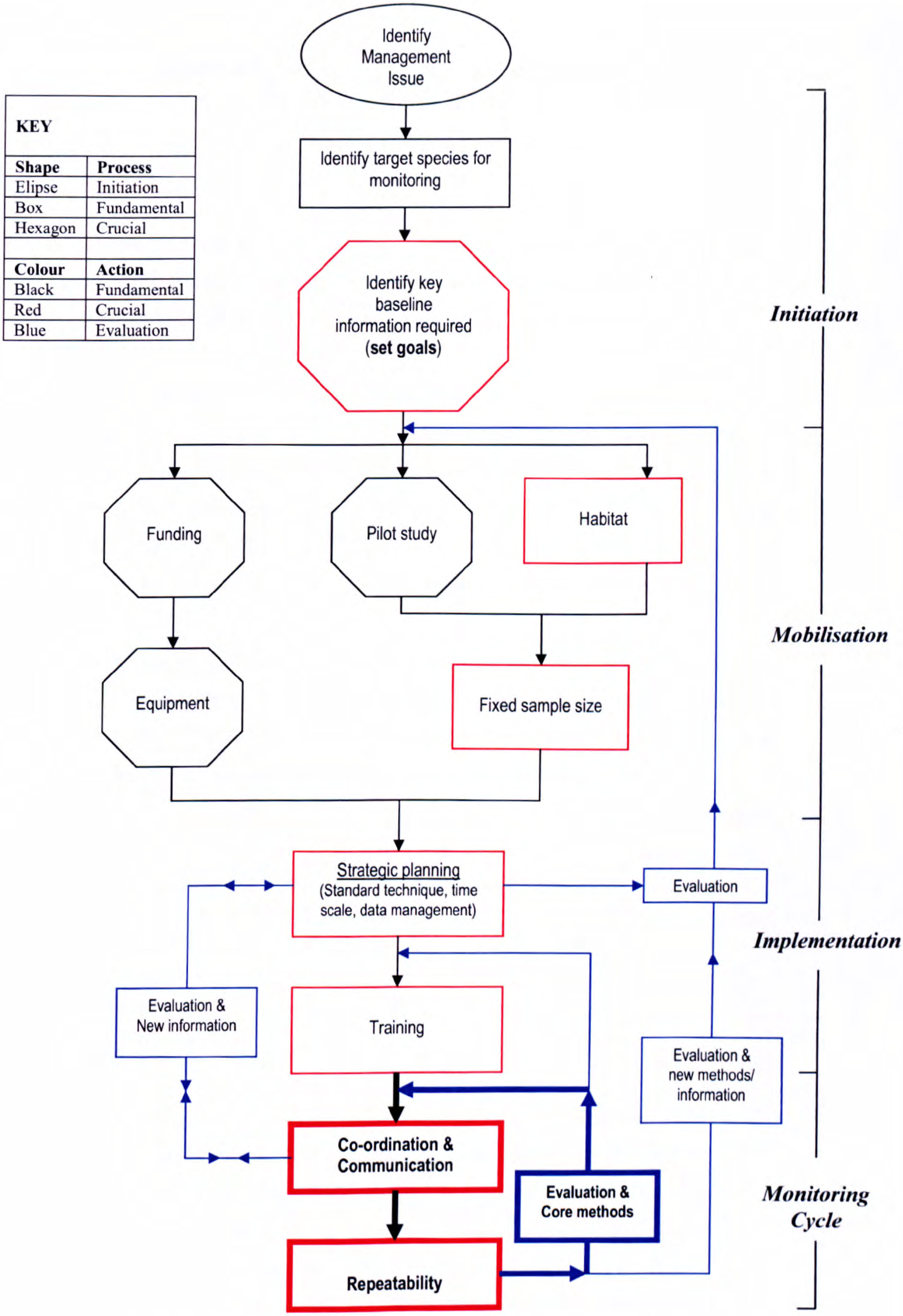


Figure 3.4: Flow chart for monitoring design.

CHAPTER FOUR: A VEGETATION MONITORING SYSTEM FOR A BLACK RHINO SANCTUARY

4.1 Pre-amble

In this chapter, the results of research into monitoring systems, is fed into the design of such a system for an important conservation issue. The flow diagram (figure 3.4, chapter 3) will be used throughout, in the design of the monitoring system.

The species in question is the black rhino and the target population resides in Sweetwaters Game Reserve – an enclosed conservancy in Kenya. The black rhino is a well monitored species across its range, and Kenya is no exception. The population in focus is heavily monitored and each individual is known and tracked daily. Therefore, developing a monitoring system to survey rhino numbers here was not required. However, there is currently not a standardised scheme for monitoring its habitat.

For a number of years, over-browsing of the trees within the reserve had been a concern (Gitchohi, OPC, 2005 pers.comm). This was a particular issue as the reserve was enclosed and browsers were unable to disperse. Kenya's black rhino conservation strategy is dependent upon small enclosed reserves which invariably experience problems of habitat damage. Therefore, a monitoring system which was efficient and able to collect information about vegetation condition, and that could detect deterioration beyond current levels, would be a useful tool in the management and monitoring of the black rhino.

4.2 Introduction

4.21 Vegetation and the importance of monitoring

Vegetation is an asset to be valued by society, functioning as a major habitat, important food supply, migratory route and territory, it can influence ecosystem function, it is dynamic and its changes over time are arguably the most significant information for management (Briggs and Freudenberger, 2006, Hong et al, 2004, Wallace et al 2006). Vegetation sampling remains a fundamental aspect of monitoring, with counts of plants and animals on areas of known size being among the oldest techniques in ecology (Krebs.C, 1999, Shuman and Ambrose, 2003). Monitoring determines change or trend over time, and vegetation monitoring is particularly important, as it indicates condition and change, and helps to identify and quantify problems, set targets, and assess management actions (Briggs and Freudenberger, 2006, Wallace et al, 2006). Depending on specific goals, vegetation can be assessed and monitored from a range of scales, from site to regional and broader (Briggs and Freudenberger, 2006).

4.22 Vegetation monitoring techniques

General monitoring techniques include the use of mapping at various scales, allowing coarse to finer scale monitoring at regional and selected sites (Briggs and Freudenberger, 2006). A habitat map can serve as the basis for evaluation and conservation of local fauna and flora, but field based assessments can be considered limited and impractical at a larger scale (Hong et al, 2004, Reinke and Jones, 2006). Remote sampling, using aerial photography or satellite imagery, can be used to provide spatially explicit information of large or fragmented areas, and when integrated with ground based sampling, ecologists can expect to acquire most of the data required to test and develop ecological models (Dougill and Trodd, 1999, Shuman and Ambrose, 2003).

Scientists have used remote sampling, ground sampling or a combination of the two methods in order to provide information on vegetation for conservation and natural resource management, and also to test the accuracy and efficiency of these methods (Abella and Covington, 2004, Agnew et al, 2000, Dougill and Trodd, 1999, Hong et al, 2004, Lunney et al, 2000, Parrikh and Gale, 1998, Reinke and Jones, 2006, Robinson et al, 2001, Shuman and Ambrose, 2003, Wallace et al, 2006).

4.22.1 Ground based sampling

Examples of studies which have used ground based surveys include studies based on comparing vegetation composition and diversity, monitoring vegetation development or restoration and the development of habitat distribution maps aimed at particular species (Abella and Covington, 2004, Parrikh and Gale, 1998, Lunney et al, 2000).

Lunney et al (2000) used ground based surveys to produce a distribution map of Koala (*Phascolarctos cinerus*) habitat. They combined community surveys and field techniques involving 20 x 20 metre quadrats to record tree species, diameter breast height, presence/absence of koalas and/or scat. GIS was used to combine results and 3 habitat types used by koalas were revealed.

Abella and Covington (2004) used ground based techniques to compare under-story composition and diversity on a pine forest restoration area treated with thinning and burning, in the South-Western United States. They used a variety of methods such as 0.04ha circular plots to sample trees, 50m point intercept transects to sample under-story and substrate characteristics, and 50 contiguous 1 metre^2 subplots along a transect line to measure species cover. These techniques were used within 20 pre-treatment plots on a 60-m grid within 12 treatment or control areas. Species area and compositional curves revealed that the sampling design did not adequately detect species across broad scales in the geographic area of the experiment after 32 plots had been sampled. This suggested that if rapid assessments of species composition were required, a design using an arrangement of subplots was more effective than the point intercept sampling used here (Abella and Covington, 2004). Parrikh and Gale (1998) used field surveys and repeat photography along 18 set transects and within 45 set circular 30 metre^2 plots, to establish a monitoring programme designed to compare vegetation development at two created wetland sites and 6 nearby natural wetlands. Quantitative vegetation and environmental data were collected from all sites, and after 3 years, patterns of increased similarity between restored and reference sites were seen. The successful monitoring was set to continue long term (Parikh and Gale, 1998).

These three examples highlight successful use of ground based surveys to identify key habitat types, refine techniques and set up effective monitoring programmes. Plot samples are commonly used to assess vegetation, either exclusively or incorporated with other techniques as briefly introduced here. For some vegetation communities, plot sampling is not sufficient, for example, Newmaster et al (2005) compared results from plot samples to floristic habitat sampling (FHS) in estimating bryophyte diversity. The study found that FHS included all potential habitats within an ecosystem (including microhabitats), and that this method proved more efficient at recording species richness than simple plot sampling (Newmaster et al 2005). Korb et al tested a variety of sampling techniques including transects (point intercept, 'Daubenmire' and belt transects) and a nested plot design (modified-'Whittaker' plots), and assessed their effectiveness in recording under-storey vegetation within restoration sites. Their study found the nested plots recorded the highest species richness, and that both belt-transects and nested plots recorded more rare and exotic species than the other methods.

There is however, no one correct technique for sampling and describing vegetation and the sampling design chosen may greatly influence the conclusions that researchers make (Korb et al 2003, Shimwell, 1971). Krebs (1999) outlines many potential methodologies for assessing vegetation abundance and spatial patterning. Examples of plot- less sampling techniques include T-squared, ordered distance, point quarter and nearest-neighbour methods. None of these methods are restricted to boundaries such as those around a plot. Instead, these methods can be used on many stratified random points, and can even be focused towards specific tree species. For example, the T-squared technique would require two measurements to be recorded at each random location: the distance from the point to the nearest tree, and the distance from that tree to its nearest neighbour (Krebs, 1999). Both order distance and point quarter methods are similar, with measurements recorded from the point to the second or third nearest tree for ordered distance, and the nearest individual within 90° quadrants from the start point, for the point-quarter method (Krebs, 1999). The point-quarter method in particular has been commonly used in forestry (Krebs, 1999). Nearest-neighbour methods are useful for developing spatial maps, by measuring the distance between an individual and its nearest-neighbour as the relevant measure (Krebs, 1999). This method was used effectively to assess the vegetation associated with rhino day bedding sites (Rice and Jones, 2006).

Where a plot can generate a lot of data, plot-less techniques may require much repetition to achieve an equivalent sample size. Greater coverage of an area may of course be highly desirable. Mahito and Takeshi (1998) describe a novel technique for fine-scale vegetation mapping using low altitude photography from a remote controlled helium balloon. Their study was successful in producing a habitat map which was ground-truthed using plot sampling. The potential of such techniques and other methods of more remote sampling will be introduced.

4.22.2 Remote sampling

An example of remote sampling includes the regional and national vegetation monitoring programmes based on time series Landsat imagery which are now operational in Australia, providing the potential to gain information for management questions (Wallace et al, 2006). Dougill and Trodd (1999) discuss the combination of ground based surveys and remote sensing methods to assess factors which cause transitions between vegetation communities based in the Kalahari, Botswana. It was stated that many years of extensive field survey would be required to understand the conditions under which irreversible ecosystem changes occur, and that spatially limited ground studies would not be able to investigate fully the various combinations of factors involved. The usefulness of satellite data was then considered, however, it was stated that either source alone would be unable to meet the information requirements, and how integration was important (Dougill and Trodd, 1999).

4.22.3 Integrating and comparing techniques

Some examples of integration include Hong et al (2004), who used remote sensing and geographic information systems (GIS), along side environmental modelling and vegetation survey techniques to develop maps to aid the development of an environmental policy strategy for wildlife habitat evaluation of national parks. Robinson et al (2001) used National Aeronautics and Space Administration (NASA) photographs taken by astronauts from low earth orbit to identify woodland areas affected by elephants in Chobe national Park, Botswana. Qualitative verification from ground based surveys indicated that the major vegetation effects of elephants could be detected using the astronaut photograph.

The accuracy and efficiency of aerial photographs compared to two ground based sampling techniques are compared by Shuman and Ambrose (2003) Estimates of percent cover, species composition, and species distribution were compared across the three sampling methods to determine how well these techniques characterised different aspects of vegetative cover in restored salt marsh sites in California . It was found that ground-based techniques were efficient in small sites, but as the size, number, or spatial distribution of sites increased, it became more efficient to use a remote technique. However, aerial photography is not as suited to assess species richness, density, and distribution when compared to ground-based sampling techniques (Shuman and Ambrose, 2003).

Reinke and Jones (2006) described compatibility issues associated with analysing field based point or plot data and landscape scale data obtained through remote sensing techniques. It was stated that although remote sensing plays a vital role in any monitoring regime by providing a total sample of the landscape, the utility of its data for assessing vegetation condition is dependent on the sampling used for collecting ground data. Poor compatibility between field-collected and remotely sensed data could cause significant problems for analysis (Reinke and Jones, 2006).

Sometimes other factors are important in choosing to use remote sensing, such as unreachable or inhospitable areas of work. For example, Agnew et al (2000) considered aerial photography to be the best way of monitoring tree canopies, especially when monitoring on foot was considered too dangerous. Their study used initial aerial photography and then ground based surveys to design a monitoring system to detect change or stability in the landscape and vegetation within the South-West Kenyan rift valley. They used canopy intercept transects up to 200 metres long, spaced 100 metres apart, within grassland and open woodland habitats in order to monitor vegetation changes following the removal of tsetse fly. Records proved to be consistent and the monitoring system resilient (Agnew et al, 2000).

Both remote and ground sampling, either separately or used synergistically, have proved to be useful tools in the monitoring of vegetation. Spatially detailed information on vegetation changes over time is a key requirement for management, and remote methods can deliver such information where static mapping and surveys may be considered limited, however, because of their advantages for species identifications, ground-based techniques will always be an integral part of vegetation sampling methodology (Shuman and Ambrose, 2003, Wallace et al, 2006). Based on this information, the nature of a small enclosed reserve makes field based sampling most appropriate.

4.23 Monitoring browse

One aspect of vegetation monitoring has been to assess the affects of browsing by herbivores. This is particularly true for assessing the impact of mega-herbivores such as elephants on their habitats (Afolayan, 1975, Barnes, 1983, Ben-Shahar. 1993,Birkett, 2002, Buechner and Dawkins, 1961, Croze, 1974, Kabigumila, 1993, Tchamba, 1995, Walpole et al, 2004).

4.23.1 Ecological impact

Much of the work into the impact of browsers has involved studying elephants, and in order to understand potential browsing implications, a review of such studies is introduced. The ecological impact of elephants browsing in their environment may be expected to be large due to the size and strength. Their recorded impacts have varied depending on the location and the study undertaken.

Following four decades of woodland decline due to elephant and fire pressure, the status and browse pressure on the woody resources of the Masaai Mara National Reserve, Kenya, were examined by Walpole et al, (2004). They found that 77% of individual plants showed signs of browsing, with plants less than and more than 1 metre in height displaying 73% and 85% browser damage respectively. The browsing pressure was also seen to vary with habitat type, with thicker, richer plots receiving a higher pressure.

Other studies have also recorded the impact of elephants directly on woody vegetation, within natural habitats, tree plantations, next to water, and on specific tree species (Afolayan. 1975, Barnes. 1983, Ben-Shahar. 1993, Buechner and Dawkins, 1961, Croze, 1974, Kabigumila. 1993, Tchamba., 1995). In Ruaha National Park, Tanzania, of 424 *Acacia albida* and 543 *Commiphora ugogensis* trees surveyed, 40% and 67% respectively were found to be dead, mostly due to elephants, and there was also a lack of young trees (Barnes, 1983). Importantly Barnes (1983) stated that different tree species behave differently under the same elephant population and that generally the rate of tree mortality increases as tree density increases. Afolayan (1975) in a study of forest plantations, found that 24.3% of trees were damaged by elephant, in all species young trees (<2m) were more susceptible to being pushed over and broken, and the incidence of damage was greater near water (Afolayan, 1975). This was also found to be the case by Ben-Shahar (1993). In this study vegetation damage was plotted against distance to permanent water, revealing that the proportion of woody plants utilised by elephants increased with proximity to both permanent and temporary water sources (Ben-Shahar, 1993).

It is not only the proximity of water which has been found to determine the severity of elephant damage. In Murchison Falls National Park, Uganda, Buechner and Dawkins (1961) found that nearly every tree was damaged by elephant to some degree, but the most severely damaged trees appeared to be the ones which elephants had developed a predeliction (Buechner and Dawkins, 1961). Kabigumila (1993) observed more elephant browse damage occurring to *Acacia xanthophloea* during in the dry season. Croze (1974) found that elephants in the Seronera area of the Serenegeti National Park, Tanzania, fed in proportion to tree height abundance, infrequently ate small regeneration vegetation and the regeneration potential was found to be adequate in compensating loss due to elephant activity. A study by Tchamba (1995) found most trees were not browsed, and those that were, were found to be damaged, rather than seriously damaged. Of all trees browsed, the majority were mature and 3 preferred species were identified. The overall conclusion was that elephant damage in this study was not serious.

Of course, elephants share their environment with other browsers. Birkett (2002), measured the impact of elephant along with rhino and giraffe on the habitat of a rhino sanctuary in Kenya. The browsing damage caused by elephants was observed as either pushed over trees, broken stems and hanging bark. Rhinos made a clean cut of the main stem, and giraffe ate the growing tips of branches and main stems. Overall, tree damage rates were high, with damage by rhinos being confined to trees lees than 2 metres in height, whilst elephant damage was found to be more evenly distributed. In another study, the combination of elephant, rhino and giraffe browse with low rainfall was seen to equate to rapid loss of *Acacia drepanolobium* trees within an enclosed savannah habitat (Birkett and Stevens-Wood, 2005). Here elephants were found to be responsible for the loss of 40% of *A.drepanolobium* trees, rhinos 33% and drought claimed a further 27%.

It can be stated that browsers unavoidably cause vegetation damage. These studies have highlighted patterns of occurrence and differing levels of severity, particularly for elephants, but also in combination with other megaherbivores, but what methods were used to collect this information and arrive at their conclusions?

4.23.2 A comparison of methods

The above studies concentrate mostly on elephant browse, with some combining the affects of other browsers such as rhinos and giraffe. Although most of the work quantifying browsing has been focussed on elephants, they still form a good case study and allow identification of a cross section of methods which have been used to survey the same type of browse and to assess its severity. These methods varied from plot surveys, tagging individual trees, transect surveys, plot-less sampling, an integration of different techniques and some studies focused on particular tree species. Methods to record the browse within the surveys were different across the studies.

In the study of Walpole (2004) in the Masaai Mara, Kenya, over 300 vegetation plots were surveyed, and 62 woody species were identified. Within each plot, every woody plant (tree and shrub) was surveyed, and measures including species, height class and browse availability up to 2 m above the ground were recorded. Buechner and Dawkins (1961) used plot surveys to record changes in vegetation induced by elephants and fire within Murchison Falls National Park, Uganda, and both plot and transect surveys were used to quantify the interaction between elephants and trees in Ruaha National Park, Tanzania (Barnes, 1983). Afolayan (1975) surveyed more than 17000 trees within 180 50 x 50 metre quadrats to study the effects of elephants on forest plantations (Afolayan. 1975). Here, tree height and the number of trees dead or damaged by elephant were recorded. Ben-Shahar (1993) used stratified habitat plot sampling to study the pattern of vegetation damage by elephants, and the extent of impact on woody plants, in relation to water proximity. The study area was split by habitat type and elephant density, the distance to water was measured, and in order to survey the vegetation, an estimated proportion of biomass missing from an imaginary intact plant was ranked in 5% increments. *Acacia* woodlands were surveyed by Birkett (2002) using 21 random plots, containing 40-60 tagged trees. These plots were also compared to two control plots free from elephant, rhino and giraffe. Within plots, tree heights were measured within the nearest 2cm, and browse was only recorded if it affected the main stem.

Kabigumila (1993) studied *Acacia xanthophloea* and damage was assessed by estimating the percentage of bark removed from the trunk, and the percentage of foliage removed from the crown of each tree. A scale of 1 – 4 was used to record the damage, with 1 representing less than 25% loss of foliage or bark, 2: 25-50%, 3: 50-75%, and 4: 75-100%. Croze (1974) used the same 4 categories during a survey using a point quarter, plot-less sampling technique to record browse damage in the Serona area of the Serengeti National Park, Tanzania. Croze (1974) also stated that foliage removal up to 75% apparently caused little fatal damage, therefore vegetation damaged more than 75% was considered dead in this study. Tchamba (1995) used an extended version of such a scale to assess elephant damaged trees along line transects within Waza National Park, Cameroon. Trees were assigned to height classes (<1m, 1-3m, >3m) and 6 classes of utilisation were established (1:no/little use, 2: ¼ tree browsed, 3: ½ tree browsed, 4: ¾ tree browsed, : all browsed, 6: uprooted). Classes 1-3 were considered damaged, classes 4 – 6 were considered seriously damaged

Browsing damage can be a management problem, and here there have been a number of techniques described which may be used to assess the impact of this type of damage. All of these methods recorded and measured browsing damage, but comparing results is difficult as the techniques are not standardised, and they focus on different aspects such as the affect of water proximity or the predilection for certain tree species or habitat types. They also were collected by different surveyors. It could be argued that a truly standardised survey requires the same person to collect the data, although this is largely impossible to do. Good practice can be learnt from such studies however, and by combining a number of techniques demonstrated here it may be possible to design an effective system for recording and measuring browse. This would incorporate both subjective and quantitative methodology, and involve piloting varying survey techniques, thus creating a thoroughly tested and robust methodology before its implementation. Such a design could be incorporated into the mobilisation stage of a monitoring system as suggested in figure 3.4, chapter 3. As indicated by this model, the design of the field technique to collect the monitoring data forms a fundamental and crucial part of a monitoring programme. There are many factors to consider in the sample design.

4.24 Sample Design

A sample survey involves estimating parameters, drawing conclusions and making inferences, in differing degrees of strength and accuracy, about the rest of the population from which the sample was taken. (Brown and Saunders, 2008, Manley, 1992). A full census covering the whole population is impractical in terms of cost and effort, sampling is faster and may be more accurate avoiding problems such as bias, data error and lost records (Manley, 1992). The larger the sample size, the more accurate the information on the population is likely to be, although above a certain size, the cost in time and money may not be worth the extra information (Brown and Saunders, 2008). Therefore, rather than a full or large survey, a small well organised sample may give better results, and using stratification (dividing sampling units into non-overlapping strata, and selecting a simple random sample from each of these strata) ensures a population is fully represented (Manley, 1992) The sample size will ultimately depend upon the amount of variance in a population and the level of precision required to answer research questions (Reinke and Jones, 2006).

It is difficult to prescribe absolute guidelines on sampling design as there will always be a trade-offs, for example, between representational requirements, data suitability and practical constraints (Reinke and Jones, 2006). One of the most important elements identified from previous chapters, is the provision of achievable aims, as these will then determine sample design. A decision must also be made to monitor more sites in-frequently, or fewer sites frequently (Carlson and Schmeigelow, 2002) Strategies to improve sample design include repeat site surveys and/or multiple studies at a single site (Brown et al, 2004, Dougill and Trodd, 1999). Reinke and Jones (2006) make other key sampling design recommendations. These include the location of plots within consistent habitat types, and a given distance away from boundaries. This is to minimise positioning and mixing errors. Also, decide on the number and distribution of plots in order to adequately represent diversity, spatial variability and condition, and to be accurate and support statistical analysis. Quantitative data should be recorded as raw measures, as these measures can be later modified into more generalised information according to requirements, and a consistent set of guidelines, by which field-based data are collected and documented, should be developed (Reinke and Jones, 2006).

In vegetation sampling, quadrats or plots are used extensively (Krebs, 1999), for example in previously discussed studies including Abella and Covington (2004), Afolayan, (1975), Barnes,(1983), Ben-Shahar (1993), Birkett (2002), Buechner and Dawkins (1961), Lunney et al (2000), Parrikh and Gale (1998), Shuman and Ambrose (2003) and Walpole et al (2004). A consideration to make is the plot shape to use. Edge effects can lead to sampling errors when deciding which vegetation to include or not, the edge of length to inside area ratio changes with plot shape (rectangle > square > circle) (Krebs, 1999). The best approach in deciding what size and shape of plot or quadrat to use is to determine the optimal, that being the best statistically (precision for a given area in terms of time and money), ecologically (most efficient to answer question), and logistically (easy to set up and use) (Krebs, 1999).

The goal is to select the design that achieves maximum information under design constraints, such as cost, with a cost-effective monitoring programme being one which achieves high power to detect trend at low cost (Carlson and Schmeigelow, 2002). In hypothesis testing, the power of a statistical test is defined to be the probability of rejecting the null hypothesis, when this null is not actually true, therefore when the probability of accepting the null hypothesis, when in fact it is false, is very small, this means that test is powerful (Krebs, 1999, Manley, 1992, Zar, 1999). Calculations of sample sizes required to detect effects of a particular magnitude are called power analysis, and this can be carried out prior to a study, for example by incorporating a pilot study, or retrospectively (Krebs, 1999, Manley, 1992). When an experiment or sample programme is being designed, the questions most likely to be asked are: how many samples will be needed, how precise must the samples be, and what is the probability of detecting a trend? (Gerrodette, 1987). Operational power analysis is important during the planning of experiments, to avoid wasted time and effort on a programme that is unlikely to yield useful information (Gerrodette, 1987). Weak studies, studies with low power, may be difficult to avoid if money or time are limited, here awareness of the relative precision of decisions is important (Krebs, 1999).

Carlson and Schmeigelow (2002) derived a sampling methodology that used power analysis to aid in identifying a cost effective strategy for large scale avian monitoring. Here power estimates were used to develop nonlinear models of the relationship between sample effort and power. The rates of increase in power were compared to rates of increase in cost. Average effort levels, those achieving between 80% and 90% power, were used. Efficiency was found to be consistent across power levels, indicating that the cost-effective sampling strategies reported here were not restricted to designs achieving between 80% and 90% power. (Carlson and Schmeigelow, 2002) Taylor and Gerrodette (1993) incorporated power analysis in surveying the vaquita (*Phocoena sinus*), an endangered porpoise, and the Northern Spotted Owl (*Strix occidentalis caurina*). For the vaquita, power to detect a decline in abundance was found to decrease as populations became smaller. For the owl, at low densities a demographic approach was found to be more powerful than estimating population size through surveying. However, surveys were found to be more powerful for owl populations of more than 100. Estimates of power for the owl led to a re-interpretation of results which had previously concluded their population was stable, this conclusion was found not to be a justified (Taylor and Gerrodette,1993).

Carlson and Schmeigelow (2002) discuss how there is a fundamental difference in the monitoring philosophies of power analysis and optimal design. They describe how a programme based on power may not be designed to answer particular questions, and may only detect broad changes regardless of the cause, thus not maximising information gained. Optimal design however aims to achieve the best estimate of the parameter of interest, thus may have a greater ability to estimate effects of specific management policies and facilitate adaptive management (Carlson and Schmeigelow, 2002). However, such a design may be short lived as questions change. Therefore it was recommended that a programme incorporated both philosophies was used, which consisted of an optimal design which also achieved high power (Carlson and Schmeigelow, 2002).

From these studies, a number of important factors in sampling design can be summarised. These included the use of a small, well organised, stratified sample design, collecting quantitative data and which has considered such effects as plot shape and size. The design must be based on achievable aims, with the number and distribution of samples set to represent diversity, spatial variability and condition but also incorporating consistent habitat types. Most importantly it must be an optimal design, that is one which is cost effective, achieving high power at low cost, and one which is the best statistically, ecologically and logistically.

4.25 Monitoring top ten and flow diagram for a vegetation monitoring system

Both the top ten list of best practice in monitoring and the flow diagram developed in chapter 3 can be implemented in the design of a vegetation monitoring programme. The top ten list can be adapted to form a list which is an accumulation from its development in chapter 3, and vegetation based information reviewed here. The top ten list for a good vegetation monitoring system therefore states that the system must:

1) Be well informed - by being based on available *vegetation sampling*, monitoring and sample design information and literature. For example, the system should incorporate a *small, stratified sample design* which collects *quantitative data.*

2) Be well planned, tried and tested – by developing *achievable aims* and through testing a variety of techniques to establish the optimum. Variability of results from a range of techniques should be explored, for example by testing *plot size and shape the effect of incorporating different surveyors*. The *number of samples should be set with ecological and spatial variability represented.* A pilot study should be carried out and evaluated, before handing the system over for continuation into the monitoring cycle.

3) Be statistically robust - by analysing *variance and power* of the technique.

4) Be *cost effective* - through using only basic equipment and incorporating a timing element into the initial design, therefore being designed to collect the maximum amount of information in the minimum amount of time.

5) Be user friendly - by using simple techniques which are *well organised,* easily transferable and quick to use in the field. The methodology should be *robust enough to cope with being used by different surveyors* and should incorporate clear and easy to use techniques to collect data in a *systematic* way. Data collection resources should be provided along with a data storage programme and an outline of appropriate analyses.

6) Collect key baseline information - by maintaining a broad survey technique, generating *quantitative data* which can be manipulated to answer many management questions. For example distributing surveys within *all habitat types* and collecting basic information such as the number of each tree species and level of browsing damage in order to generate data from which patterns can be assessed.

7) Plan for the future - by being *flexible* enough to expand, potentially incorporating new data collection techniques to answer specific questions which may arise in future.

8) Put the monitored species first - by being as low key and unobtrusive as possible, *avoiding stress to animals and not impacting on the vegetation.*

9) Incorporate co-ordination - by having an in built data storage and analysis allowing for a quick turn around of results, and allowing ease of communication. Also by adhering to a time limit after which evaluation is recommended.

10) Be continued - by being *sustainable* i.e. easily repeatable, expandable, and easy to review enabling continuation on a long term basis.

4.26 Initiation stage: Management issue, target species and baseline information

4.26.1 Site information

Ol Pejeta Conservancy (OPC) is situated in central Kenya on the Laikipia plateau, in between Mount Kenya and the Aberdares and c.260 kilometres north of the capital city of Nairobi, near the town of Nanyuki. The conservancy spans the equator and lies at an altitude of c.1800 metres above sea level. The area is seasonal, with the wet seasons falling most reliably March to May (long rains) and October to December (short rains). Average annual rainfall is recorded as 720mm in Nanyuki with mean maximum and minimum temperatures of $22^0$and 10^0 centigrade respectively.

In 2005, when this research started, Sweetwaters Rhino Sanctuary measured 12km East to West and 9 kilometres North to South, and lay within the 46 000 hectare Ol Pejeta Ranch. This original sanctuary area is the site where the vegetation monitoring system is to be designed. Within the site area, water supply is good all year with the Ewaso Ngiro River flowing from North to South through the reserve, and 5 supplementary earth dams built in catchment areas in the South and East. The soil is black cotton soil, a grey/black loam, normally formed from decomposed volcanic rocks. Large areas of the site are covered by woodland in which *Acacia* *drepanolobium* is abundant. *Euclea divinorum* dominates low-lying areas along watercourses, *Acacia xanthophloea* is found along the main river, and open grassland plains occur on higher ground.

4.26.2 Conservancy development

Sweetwaters was created in 1989 for the protection of Black Rhino, and was surrounded by a 40 kilometre electric fence. The fence, designed to keep Rhino in and poachers out, also restricted the movement of other species such as elephant. By the end of March 2007, the fence separating Sweetwaters from the rest of the ranch area was pulled down, creating Ol Pejeta Conservancy, a prime area for wildlife conservation (Mutista.S, pers.comm, 2007).

The OPC annual report, 2007, describes how prior to the fence being removed, there were a total of 49 black rhino within the Sweetwaters sanctuary area. The sanctuary also held 6 white rhino (4 males, 2 females), which had been brought in (5 from Lewa, 1 orphan calf from Solio) at various times during 2005 and 2006. In February 2007, coinciding with the expansion of the reserve into the Conservancy, 27 black rhino (18 males, 9 females) were translocated into the previous ranch area of OPC, from Solio and Ol Jogi. This made the population in early 2007 (also after births and deaths) 75 black rhino (38 males: 29 adults, 6 sub-adults, 3 calves, 32 females: 18 adults, 9 sub-adults 5 calves, and 5 unsexed rhinos), with an average inter-calving interval of 3.1 years, and average age at first calving of 8.4 years (OPC, 2007).

OPC implements a rhino monitoring programme, incorporating both population performance and habitat dynamics, and that complies with the KWS monitoring strategy (OPC, 2007). Since early 2007, OPC has been divided into 3 sectors, each subdivided further into patrol blocks. The eastern sector consists of the founder population while the western and the southern sectors host the newly introduced population from Solio and Ol Jogi Game reserves (OPC, 2007).

4.26.3 Concerns over vegetation change

The field seasons for this research were in 2005 and 2006, prior to removal of the fence, and the expansion of what was then Sweetwaters into OPC. At this time, there was a concern about the vegetation of the reserve area suffering from possible over browsing. This was supported by Birkett, (2002) who found the habitat in the enclosed black rhino sanctuary, Sweetwaters game reserve in Kenya, to be altering as populations of elephant, giraffe and black rhino were increasing. It was also estimated that if rhino and elephant population increases continued, in the 7 years that followed the study, an unsustainable 5% yearly loss in tree density could be expected (Birkett, 2002). Birkett and Stevens-Wood (2005) highlight the particular problems faced by enclosed reserves, such as the inability of animals to move to avoid environmental stress, rapid population changes and habitat alteration. At the time of this study, environmental stress was high in Sweetwaters, due to prolonged dry conditions and damage to *Acacia* could be seen throughout the reserve, with the precise causes unknown, although suspected to be browsing. The combination of elephant, rhino and giraffe browse, and low rainfall, was found to have produced a rapid reduction in the number of *Acacia drepanolobium* trees (Birkett and Stevens-Wood, 2005). This study gave an insight into the vegetation dynamics of a woodland savannah during a period of severe environmental stress. Such a situation may become increasingly common with climate change, potentially having severe implications for enclosed reserves (Birkett and Stevens-Wood, 2005).

Therefore, following the flow diagram developed in chapter 3 (figure 3.4), the *management issue* can be described as the browsing damage caused by herbivores within an enclosed black rhino sanctuary, and whether this is sustainable. The *target species* is the black rhino, the animal for which the reserve was initially established to protect. More specifically, the target for monitoring is a representative sample of the main habitat types and woody tree species within them, which are likely to be affected by browsing damage. The target, browse damage, is caused primarily by three large herbivores: elephant, rhino and giraffe. The *baseline information* required includes a reliable estimate of the level of browse damage (simply the number/proportion of trees damaged) and a measure of its severity, compared to the number of trees with little or no damage. These measures can be compared per habitat type, per browser and per tree species. The baseline requirement, and an aim of the monitoring system, is to provide a snap shot of the condition and pressure the vegetation may be under on a yearly basis, and the ability to record change in vegetation damage over a set time period. A period of 5 years is suggested for the designed monitoring system to complete its post development cycle. This is important as it provides a long enough time period to detect trends, but is also a good timescale to assess the effectiveness and evaluate the monitoring system.

This system is to fit in with the general aims of managing and monitoring the black rhino. The information gained in previous chapters, highlighted the heavy management of black rhino, with an in situ approach incorporating translocation of individuals between populations to prevent inbreeding. The African rhino action plan (Emslie and Brooks, 1999) states that ongoing monitoring can build up an accurate picture of a populations' performance, forming the basis for biological management and for rhinos - it is the first line of defence against poaching. It is also stated that populations approaching 75% of ecological carrying capacity should be translocated to suitable areas within their historic range, such areas would require pre-monitoring. It is therefore inherent within the management of rhino populations that resource availability and the monitoring of such, plays a key part.

Direct rhino monitoring in Kenya is nationally standardised and within Ol Pejeta Conservancy and other sites, rhinos are individually known and recognised through the use of ear notch marks. OPC was named as an 'important' black rhino population (Emslie and Brooks, 1999). With its population increase, particularly since the translocation, and the increased size of the conservancy, OPC's rhinos may well now be considered as a 'key' population (Key 2 = population increasing or stable and n = 51-100) (Emslie and Brooks, 1999). Therefore good monitoring as part of conservancy management has become increasingly important. In terms of the vegetation monitoring system to be developed for OPC, it is important that the monitoring information gained from this design is at a standard from which various management initiatives can be judged or implemented.

There are three parts to this chapter:

Part A: Designing the optimum survey technique in the form of a pilot study
Part B: Testing and analysing the developed monitoring technique
Part C: Entering the monitoring cycle

4.27 Aims and Objectives

After initiating the monitoring programme by identifying the management issue, target species, and baseline information required, within the framework of the top ten list and the flow diagram, the precise aims and objectives of the study are as follows:

4.27.1 Aims:

1. To develop a monitoring programme for use in the conservation of a critically endangered species
2. To design, test and implement a monitoring system powerful enough to detect a change in browsing damage within a black rhino sanctuary over a 5 year period
3. To incorporate both power and cost effectiveness into the monitoring system design and address the problem of bias caused by different people collecting monitoring data.

4.27.2 Objectives:

- To test field techniques for sampling woody vegetation and identify the optimum methodology in terms of gaining maximum information for minimum costs.
- To establish the effectiveness of the system to monitoring browse impacts on vegetation within an enclosed sanctuary.
- To show how local staff can be trained to implement and maintain the developed monitoring programme.

4.3 Part A: Designing the Optimum survey technique

4.31 Method

In order to incorporate all major habitat types within areas of high, medium and low rhino density, a stratified random sampling system was designed. The goal of this was to have 5 survey locations per rhino density and 3 in each habitat type, this way the potential range of habitat types would be covered, and none would be under represented. The same is true for rhino densities, as a heavier density may be expected to have different vegetation damage than in areas with fewer rhinos. The habitat types were pure *Acacia drepanolobium*, mixed *Acacia drepanolobium* dominant, mixed *Euclea divinorum* dominant, mixed habitat and finally riverine and were classified in this way based on existing vegetation maps. This created a total of 15 survey sites (figure 4.1). These sites were pin pointed by overlaying a map of rhino density and habitat type, followed by a GPS map in order to identify the specific co-ordinates. The number of sites was also set at 15 to enable logistical management of the fieldwork in the time available to carry it out. Site characteristics are explained in table 4.1. The power of the 15 sites to monitor vegetation change is part of this pilot study which is to be tested later.

A variety of commonly used vegetation survey methods were selected. The methods were chosen to cover a range of techniques and compare them against each other (e.g. plot survey versus plot-less sampling, transect line versus plot survey, square versus circular plot, large versus small plot). These methods were then chosen and carried out by Manchester Metropolitan University (MMU) BSc and MSc students. The methods and data collected were to form the basis of their individual dissertations.

The GPS co-ordinates of the 15 plots were used as the starting point for each method. Students carried out the field work in a rotation between May and August 2005. Each student used one method and surveyed all of the 15 monitoring points once in no particular order. Students worked in pairs with one surveyor responsible for their method, and the other acting as a recorder taking down the information. This worked well logistically as the entire team relied on the availability of 3 guards and one vehicle. Most days, the field routine would encompass an area of plots and students would walk with a guard between adjacent sites. The methods are described in figure 4.2.

All methods (except for plot-less sampling techniques) also involved a dung survey of their area. Dung counts were included as the results of which could have the potential to assess the distribution of species which may impact upon the vegetation, or could be used to correlate species presence with observed damage. Ultimately the dung counts also provide an additional variable, consisting of simple count data, on which to assess variability in results between surveyors and methods. The dung surveys consisted of a simple count of the dung present, identification of the species responsible for it and whether it was fresh (within the last week) or old. Again, training was given to each student and there was always a knowledgeable guard present to assist in identifying and aging the dung. Old dung was generally classified as crumbling to the touch, with no fresh smell or appearance.

Each student surveyed their area around each co-ordinate following their own methodology. For example, the GPS co-ordinate formed the South West corner of the nested plots, the Northern centre-point for the belt transects, and it was the centre point for the circle plot. The co-ordinate was the starting point for the point intercept transects, this surveyor walked west from each point. For the plot-less sampling techniques, students used the GPS co-ordinate for the first point, then walked a set distance North, then East for the point quarter method, and also south for the T-squared and ordered distance. In addition to the actual survey, students were also asked to record the amount of time taken to carry out the survey at each point.

The vegetation data were recorded following an identical technique incorporated into each of the methods. Students recorded the tree species and estimated each tree height to the nearest ten centimetres up to four metres, after which the tree was simply recorded as being greater than four metres. This data would later be put into 3 height classes (height class 1: 0-1.9m, class 2: 2-3.9m, class 3: >4m). Each tree was then assessed for browse damage by three species, elephant, rhino and giraffe. Elephant browse could be identified by the snapping or twisting of branches and stems. Bark stripping was not encountered during the study. Rhino browse was identified by a clean cut of small branches and twigs below 2 metres in height. Giraffe browse was generally restricted to the tops of the vegetation and was identified by the appearance of 'nibbled' or 'chewed' twigs with stripped leaves. All students had been given the same level of training in the field to recognise the browse. Also, an experienced guard was always present who would assist in identifying the cause of any damage. If damage was found, a simple 'damage class' was assigned, taking into account its impact on the canopy as a whole. The damage classes were: class 1 – less than 25% of the tree canopy snapped or broken, class 2 – 26-50 %, class 3 – 51-75% and class 4 – more than 75 % broken (based on Tchamba, 1995, Kabigumila, 1993, Croze, 1974). In addition to the designation of a damage class, the number of main stems for each tree was assessed and recorded. If damage to any main stem had occurred, this was also recorded by counting the number broken. This would allow the number of damaged main stems to be converted into a proportion of the total main stems present per tree. It also enables a more quantitative measure for the worst type of damage observed in the field, especially for a tree that may have been designated a damage class of 3 or 4 (>50 canopy broken). For this, a main stem class score in relation to the proportion of main stems damaged could be applied later for analysis (Main Stem Class 1 = <0.25, class 2 = 0.26-0.5, class 3 = 0.51-0.75, class 4 = >0.75)

As each student was carrying out each method individually as part of their own projects, any difference seen in the results of the surveys could then be attributable to the different people, rather than an inherent difference in the methodologies (it was not possible within the time constraints imposed by the students length of stay for each individual to use all methods). Therefore, nine students also surveyed an identical plot (10m x 10m) and transect line (30m x 2m) using the same vegetation sampling and dung count technique as they were using in the field. The surveys were repeated by four students after four weeks of fieldwork. This exercise was organised to specifically address the potential differences between the surveyors, and also to see if there are any effects caused by experience on the same surveyor. The plot and transect were located within 100 metres of the research centre and the survey was carried out in the students spare time, with a guard present so as to maintain field conditions.

4.32 Results

4.32.1 Robustness of the survey

4.32.11 The 15 monitoring plots

The 50x20 metre belt transect recorded 2091 trees, this was followed by the 20 metre circular plot which included 1438 trees in total. Figures then ranged from 760 with the point intercept transect down to 169 for the ordered distance method. The total number of trees for analysis was 5218.

The proportion of trees in each height class (1-3) was calculated for each method (figure 4.3). It can be seen that every method has identified that the vast majority of trees surveyed are below 2 metres tall, with very few trees reaching a height of over 4 metres. When comparing the methods, the proportion of trees recorded as damaged by each surveyor (figure 4.4) ranged between 0.26 (26%) and 0.62 (62%). There is a significant difference in the number of trees recorded in each height class and in the number of trees recorded as damaged by each method and surveyor (height class χ^2 = 857, p = <0.001, df = 12, damaged trees χ^2 = 1271, , p = <0.001, df = 6)

Of the mean total number of trees surveyed for all the methods, 41% were recorded as browsed. Of this browse, elephant accounted for 46% (17% of mean total number of trees surveyed), rhino 41% (16% of mean total number of trees surveyed) and giraffe 18% (7% of mean total number of trees surveyed). There is some overlap as trees were found browsed by more than one species at a time. Of the mean total number of trees surveyed main stem damage was recorded on a mean of 11 %, 7%, and 1% for elephant, rhino and giraffe respectively. For the mean number of trees surveyed as damaged, main stem damage from elephant accounted for 26%, rhino 16% and giraffe 0.4%. When comparing the methods to each other (figure 4.4), there is a significant difference in the number of trees recorded as having elephant, rhino and giraffe browse (χ^2 = 109, p = <0.001, df = 12)

When considering the distribution of browse by each species across the tree height classes for each method, a similar pattern of elephant, rhino and giraffe browse has been recorded by each surveyor. For elephant browse (Figure 4.5a), damage is seen to be concentrated in the smallest height class (<2m), decreasing with increasing tree height. This follows the pattern of tree abundance shown on Figure 2. Only the 10 x 10m plot deviated from this pattern showing height class 2 to be slightly more commonly browsed by elephant. For rhino browse (Figure 4.5b), all surveyors identified the vast majority of total rhino browse to be found on trees less than 2m tall, this pattern is also in accordance with the proportion of trees at this height. Some taller trees also recorded rhino browse but at a much smaller proportion. For giraffe browse (Figure 4.5c), most surveyors recorded a slightly greater use of height class 2 (2 – 3.9m) than those trees less than 2 metres tall, this is disproportionate to availability. A small proportion of browse was found on trees greater than 4 metres tall. Therefore it can be said that the animals have browsed on trees in a particular height class, and not that they are showing a preference. What is important is that each method shows the same trend and the same differences between the browsers.

The proportion of elephant, rhino and giraffe browse to fall into each damage class (1-4) and each main stem class score (1 -4) were calculated for every method. The results are shown on figures 4.6 to 4.8. For elephant (figure 4.6, a & b), the majority of browse is recorded in damage class 1 (<25 % canopy broken). All methods recorded a low proportion of the total browse falling into the higher classes. Where main stem damage did occur, proportions were fairly even, but most methods recorded most of the main stem damage to be in the more severe classes of 3 & 4, >50% of the trees total stems were broken.

Rhino browse (figure 4.7 a & b) was also found by all methods and surveyors to fall mostly into damage class 1 (<25% canopy affected). Where main stem damage was recorded, interestingly, all methods and surveyors found most in the severest class score of 4, accounting for more than 0.75 (75%) of the main stems broken.

Giraffe browse (figure 4.8 a & b) was found to occur almost exclusively in damage class 1 by all surveyors and methods, with only a tiny proportion seen in the higher damage classes. Strangely, where main stem damage was recorded, it was of the highest severity falling into a main stem class score of 3 and 4. These data are for 1 or 2 trees recorded by 4 different surveyors.

An important result is that irrespective of which method is used, the same conclusions can be drawn, whereby the majority of browse from elephant, rhino and giraffe was assessed as damage class 1 (<25% broken). Main stem damage for elephants and rhinos was assessed as class 3 & 4 (>50% total stems broken) and class 4 (>75% total stems broken) respectively. On the whole, giraffe rarely caused damage to the main stem)

4.32.12 Test transect and plot

Nine students surveyed the transect and plot during the initial stages of the field season. The mean time taken to survey the vegetation and dung of the original transects and plots were 23.4 and 33.6 minutes respectively. Therefore on average the plot took longer to survey, but not significantly so (paired t test: $t = -2.07$, $p = 0.07$, $df = 8$).

For the dung survey, the mean number of dung piles counted was 15.3 for the transect line and 5.3 for the plot. The number of species identified from the dung count was a mean of 4.8 species along the transect, and 3 species within the plot. It was obvious in the field that there was more dung in the transect area than in the plot, therefore the difference is not attributable to the change in method. The standard deviation for the number of dung recorded was lower for the plot than for the transect (plot = 2.5, transect = 6.4, table 4.2) and for the number of species recorded from dung the reverse was true (plot = 1.2, transect = 0.8).

The mean number of trees included in the vegetation survey was 6 for the transect line and 24.6 for the plot. Although there were more trees surveyed within the plot, the proportion of trees recorded as browsed along the transect and within the plot was not significantly different (Mann Whitney U test: $U = 74$, $n = 9$, $p = 0.33$). Therefore, combining the results of all surveyors, the vegetation survey technique revealed similar proportional damage levels in the two different areas using the two methodologies. However, on calculating the percentage difference for the highest and lowest value recorded for five variables, large differences in the data from different surveyors are apparent (Figure 4.9). For the number of trees surveyed, the proportion recorded as damaged, the number of dung recorded, the number of species identified from the dung and for the time taken to carry out the survey, the percentage difference between the highest and lowest values recorded all exceed 100%, with the maximum being an 800% difference. Higher percentage differences were found in the plot for the number of dung piles, and the number of species identified from the dung, whereas for the transect, higher percentage differences were seen for the number of trees recorded, surveyed as damaged and the time taken. Therefore, the plot sampling technique showed the lowest percentage difference and variability between surveyors for the vegetation survey and the time taken, although percentage differences are still high.

The five variables were ranked for each surveyor (Table 4.2). As there were 9 surveyors, the highest rank is 1, and the lowest is 9. A person who consistently scores rank 1-4 could potentially be positively biased, whereas a person scoring 6 – 9 may be negatively biased in comparison to the rest of the group. In both the plot and transect survey, surveyor number 2 ranked consistently between 1 and 4. For all variables, apart from time taken, surveyor number 5 in the plot survey, was fairly consistently around a middle rank, possibly suggesting neither negative or positive bias. This surveyor was less consistent on the transect. Some surveyors scored a low rank for the vegetation part of the survey, and a high rank for the dung count (e.g. surveyor 9 in the plot) indicating possible individual strengths and weaknesses.

When focusing on the proportion of trees recorded as damaged, consistency can be seen for a number of surveyors, whose rank score was only 1 different for both the plot and transect survey (Figure 4.10). Surveyors 4, 8 and 9 ranked consistently low (7-8), surveyors 1 and 2 ranked consistently higher (≤4), and surveyor 5 was again consistently middle ranking (4-5). Individual variation should therefore be expected, with some people being positively or negatively biased. On the whole, in this survey, surveyor 5 appeared to be the most consistent. There was a significant correlation for the number of species identified from dung counts (Spearmans rank, $r_s = 0.821$, $n = 9$, $p = <0.05$). However, there was no significant correlation for the remaining four variables (tree number, proportion damaged, number of dung recorded, and time taken), in the plot and transect survey carried out by the 9 surveyors. (Spearmans rank correlation: number of trees, $r_s = -0.1$, $n = 9$, $p = >0.05$, proportion damaged, $r_s = 0.538$, $n = 9$, $p =$

>0.05, number of dung, $r_s = 0.625$, $n = 9$, $p = >0.05$, time, $r_s = 0.013$, $n = 9$, $p = >0.05$). Therefore some surveyors are consistently different regardless of sample type.

Four of the nine students volunteered to re-survey the same areas after 4 weeks of experience in the field. Paired T tests were used to analyse the variables (table 4.3). In comparing the performance of these four students between their first and second surveys, there was no significant difference in the time taken by the surveyors for the plot and transect survey. For the transects, the only significant differences observed were for the amount of elephant and rhino browse recorded. The number of trees surveyed, the number of trees recorded as browsed and the number with giraffe browse was not significantly different between the two transect surveys. For the repeated plot, there was no significant difference in the number of trees included, the total number with damage or the number recorded with elephant, rhino and giraffe browse. Therefore, when considering the data collected as a whole from the 4 surveyors, the vegetation sampling design seems to be 'robust', particularly within the 10x10 metre plot, as shown by the lack of significant differences in the results. However, these results do not highlight potential differences in the ability of the individual recorders.

Rank scores for the four surveyors for their initial and repeat surveys were calculated and compared (Figure 4.11). Surveyor 1 is high ranking for both the plot and the transect on the first and second survey (rank 1-2). For the other surveyors there seems to be no clear pattern. To assess the effect of experience on potential bias between recorders, the percentage difference between the highest and lowest values for the four surveyors from the first and second transect and plot surveys were calculated. In total for all 4 surveyors together, for the five variables and for both methodologies, the mean percentage difference fell from 103.5 to 63.7 for the first and second survey respectively. For the transects as a total, mean percentage difference fell from 126.3 to 80.6 and for the plots from 69.5 to 57.9. For the transect survey, percentage difference fell for 3 variables (number of trees, proportion damaged, time), but increased for 2 (number of dung, number of species from dung) (Figure 4.12). For the plot survey, percentage difference fell for 3variables (number of trees, number of dung, time), stayed the same for 1 variable (number of species from dung) and also increased for 1 variable (proportion of trees damaged). It is difficult to state empirically the affect of experience with such a small sample size, however there are clear indications that variability between surveyors does appear to reduce with increased experience. Also when considering methodologies, overall the plot survey produced less percentage difference, although values are still high. For the separate variables, most saw reductions in percentage differences between minimum and maximum values, and when increases did occur they were not as distinct. There is evidence however for potentially great variability in the data received from different surveyors even when using the same technique to survey the same area.

4.32.2 Determining the optimum

Weigarts method to determine optimal quadrat size (Krebs 1999, p111) was adapted and used to determine the optimum method to survey the maximum number of trees, the maximum number of trees found to be damaged, the maximum amount of dung, and the maximum number of species identified from dung.

Results for each method were made relative by converted into their equivalent for an area of $100m^2$. The relative cost (mean time ÷ minimum mean time) and relative variance ((standard deviation)^2 ÷ (minimum standard deviation)^2)for each method were calculated. The relative cost was then multiplied by the relative variance to give the 'product number'. A small product number indicates an optimal quadrat size or shape in terms of cost (time) and accuracy (variance).

Figures 4.13 to 4.15 illustrate the product numbers. The lowest product is represented by the smallest bar on each chart, and is therefore the method which will give the maximum precision for the minimum cost.

For the mean number of trees surveyed per method, the optimum method is the joined plot less method of T squared and Ordered distance. This is followed by the 1km point intercept transect. The best of the three plot methods is the 50 x 20m ($1000m^2$) plot. For the number of trees found to be damaged, the lowest product is for the 1km transect followed by the point quarter survey method. Of all the plot surveys, the 10x10m ($100m^2$) is the optimum. The 20m diameter circular plot is by far the most costly of all the methods used to survey vegetation damage. The lowest product value for the number of dung surveyed and for the number of species identified from the dung counts is for the 10x10m ($100m^2$) square plot, the highest is also the same for both, and is the 50x20m ($1000m^2$) plot.

In addition to calculating optimal quadrat size and shape, the areas surveyed by each method (plot-less sampling was removed from this analysis) were plotted against the proportion of the total number of trees surveyed found to be damaged, the mean number of dung surveyed and the mean number of species identified from the dung counts for each method. A quadratic equation was used to fit the best trend line possible to these data points (R.Jackson, pers comm. 2006). The peak of this curve can be interpreted as the maximum amount of information for a certain area. Figure 4.16a shows that the optimum proportion of damaged trees may be surveyed in an area of around $400m^2$. Figures 4.16b & c illustrate the optimum area for the volume of dung encountered, and the number of species identified from these counts is around $800m^2$. A summary of results from this analysis can be seen in table 4.4.

4.4 Pilot study: Summary and Recommendations

Although for the 15 monitoring plots there was a significant difference in the number of trees recorded as browsed by each method, it is significant that each method showed the same trends and the same differences between the browsers when considering the distribution of browse across tree height classes. The same can be said when considering damage class for each browser. All methods recorded the majority of browse for all 3 browsers to be in the least severe category. Therefore, irrespective of which method is used, and which surveyor collected the information in the field, these same broad conclusions can be drawn.

When results for all nine surveyors are combined, for both the test plot and transect there is no significant difference in the proportion of trees damaged. There are however large percentage differences in the results for individual surveyors. Some surveyors were also either consistently high or low ranking (positively or negatively biased) in their data collection, and others were highly variable. Only one surveyor (surveyor 5) was consistently middle ranked for all variables, except for time taken, and only in the plot survey.

Similar patterns of variability were seen for the 4 surveyors who repeated the test plot and transect survey. As a whole large percentage differences between results for each surveyor were seen, but differences were less for the plot than the transect (although still high). When results are combined for the initial plot survey and compared to those for the second plot survey, there was no significant difference in the number of trees surveyed, recorded as damaged and browsed by elephant rhino and giraffe. Results for the transect were more variable, particularly for the specific browsing data. Therefore conclusions from combined data would be the same from the two separate surveys, but variability between separate surveyors can be expected.

The differences between individuals shows there is potential for great variability between surveyors recording data from the same area, using the same techniques, following the same training and in the same conditions. However, results following the repeated survey indicated that variability decreases with experience. All of the results also indicate that a plot survey may be more 'robust' in terms of the data collected being less variable compared to a transect.

From the optimum design results, a survey methodology for incorporation into a monitoring programme could be designed. It is suggested that the survey technique should be a plot sample, as plots have been shown here to be more 'robust' (no significant differences between surveyors recording key variables). Through Weigarts method to determine the optimum, plots were also identified as an optimal method for recording the number of trees, the number of trees damaged, the number of dung, and species identified from dung counts (Table 4.4). In identifying the optimal area for the proportion of trees damaged and the amount of dung and species identified from dung, the area lay between 400 and 800 square metres. The 100 metre square plot had also been found to be the optimal method, for recording the number of damaged trees, the number of dung piles and the number of different species identified from the dung present. This suggests a small area may be sufficient to collect the information required. It also may have logistical advantages and prevent error caused by fatigue and possibly loss of bearings within the plot. The 10 x 10m plot methodology was also used by the surveyor who was calculated to be the most consistent in the test plot survey (surveyor 5).

My suggestion therefore, is that small areas should be sampled separately within a larger study plot. This could be achieved by using a square plot measuring 20 metres by 20 metres, subdivided into 10 metre by 10 metre blocks, thus covering an area of 400 square metres, sub divided into 100 metre square blocks (figure 4.17).

The goal of the new survey technique and vegetation sampling system is to meet the suggested optimal strategy suggested by Krebs (1999). The survey is therefore designed to be the best statistically, providing the optimal level of information for a given area and with low cost in terms of time. It is also designed to be the best ecologically, as the design will collect specific information in order to answer management questions about the sustainability of browsing damage occurring. Finally it is designed to be the best logistically, by using basic equipment, being easy to set up, and easy to use. The set routine and raw data collection technique also adheres to the suggestions of Reinke and Jones (2006), by locating plots within some consistent habitat types and recording quantitative data as raw measures, later modifying them into classes for analysis. Finally, although differences between surveyors are important, in this study, the deductions which have identified the optimum technique have consequentially identified the technique used by the most consistent surveyor.

4.5 Part B: Implementation - strategic planning and testing

This section tests and analyses the optimum survey design developed in part A, and incorporates both cost effectiveness and power into the monitoring system design. The effectiveness of this system in monitoring the browse impacts on vegetation within the black rhino sanctuary is established. Also, information gained from the pilot study is used to develop a robust monitoring technique, which would be able to quantify the number of trees damaged, both generally and specific to tree and browser species, and develop a measurement of scale to assess the severity of damage on a yearly basis. The power of this system to detect a statistically significant change in the level of browsing damage over a set length of time is also investigated

The survey design block (20x20m subdivided into 10x10m quadrants, figure 4.17) was designed to maintain orientation within the total plot area, to provide the ability to break samples down to smaller sizes if necessary, and to help manage fatigue and maintain momentum in the field. Monitoring plot analysis focused on the vegetation data and were analysed in terms of their ecological importance, as a basis for future comparisons, and to assess potential impacts on design.

In addition to the monitoring plots, a number of sites were selected and identically surveyed, thus forming 'comparison plots'. These were used to assess whether similar results of the state of the vegetation were achieved from adjacent plots, whether the main monitoring plots were representative of the reserve as a whole, and to assess the potential impact of geographical patterns and patchiness.

To test the technique further, a grid of control plots was also be set up, and a repeat survey was carried out by 2 surveyors. The control plots were carried out to test the optimum plot designed in part A, the pilot study. This control grid consisted of 8 20x20 metre plots, with 4 subdivided as suggested by the pilot study, and the 4 remaining plots in the grid left whole. The survey of these plots was carried out to investigate the level of variation between the whole and subdivided plots, and to test if there is any benefit of subdividing the area.

The monitoring survey technique was analysed to determine if the designed monitoring system is powerful enough to detect a change in browse damage over a projected five year period. The period of five years was chosen for the analysis, as although a monitoring system is designed to be long term, a good technique should be expected to uncover vegetation change in a short time, and enable management decisions to be made effectively.

4.51 Method

A 20 x20 metre square plot, subdivided into 10 x 10 metre blocks, covering a total area of 400 square metres (figure 4.17), was used to survey 15 monitoring points located within the original Sweetwaters Game reserve, now Ol Pejeta Conservancy.

These points were divided between major habitat types and rhino densities (Table 4.1, part A).

The plot was set up routinely at each survey point by locating the GPS point and initially marking this as the centre. The North, South, East and West points were then measured 10 metres away from the centre and marked. Each corner was then measured out and marked. The equipment required consisted of a GPS unit to locate the points, a tape measure and markers such as coloured stakes or most effectively, multi-coloured bio-tape. The plot was then be surveyed strategically. This involved sampling the vegetation in the North West block first, followed by the North East block and rotating clockwise until all blocks were complete.

The 10 comparison plots were surveyed in an identical fashion to the 15 monitoring plots. In order to standardise the location of comparison sites, each of the 10 plots was a set distance of 1 kilometre away from the monitoring plot GPS point, within an area which represented the same habitat type. Therefore, each of the first 10 main monitoring plots had a comparison plot 1 kilometre away.

The grid of 8 control plots was set up with 4 plots on one side of the grid sub divided into 10 x 10 blocks ('subdivided' plots), and the 4 on the other side were left 'open,' as 20x20 metre plots ('full' plots). Each plot was surveyed separately by 2 MSc students who had been using the sampling technique for a number of weeks in the field and were confident with the procedure. Data from the subdivided plots could then be pooled to allow comparisons to be made to the full plots.

The vegetation survey technique used for all plots followed the original procedure used in part A, and a set data recording sheet was designed (figure 4.18). The data recorded included basic tree information (tree species, height (to the nearest 10cm estimate), number of main stems), elephant damage (damage class: 1: <25%, 2: 25-50%, 3: 50–75%, 4: >75%, number of main stems damaged, and a tick box for fresh damage), rhino damage and giraffe damage in the same format as that for elephant. The data collection sheet was designed to be systematic and very simple to use to aid speed of collection in the field (figure 4.18). Also, in order to simplify the process, the data storage spreadsheet was set up prior to the fieldwork taking place. A set of summary statistics to be compiled were also listed (figure 4.18).

In order to clearly understand the level of damage caused by each browser considered here, a single figure representing both damage class and main stem damage was formulated, the damage product number (DPN). This gives the ability to make comparisons using one index. In the field each tree is assigned a damage class per browser (1-4), and on each tree, the number of main stems is counted, and if main stem damage has occurred, the number of main stems affected is also counted. The number of damaged stems can then be divided by the total number to give a proportion. This proportion is then categorised to give a 'Main Stem Class Score' (CS). The classes correspond with the damage classes of 1 – 4, whereby 1 = a proportion of <0.25, 2: 0.25-0.50, 3: 0.50 – 0.75 and 4: >0.75. The DPN is simply the sum of the damage class and the main stem class score. To standardise this number the 'Damage Product Score' (DPS) can be calculated (Figure 4.19), which simply divides the sum of DPN by the number of trees included in the survey as a whole, in each plot, and for each tree species. The higher the DPS value the greater the level of damage.

This has been developed in order to standardise the results for each year of the monitoring programme, and enable conclusions about the level of damage occurring to remain relative to the actual number of trees included in each survey. The calculation also combines a subjective technique of assessing damage (assigning a damage class) with a quantitative technique (main stem damage assessment), to make a single index value. An important note is that here the DPS does not include 'other damage,' it is designed to be browse specific.

4.52 Results

4.52.1 Monitoring plots

Summary data are shown in appendix 4. The monitoring, comparison and control plot data was collected over a period of 6 weeks. The full 15 monitoring plot survey would be achievable in one week without logistical constraints. Each plot took between 14 and 33 minutes (mean = 26 minutes) depending on vegetation density, with the total survey taking 390 minutes (6 ½ hours not including set up and location). The total number of trees surveyed was 1050, 469 of these were recorded as damaged to some extent (44.7%). Of all the trees surveyed, 77.5 % were in height class 1 (<2m), of which 34.9% were recorded as damaged, that is 27% of the total number of trees included in the survey. Height class 2 (2 – 4m) held 20.3% of woody vegetation recorded, of which 77.5% were damaged (15.7% of total). Only 2.2% of trees surveyed were in height class 3 (>4m), and of those 87% were damaged to some degree (1.9% of total).

The most commonly surveyed trees were *A. drepanolobium, E. divinorum*, and *P. punctulata*, followed by *S. myrtina, R. staddo and R. natalensis* (Table 4.5). The remaining 3.8% of the vegetation surveyed was made up of 7 species, with less than 20 individuals each. All tree species included in the survey, except for two (*P. punctulata and G. similis*), had more than 40% of their total number of trees damaged to some degree (Table 4.5). Some had more than 75%, and for two species, *M. triphylla, B. glabra*, 100% were damaged. For all but four species of tree, main stem damage accounted for more than 50% of the damage recorded (Table 4.5). The proportional difference between the number of damaged and undamaged trees in each tree species was found to be significant ($\chi^2 = 153.2$ df = 12 p = <0.001). In order to test if results were still significant for species represented by small sample sizes, species which comprised less than 3% of the total number of trees were analysed. The difference remains significant when analysing these less common trees species ($\chi^2 = 20.8$, df = 7, p = 0.004). Of the total number of trees included in the survey (1050), 17.8%, 22.2%, 10.7% and 1.6% were damaged by elephant, rhino, giraffe and other causes respectively. Of the 469 damaged trees, 39.9% were browsed by elephant, 49.7% browsed by rhino, 23.9% browsed by giraffe and 3.6% were damaged by other causes (e.g. natural damage, unidentifiable damage, other herbivores, fire). Of all the Elephant, rhino and giraffe browse surveyed, 55.6%, 50.6% and 4.5% respectively resulted in damage to the main stem(s). This equates to 9.9%, 11.2% and 0.4% of the total number of trees in the survey with main stem damage from elephant, rhino and giraffe respectively.

The proportion of elephant, rhino, giraffe and other damage to fall into each damage class was calculated (figure 4.20). For all browsers, it can be seen that the most common damage class is class 1 (<25 % of total tree broken). Of all the elephant damage recorded, the majority (64.2%) was categorised as damage class 1, and only 10.7% was recorded as damage class 4 (>75% broken). For rhino and giraffe browse, 51.9% and 99.1% respectively was categorised as damage class 1, and 2.6% of rhino browse was categorised as damage class 4. No giraffe browse was found to be class 4.

Differences between the number of trees in each damage class per browser species were found to be significant ($\chi^2 = 100$ df = 6 p = <0.001), and the differences between the number of trees damaged per plot, per browser species were also found to be significant ($\chi^2 = 134.4$ df = 28 p = <0.001). Therefore, the number of trees damaged by browse appears to be different across the plots. The DPS per plot (figure 4.21) shows that plots 14, 9 and 4 respectively have the highest level of non species-specific browsing damage (elephant, rhino and giraffe combined). Reference to table 4.1 (part A) shows that these plots are located within '*Acacia*', and 'mixed *Acacia* dominant' habitat types. The total DPS for 2006 (plots combined) is 1.42. This sets a baseline for sampling in subsequent years.

Although designed to quantify browsing damage as a whole, the DPS can be used to look at browser specific damage. The total DPS for elephant (DPS elephant = $\sum$elephant DPN / total number of trees in survey) is 0.55, rhino 0.74 and giraffe 0.13. When considering the DPS per browser per plot (figure 4.22). It can be seen that elephants show two clear peaks in plots 4 (*Acacia* dominant) and 15 (mixed), and a low DPS for plots 3 (riverine) and 12 (mixed). Rhinos have a high DPS in plots 3 (riverine), 9 (*Acacia*) and 14 (*Acacia*), and low DPS in plots 5 (mixed *Euclea* dominant), 10 (Mixed), 11 (Acacia) and 15 (mixed). Both elephant and rhino have similar DPS values for plots 1(mixed *Euclea* dominant), 2 (riverine), 5 (Mixed *Euclea* dominant) and 10 (mixed), other than these four plots, the general trend seems to be where elephant DPS is high, rhino DPS is lower and vice versa. Giraffe have a peak in plots 9 (Acacia) and 14 (Acacia), but have a low DPS for all other plots. A spearman rank correlation for the DPS per browser species found there to be no significant association between elephant DPS and either rhino ($r_s = 1.42$, n = 15, p = >0.05) or giraffe ($r_s = 0.131$, n = 15, p = >0.05). There was however a significant association between rhino DPS and Giraffe DPS ($r_s = 0.535$, n = 15, p = <0.05).

When considering DPS per tree species, it can be seen that some species are suffering more damage than others (figure 4.23), specifically it seems that the least common tree species are achieving the highest DPS values, and their values exceed the total DPS calculated to represent browsing damage in full. This is supported by a significant association between DPS and the total number of each trees species, with the least common trees more likely to have a higher DPS (Spearmans rank correlation: $r_s = -0.824$, n = 13, p = <0.001). When focusing on the specific DPS of elephant, rhino and giraffe for each tree species, the top three tree species for each browser can be identified (figure 4.24). For elephant, these top three tree species are firstly *B. glabra* then *M. triphylla* and *S. myrtina*, for rhino *C. edulis*, *A. xanthophloea* and *M. triphylla*, and for giraffe *R. staddo*, *S. myrtina* and *A. drepanolobium*. However, a Spearmans rank correlation found no significant association in the DPS and the abundance of each tree species for elephant or rhino (elephant: $r_s = 0.136$, n = 13, p = >0.05, rhino: $r_s = -0.434$, n = 13, p = >0.05). There was a significant association for giraffe ($r_s = 0.703$, n = 13, p = <0.05), with only 4 of all tree species (which were also the most abundant: *A. drepanolobium, E. divinorum, R. natalensis, S. myrtina*) scoring a giraffe DPS at all. Therefore, although as a total the DPS has the potential to give an idea of preference to browsing certain woody species, significant patterns are unclear when considering the separate browser species and their possible preferences to specific tree species.

4.52.2 Comparison plots

The comparison plots were used to investigate whether as a group they provided a similar picture of the vegetation of the reserve as the original 10 monitoring plots. There was no significant difference in the number of trees surveyed in the monitoring and comparison plots (two sample t test. t = -1.19, p = 0.25, df = 18). This was also true for the number of trees recorded as damaged (t = -0.5, p = 0.6, df = 18). To compare the total number of trees in each height class, the number of trees was converted to be proportional to the total area surveyed. Both the monitoring and comparison plot results achieved the same conclusion, that trees less than 2 metres were the most abundant, and trees greater than 4 metres were scarce (figure 4.25). When considering browsing damage in each height class, again, results from monitoring and comparison plots reached the same conclusion, the occurrence of browsing damage decreases with height class, and appears to be in proportion with abundance (figure 4.26).

When separating elephant, rhino and giraffe browse in the monitoring and comparison plots, by damage class, it can be seen that the pattern of damage is similar for each browser species (figure 4.27a - c). For both elephant and giraffe, most damage falls into class 1 (<25% of whole tree broken), this is also true for rhino damage, but there appears to be more occurring in classes 2 and 3 (25 – 50% and 50 – 75%). After calculating the DPS for each browser species, there also appears to be a very similar pattern between the first 10 monitoring plots and their corresponding comparison plot (figures 4.27a - c). There are some localised peaks which may indicate patchiness in browsing damage for each species of browser, for example giraffe browse in monitoring plot 9. This observation is supported by the fact that there is no significant difference in the DPS of elephant and rhino between the 10 monitoring plots and the comparison plots surveyed (Mann Whitney U test: elephant: $U = 24$, $n = 10$, $p = >0.05$, rhino: $U = 21$, $n = 10$, $p = >0.05$), but there is for giraffe DPS ($U = 84$, $n = 10$, $p = <0.05$).

The occurrence of any geographical patterns and patchiness was investigated. A spearman rank correlation found there to be no significant association between the number of damaged trees surveyed in first 10 monitoring plots and their adjacent 10 comparison plots ($r_s = 0.13$, $n = 10$, $p = <0.05$). Although a correlation of species specific browse, found associations between the monitoring and comparison plots to be significant for elephant and giraffe (elephant: $r_s = 0.655$, $n = 10$, $p = <0.05$, giraffe: $r_s = 0.855$, $n = 10$, $p = <0.05$), but not for rhino ($r_s = 0.33$, $n = 10$, $p = >0.05$).

The results in this section indicate that choosing a different set of plots provides a similar picture of the levels and types of damage overall, which suggests that the original plots are representative of the reserve as a whole. There is however some evidence of patchiness, at least for rhino.

4.52.3 Control Plots

Table 4.6 displays the control plot survey data. A two way Anova (table 4.7) found there to be no significant difference in the time taken to carry out the plot surveys regardless of plot type or surveyor. There was also no significant difference in the number of trees included and the number of trees recorded as damaged. When considering specific damage, there was no significant difference in the number of trees recorded as browsed by elephant for plot type or surveyor. There was a significant difference in the number of trees recorded as browsed by giraffe for plot type, but not surveyor. For rhino browse, there was a significant difference in the number of trees damaged for both plot type and surveyor

For all browsers, the mean number of trees recorded as damaged was higher for the subdivided plots than the full plots. When comparing surveyors, means were higher for both surveyors in the the subdivided plots than the full plots, and surveyor X recorded slightly higher means than surveyor Y for elephant and giraffe browse, and lower means for rhino browse and dung counts regardless of plot type (table 4.8). For the number of dung recorded, there was no significant difference for the surveyors, but there was a significant difference in the number of dung recorded when considering the plot type. The mean number of dung recorded was higher in the subdivided plot than in the full plot.

The mean DPS was calculated for the survey for each plot type (4 subdivided plots and 4 full plots) per surveyor (X & Y). The results for each plot type are very close (figure 4.28) with a DPS of c.2 for subdivided plots and a DPS of c 1.5 for full plots, regardless of the change of surveyor. When considering damage caused by each browser species (figure 4.29), it can be seen that surveyor Y recorded a lower DPS for elephant and giraffe in each plot type, but higher DPS for rhino. In general elephant DPS was found to be the highest, followed by rhino and then giraffe. Both elephant and giraffe DPS were similar for both plot types, with elephant DPS lying between c.1 – 1.3, and giraffe c.0.2. Rhino DPS was higher in the subdivided plots (subdivided c.0.4-0.6, full c.0.2-0.4). Analysis of the total DPS for each plot type reveals that there is no significant difference in the DPS values between subdivided and full plot types, and between surveyors X and Y (Mann Whitney U test: plot type: $U = 87$, $n = 8$, $p = 0.52$, surveyor: $U = 71$, $n = 8$, $p = 0.79$). Therefore conclusions using this measurement of browse damage would be the same.

Subdivision of the plot does not impact on the time taken to carry out the survey. Also, in general, the DPS values were similar regardless of plot type or surveyor, but where there is a significant difference in results due to the plot type, the subdivided plot yields the highest mean. The difference seen in the recording of rhino browse may have been the result of an observation that surveyor Y was more likely to classify a dry broken branch as rhino browse. Therefore, taking these results into account, on the whole the technique appears to be reliable and incorporating subdivision appears to improve a plot survey, by maintaining orientation within an area, thus helping to prevent both 'missed', and potentially duplicated data collection.

4.53 Power of the monitoring technique

As well as enabling the calculation of many combinations of vegetation statistics to answer a wide range of management questions, the technique must also be effective enough to detect a statistically significant change in the level of browsing damage over a set length of time. In order to test if the proposed monitoring regime had sufficient statistical power to detect such a change over 5 years, the data for the number of damaged trees in each of the 15 monitoring plots in 2006 was extrapolated over a further 4 years up to 2011. A spreadsheet was designed which expanded the data and performed a regression on the number of damaged trees recorded, over the five year time scale (Fielding, pers.comm). The number of damaged trees recorded was varied by a random factor based on the percentage change the technique would be required to detect, which could be varied throughout the analysis. In order to simply calculate the power of the technique, the regression was simulated 100 times at varying sensitivity (percentage change detected). Only significant results were counted ($p = <0.05$), and these counts could be converted into a percentage. A powerful technique was identified as one where more than 80% of the simulations produced a significant relationship (even though all relationships were real). At this point, the detectable effect size, or the percentage change detected, could be identified. The simulations were carried out in increments of 5% change (table 4.9), and in this case, the technique was calculated to be powerful enough to detect a 42% change in the number of damaged trees over a 5 year period (example $R^2 = 0.9988$, $p = 0.03$, figure 4.30). That equates to detecting a change of 8.4% in the number of damaged trees per year.

This simulation was repeated, but using the calculated damage product scores (DPS) for each plot in place of the number of trees damaged. Simulations this time proved the technique to be more powerful (table 4.10). Here, the technique was calculated to be powerful enough to detect a 28% change in the DPS over a 5 year period (R^2 = 0.9986, p = 0.03), which is equal to a 5.6% change in DPS per year.

4.6 Design Test: Summary and Recommendations

The analyses here agree with the main patterns discovered in the pilot study, which is important in establishing the reliability of the survey design. Most damage occurred to trees less than 2 metres tall, in proportion with abundance. Rhino browse was the most common browse surveyed, and as with all types of browse, the majority did not cause severe damage. There was also a possible association between feeding sites for rhino and giraffe, or an indication that rhinos and giraffe avoid elephants. There is also potential for this method to indicate possible preferences of browsers to certain trees species. Analysis of comparison plots revealed the monitoring plots to be potentially representative of the reserve as a whole, but that there are effects caused by patchiness (e.g. browsing is not uniform). The techniques can therefore detect patterns and differences between browser and tree species and the plots are also representative of the reserve, but must be sited in a stratified random way to encompass possible patchiness.

From the control plot grid survey, regardless of the surveyor, plots took a similar amount of time to survey, and a similar numbers of trees and trees damaged were recorded. There is potential for variation in figures for specific browser species. This may indicate the need for improved training on this aspect, or the need to use experienced personnel who are more familiar with browse identification. Regardless of this however, there will always be some level of subjectivity and variability, particularly if using different surveyors. This may then indicate the importance of consistency, with the same surveyors carrying out the monitoring system, which was also concluded following the pilot study in part A. This is particularly true if the aim is to analyse browse damage at a fine scale i.e. from specific species, as opposed to on the whole. An important point however, is that regardless of these differences in specific browser data, the DPS analysis for each browser resulted in the same conclusions regardless of the surveyor or plot type in the control plot survey. Therefore, combining damage data into a single index can be recommended. As can the subdivision of a plot into smaller, equal sections. The control plot survey showed the subdivided plots tended to produce a higher mean for variables, and from both the results and observations in the field, the subdivision reduced confusion as to which trees, and dung, had been included or not.

The simple power analysis undertaken here revealed the technique to be powerful enough to detect a range of 8.4% (from the number of trees damaged) to 5.6% (from DPS) change in the vegetation damage per year over a 5 year period. It can be suggested that this is a sufficient minimum level for management, and importantly that a serious change in vegetation damage would be detected.

From these results, the monitoring survey design can be finalised and for future interpretation of the monitoring system results, a number of key outputs can be suggested. Such outputs could be calculated yearly to give a consistent idea of the condition of the vegetation, and can be represented by visual charts for easy comparison over time, alongside the use of other statistical analysis techniques.

Therefore the annual monitoring system is to consist of a minimum of 15 plots, equally representing each habitat type and rhino density, but randomly located within those sites. The survey plot will be a square of 20x20 metres, with its centre located on the GPS point, and set out with its boundaries 10 metres North, South East and West of that point. The plots will then be subdivided into 10x10 metre quadrants (NW, NE, SW, SE), and should be surveyed strategically, one quadrant at a time, by the same surveyor/s each year. Key outputs for comparison include the total number of damaged trees per plot, total number of damaged trees per year (all plots combined), the proportion of damaged trees per plot and the mean proportion of damaged trees per year, the DPS per plot, total DPS per year, total running mean (number of damaged trees) and the DPN per browser species per plot/year.

4.7 Part C: Entering the Monitoring Cycle - communication and workshop

After the monitoring technique had been tested and finalised, it was handed over to the research department staff of Ol Pejeta Conservancy, and training provided. Showing people how to implement the monitoring programme remains part of research design, because if people cannot be trained to use the survey design reliably, it is not a good design. This communication phase in designing the monitoring system aimed to deliver an effective programme for practical use which would compliment the work already undertaken by the research department.

4.71 Method

A training workshop was compiled, and implemented in June 2007. The workshop was run over a 5 day period which included full theoretical and practical training in field work methodology and the survey procedure and the collection of data from the 15 monitoring plots. This was followed by training in data entry into the specifically designed spreadsheets, how to collate the data and simple data analysis. The whole monitoring programme procedure was not only communicated through practical training, but a resource pack and CD was provided to accompany the workshop.

The workshop generated another round of data from the set 15 monitoring points that had been used in 2005 (pilot study) and 2006 (testing the technique). The main difference here was that the data were collected as part of a training workshop, and instead of a solitary surveyor, the plots were surveyed as a team of 6, which logistically worked better with two teams of 3 people working together to carry out the survey. Each team of 3 surveyed 2 of the 4 blocks per plot, i.e. team one surveyed the North West and South West blocks, with team two then surveying the North East and South East blocks of each of the 15 monitoring plots.

4.72 Results

There were 841 more trees recorded by the team in 2007 than in 2006, an observation was that the team was more effective at separating clumped woody vegetation into separate trees, which may have been regarded as one tree in the 2006 survey. Of all trees surveyed, 71 % were recorded as damaged in 2007 compared to 45% in 2006 (Table 4.11). Analysis revealed there to be a significant difference in the number of trees recorded as damaged (paired t test: $t = -5.73$, $p = <0.001$). However, the percentage of all the trees included in the survey which were recorded as having main stem damage was almost identical (22.19% in 2006, 22.95% in 2007).

Summary data and key output charts from the workshop are shown in appendix 5. The running mean for the number of trees damaged per year (mean no. trees damaged year 1 + mean no. trees damaged year 2 / 2) will give a standardised measure as the monitoring programme continues and will be more valid with a continuing team. For 2006 and 2007, the running mean shows an increase in the number of trees recorded as damaged (2006 = 31.3, 2007 = 60.4). These results may appear surprising initially, but then consider that the team in 2007 recorded far more 'other' damage than in 2006 (2007: 28.5%, 2006: 3.6% of the total number of trees included in the survey).

The number of trees recorded as damaged by elephant, rhino and giraffe also increased in 2007. The biggest increase was seen for rhino, with browse increasing by almost 10% of the total number of trees surveyed in 2007 compared to 2006. However the proportion of trees damaged by rhino actually fell by 4%. Both elephant and giraffe damage rates (percentage of total trees damaged) appear comparable, increasing slightly for elephant, and decreasing slightly for giraffe browse in 2007 (Table 4.11). Paired t tests reveal there to be a significant difference in the number of trees recorded as browsed for each browser species. (elephant $t = 3.2$ $df = 14$ $p = 0.006$, rhino $t = 6.5$ $df = 14$ $p = <0.001$, giraffe $t = 2.3$ $df = 14$ $p = 0.037$). Of the total number of trees surveyed, elephants damaged the main stem(s) of 10.5%, rhinos 9.3% and no main stem damage was recorded for giraffe.

When comparing the total browsing DPS (elephant, rhino and giraffe browse combined) in 2007 (DPS = 1.34) and 2006 (DPS = 1.42), similar values are seen, but the DPS was actually higher in 2006. A Wilcoxon matched pairs test was performed on the DPS data for the 15 plots in 2006 and 2007 which revealed there to be no significant difference in the DPS for the two years (Wilcoxon $Z = 0.568$, $p = 0.570$). The total DPS per browser (elephant, rhino, giraffe) per year also shows that the level of browsing has remained largely similar for each species from 2006 to 2007, only increasing marginally for elephant (figure 4.31).

4.8 Training workshop: Summary and Recommendations.

All members of the workshop understood the monitoring technique, finding the data collection to be easy and straightforward. They all used the spreadsheet correctly and easily understood methods of collation and data analysis. Therefore the monitoring programme translates well through such training.

The larger team did appear to collect more data, with apparently more trees included. However the differences seen in the numbers of trees damaged may have been caused by an increase in the recording of 'other' damage, and a change in survey style (e.g. large clumps broken down into more separate tree species) rather than a real increase.

When focusing on browsing damage by elephant, rhino and giraffe, damage to vegetation over the two year period largely appears to have remained at a similar rate of occurrence and severity, however differences in the number of trees recorded as damaged were significant, this again could be partly due to a change in survey style. It must be said however that, the percentage change in rhino browse may actually be more significant, and actually indicate an increased level of browsing. The DPS for 2007 was not significantly different than for 2006, resulting in an overall conclusion that browsing is currently stable.

This was a training workshop, and because of the potential impact of different surveyors collecting the data (as discovered in part A and B), trends recorded here in 2007 and compared to 2006, may not be reliable. It is suggested at this point that the potential for subjectivity is reduced by using the same surveyors. Therefore, for the monitoring system to be effective and consistent, and to reduce potential error, each plot should be carried out by the same team of one or two surveyors. The short time available for the entire monitoring workshop restricted the time available in the field to do this in 2007.

4.9 Discussion

4.91 Successful development of a monitoring programme

Any successful monitoring programme has to have good foundations, with much work put into the planning and testing of techniques, refinement of goals and reduction in sources of error before actual monitoring can take place. The advantages in taking the time and expending the effort, and cost, to establish the most effective programme must remain in the forethought of managers who are anxious to get answers quickly. The right information which takes time to get is undoubtedly better than the wrong information which is gained quickly, particularly if management decisions are made which may affect the viability of an endangered species. It is recognised that many decisions have to be made quickly, but it is of great benefit to have in place a system which consistently provides baseline ecological information, from which future decisions can be made. This is particularly true when considering the monitoring of vegetation, on which many species rely.

4.91.1 Achieving programme initiation.

The initiation phase involved three main points of the top ten list of requirements for a good monitoring system (Chapter 3): a programme must be well informed, identify key information and put the monitored species first. The main activity in this phase of development is research to identify the key information required to inform effective management, determine how to collect it and to set out the main goals.

The need to quantify the level of vegetation damaged by browse within the Sweetwaters reserve area was identified. Vegetation is an asset (Briggs and Freudenburger, 2006) and indeed, its presence is fundamental to conservation and its monitoring is essential for effective management. Although effective large scale monitoring can be achieved by remote techniques (satellite and photography) (e.g.Wallace, 2006), and with the most severe damage being detected using such methods (e.g. Hong et al, 2004), in order to record the detail needed for effective vegetation monitoring in response to specific browsing, ground based sampling was considered to be the best and most practical method to use. The potential to incorporate remote sampling into Ol Pejeta Conservancies' (OPC) vegetation monitoring is great. It could for example, indicate the occurrence of severe damage and monitor large scale changes such as the spread of certain tree species, and the broad response of habitats to management activities over time. Even if this option was chosen in the future, good ground based sampling would still be required to ground truth remote data (Reinke and Jones, 2006), and also to collect more detailed information such as tree species diversity, regeneration and trends in specific browsing damage, rather than just an overall snapshot. A combination of remote and ground based monitoring may be of future benefit in vegetation monitoring for the now expanded OPC (e.g. Dougill and Trodd, 1999, Shuman and Ambrose, 2003).

The data collection technique which was developed for this vegetation monitoring system incorporates elements from many past studies carried out to assess browsing damage, particularly that caused by mega-herbivores such as elephants and rhinos. Many of these studies used plot surveys (e.g. Afolayan, 1975, Barnes, 1983, Ben-Shahar. 1993, Birkett, 2002, Buechner and Dawkins, 1961, Walpole, 2004), sometimes located to incorporate different habitat types and characteristics (e.g. Afolayan, 1975, Ben-Shahar. 1993, Birkett, 2002, Buechner and Dawkins, 1961), and scoring systems for assessing vegetation damage (e.g. Croze, 1974, Kabigumila, 1993, Tchamba, 1995). Results from such studies have found severity of browsing to vary with habitat type, with denser habitats or those closer to water, suffering from higher browsing pressure and tree mortality (Barnes, 1983, Ben-Shahar, 1993, Walpole et al, 2004). Therefore the monitoring system was designed to represent the variety of habitats within the reserve. The system also incorporated suggestions that a full population must be represented, but that a full census is impractical. Instead survey sites should be located within consistent habitat types, distributed to represent spatial variation and that raw measures (quantitative data) are collected in the field for later refinement (Brown and Saunders, 2008, Manley, 1992, Reinke and Jones, 2006). Having its foundations based in literature the vegetation collection technique was developed and on achieving the initiation phase of development, mobilisation could begin.

4.91.2 Mobilising the monitoring programme

The main activity of the mobilisation phase of monitoring system development is to carry out a pilot study incorporating knowledge carried forward from theoretical research. In this study, the pilot involved testing the vegetation data collection technique, on the survey sites but by using different field methodologies, in order to identify the best of them. A perfect scenario would have been for one surveyor to collect all the data using a variety of methods, but with time and funding constraints, a number of surveyors collected the data using their own methodology, which also provided the opportunity to test variability between surveyors.

An important finding from this study is that even with thorough training and consistent field conditions, there is the potential for great variability in results derived from different surveyors, even when surveying the same area. Some surveyors were found to be consistently positively or negatively biased in their data collection, with others highly variable. Variability was also seen with the same surveyors repeating the same plot and transect survey. Out of nine surveyors, one was found to be consistently middle ranking for ecological variables recorded within the test plot survey. This is a significant finding and may prove the benefit of pre-training and testing surveyors which are available for collecting field data. This would then lead to choosing the one or two which are most consistent, in order to reduce error and achieve the most effective monitoring. It also proves that without doubt to achieve the best monitoring, the data must be collected by the same surveyor year on year, but variability should always be expected, even though variability was seen to decrease with experience.

Notwithstanding the variability between surveyors, the pilot was successful in that it demonstrated the vegetation data collection technique itself to be effective. Results from each method and surveyor would have concluded most trees to be below 2 metres tall, with both elephant and rhino damage to be in accordance to abundance, occurring mostly to trees under 2 metres tall, and that the majority of browse was not severe. Therefore similar trends were seen for each method. Results of the pilot study also provided basic ecological information for future comparison by calculating a mean level of damage. At this stage, there was a mean of 41% of trees recorded as damaged, and of the total number of trees included, elephants had browsed a mean of

17%, rhino 16% and giraffe 7%. These results suggest that there is less damage here than in other sites. For example, Walpole et al (2004) recorded 77% of individual plants to be browsed by elephant in the Masaai Mara, Kenya, and Afolyan (1975) found 24.3% of trees in a forest plantation to be damaged by elephant. In their study, Birkett and Stevens-Wood (2005) found elephants responsible to 40% of *Acacia drepanolobium* losses, and rhinos 33%. However drought affected another 27%, and may even have hindered the recovery of browsed trees. In concurrence with a similar study by Tchamba (1995), the pilot study found most trees un-browsed, and most browsing not to be serious.

Following the success and applicability of the data collection technique, this was carried forward in the development of the monitoring system. One of the main aims of the monitoring system was to collect the maximum amount of information with minimum costs, an important factor also recognised by Carlson and Schmeigelow (2002). They recognised that effective monitoring requires efficient use of funds and their study involved integrating power and cost analyses to identify a cost-effective sampling strategy for forest birds. Their advice was to take a hybrid approach in monitoring system design whereby both power and optimisation are considered: such an approach was taken by this study.

Firstly, it was important to incorporate cost effectiveness into the design of the monitoring system. Costs in this study were understood to be the cost of equipment, and most importantly the time taken to carry out the data collection. It was obvious that the larger survey sites took longer to survey and also to set up in the field. It was therefore decided that to determine the optimum design, the amount of ecological data would be weighed against the area surveyed, thus identifying the area which would give maximum information, but with minimum cost (time). The analysis was successful in identifying the optimal method (10x10m plot), and the optimal area ($400m^2$), and the field design was established (20x20m plot subdivided into 10x10m blocks). The optimisation analysis had also identified the method which was used by the most consistent surveyor, therefore the positive and negative biases, or variability measured with the other surveyors have minimal impact on the final field design for this monitoring system. At this point, the optimal system had been established but its power was still to be determined.

4.91.3 Implementing the designed system.

Testing the developed technique through implementation in the field could be described as the true pilot, and forms part of the strategic planning stage of the implementation phase of the monitoring development model. It is also during this part of development that original goals identified during initiation are refined. The main aim was for a monitoring system to be powerful enough to detect a change in browsing damage over a 5 year period.

Ecological results indicated the technique to be reliable, as similar levels of damage were seen compared to the mean values determined from the original pilot study during programme initiation. Overall damage was recorded as increasing by 3.7%, with elephant browse increasing by 0.8%, rhino 7.2% and giraffe 3.7%. This may reflect true changes in the levels of browsing, or it may be due to variability as the same surveyors were not recording the new field data and these results are a single calculation, not a mean value. Also damage which may be a year old will still be recorded by the method, some trees may recover quicker than others causing variability in the levels of damage recorded. It is good however that the method concentrates on a full survey rather than just recording new damage as this cancels out the effect of potential seasonal variation, the problem in identifying how old is too old, and any increase in browsing will still be detected. What is encouraging is that the same conclusions as the previous survey can be drawn: most damage occurred to trees less than 2 metres tall, rhino browse is the most common browse type, the majority of browse recorded did not cause severe damage, and there are more trees un-browsed than browsed by elephant, rhino and/or giraffe.

The survey was found to have the potential to quantify other ecological information which may be of possible management interest, such as the indication that some plots are browsed more than others and that rhinos and giraffe like to feed in similar areas, or potentially that both species avoid browsing in the same areas as elephants. Another explanation could be that elephants browse more generally, causing there to be no detectable statistical association with other species. Such indications have been made possible by the calculation of the Damage Product Score (DPS). In combining the collected quantifiable data (number of main stems damaged) with the more subjective grading data (damage class), the DPS is successful in providing one measure of browsing damage which not only measures damage presence but also its severity. Therefore, the higher the DPS, the greater the presence and severity of browsing damage. This can be calculated per survey, per plot, and even though it was designed to give an overall picture of browsing damage, it can also be separated for each browser and tree species should management require such information. The potential usefulness of such a measure is further demonstrated with findings such as the least common trees having a higher DPS. Therefore, on the whole, the technique also has the potential to identify a possible predeliction of browsers to certain tree species, although separate associations between browsers and trees were less clear. The obvious usefulness of the calculation of the DPS is to provide a baseline measure of overall vegetation damage on a yearly basis. For 2006 the DPS was 1.42, which may then provide the starting value for future monitoring to be compared to.

This study found the 15 monitoring points to be on the whole representative of browsing damage occurring within what was the Sweetwaters area, following results from comparison plot data. This is encouraging in that the initial set up, based on theoretical advice, was successful in determining plots which were fully representative. However, the comparison plots were located only 1km away from the original plots and therefore may have been classed as the same habitat type and may also be within the range of the same animals which browsed the monitoring sites. There was also evidence of browsing patchiness. Although overall conclusions from the comparison and monitoring plots would have been similar for the levels and types of damage, browsing was shown not to be uniform. Therefore, different sites, even if close by can be expected to have variable levels of species specific damage. This was found to be the case for rhino, indicating they do not browse particularly evenly. The monitoring sites succeed in providing and overall picture of vegetation damage due to browsing within the Sweetwaters area, but to be representative of the full area of OPC, it is suggested that the number of monitoring sites would need to be expanded in proportion to the area of each habitat type now included.

Where programme initiation found the possibility of problems caused by variability in the data collected by different surveyors, the control plot survey using the designed field technique actually provided encouraging indications that the method is as stable as possible. Overall, regardless of a change in surveyor or plot type (sub divided or full) no significant differences in the total number of trees and trees recorded as damaged were seen, potentially the most important variables in the monitoring system. Some differences were recorded for specific browsers, particularly rhino but this mostly may have been due to a difference in the perception of what was true rhino browse by one of the surveyors. It was also clear that sub-dividing the plot had obvious benefits by maintaining motivation and aiding orientation in the field and in the fact that the subdivided plots consistently recorded higher means for the variables collected. It is suggested, therefore, that fewer trees and so fewer data are missed by surveying an area in such a clear strategic way. Even though such results suggest the technique may be reliable, the test involved using only two surveyors which were also experienced in using the method. It confirms therefore, that an optimal monitoring system should use the same surveyor to collect the data repeatedly, as individual people will undoubtedly differ in the visual data they collect, as indicated by the pilot study.

Although this study shows the developed system uses an optimal survey design coupled with an effective data collection technique, this is not entirely useful unless the full survey is powerful enough to detect true trends. Following on from the suggestion of Carlson and Schmeigelow (2002), the potential power of the system needed to be combined with the optimal design. Through the use of linear regression analysis on extrapolated data for the number of damaged trees recorded, the technique was found to be powerful enough to detect a 42% change in the number of damaged trees over 5 years (8.4% a year). It must be remembered that this represents all browsing damage, including minor damage, and does not mean that it only detects severely broken trees that will not survive. Birkett (2002) studied elephant, rhino and giraffe browse on tagged *Acacia drepanolobium* trees in Sweetwaters and found tree damage rates to be high, and predicted that if elephant and rhino populations continued to increase as they were at that time, 32% of *A.drepanolobium* trees could be lost (4.6% p.a). This monitoring system is not tree species specific, and so it has its benefits in representing all woody vegetation, but it may not be sensitive enough to detect the rate of decline predicted specifically for *A.drepanolobium* trees. However, the technique was calculated as being more powerful when incorporating the DPS per plot into the analysis. Here the technique could potentially detect a 28% change in DPS over a 5 year period (5.6% p.a). This would be more useful than just detecting the number of damaged trees, as the DPS represents occurrence of damage and its severity. Therefore, if DPS was recorded as increasing on a yearly basis, this is an indication that the severity of damage and not just its occurrence is also increasing. What this study does not quantify is the occurrence and rate of recovery or recruitment of new trees (e.g. Birkett, 2002). An indication of the number of trees of recruitment height (<2m) could be indicated by this monitoring system, but on the whole damage is the focus, so including measures of recruitment and re-growth into monitoring may be a management option should a system such as this be adopted.

4.92 The end goal – Effective monitoring.

4.92.1 Has development been successful?

The design stage of any monitoring programme demands considerable attention (Smyth and James, 2004), and any successful long term programme must be cost efficient as well as effective enough to answer management questions and meet objectives (Carlson and Schmeigelow, 2002, Caughlan and Oakley, 2001, Watson and Novelly, 2004). This study followed a development system which was derived from literature and the opinion of conservationists and scientists as to what is required for a good and successful monitoring system. Other studies have focused on financial costs (e.g. Caughlan and Oakley, 2001) as a basis around which to develop a monitoring system, this study has also focused on reducing basic cost: time, but has also involved programme optimisation and power as suggested by Carlson and Schmeigelow (2002). Watson and Novelly (2004) stated that the strength of a monitoring system would be compromised if it attempts to answer too many questions, or if a single question is posed too broadly. The planning of this system involved finding a survey which could detect a change in vegetation damage over a 5 year period, this question would also not change over time. It is therefore suggested that this system has grown from a simple need to quantify vegetation damage reliably and with sustainability in mind.

The development of this system moved smoothly through each stage of the process and has successfully incorporated an awareness of cost, variability, optimisation, power, reliability and sustainability into its core design. It is a process which takes a lot of time, funding and energy to enact, with the potential for many evaluations to take place, causing the process to step backwards and for changes to be made. This monitoring system achieved the processes of initiation, mobilisation and implementation as suggested by the development model, and so development has been successful.

4.92.2 Will this system work?

In summary, the monitoring system tested here has a strong theoretical basis, with both power and optimisation incorporated in its development. The system uses a 20x20 metre plot, subdivided into 10x10 metre block, which is easy to set out, quick to survey, and which helps to maintain orientation and momentum during the data collection. Plots are located within the main habitat types and within areas of varying rhino density, and are proven to be representative of the reserve, but it is recognised that browsing is not uniform and some areas may appear more damaged than others. The problem of potential variability and bias between different researchers has been explored and recognised that it is undoubtedly optimal to have the same person collecting the key monitoring data on a yearly basis.

The survey technique has been found to be potentially effective during its development. Should the programme be adopted by management of OPC, some suggested measures provided by this system which may be the most useful include: the percentage and/or proportion of damaged trees and the DPS per year, particularly as the DPS incorporates a measure of damage severity. More variability can be expected with the finer scale data, for example specific damage caused by browser species or suffered by specific tree species, but the system is also able to give an indication of patterns in those variables.

Translation of the system to the research department was successful in that the staff involved quickly acquired the set techniques in the field and used the data storage and analysis supplied with the workshop successfully. The flexibility of the system also makes it possible for other important data to be collected, for example to monitor the spread of *Euclea divinorum* within the area, and it could possibly be expanded to incorporate monitoring of the vegetation across the whole of the conservancy now the fences have been removed (Gitchohi, pers.comm, 2007).

Overall, in following the top ten requirements, and the monitoring system development model, as well as incorporating power and optimisation, testing for bias and including training, the system is believed to have good potential to monitor the impact of browsing on the vegetation of what was Sweetwaters game reserve. If such information is required by the management of OPC, here is a system which is able to be expanded, and collects key information with minimal costs (time, equipment), is easy to use (both in collecting and analysing the data) and which can identify true trends, thus effectively monitoring damage to vegetation caused by elephant, rhino and giraffe browse.

4.10 Conclusions

- A successful monitoring system requires good foundations and recognition that correct information gained over a longer time period is better than hastily gathered information which may be unreliable, particularly for the management of endangered species.

- Ground based sampling is the most practical method to obtain detailed vegetation data, but there is potential to incorporate remote sampling to give a broad assessment of severe damage and vegetation change.

- With thorough training and consistent field conditions, if using different surveyors the potential for variability in results is high, although variability decreases with increased experience.

- Browsing is not uniform and variability in data collection should always be expected, particularly with fine scale data.

- To achieve the best monitoring standards, data should be collected by the same surveyor for the entirety of the programme, and pre training and testing surveyors to identify the most consistent is recommended.

- The vegetation data collection technique has been shown to be effective, with the calculation of the DPS providing one measure of browse incorporating both presence and severity.

- Plot subdivision stratifies data collection, maintaining motivation and orientation, thus less data are missed.

- The 15 monitoring plots are representative of browsing damage across the Sweetwaters area, but to be representative of the whole of OPC the number of plots would need to be expanded proportionately.

- This system is both optimal (time efficient) and also powerful enough to detect true changes in vegetation damage annually.

- This study has successfully designed a system which meets the top ten requirements, has successfully completed each stage of the design process, and which now has the potential to monitor the long term impacts of browse on the vegetation of OPC.

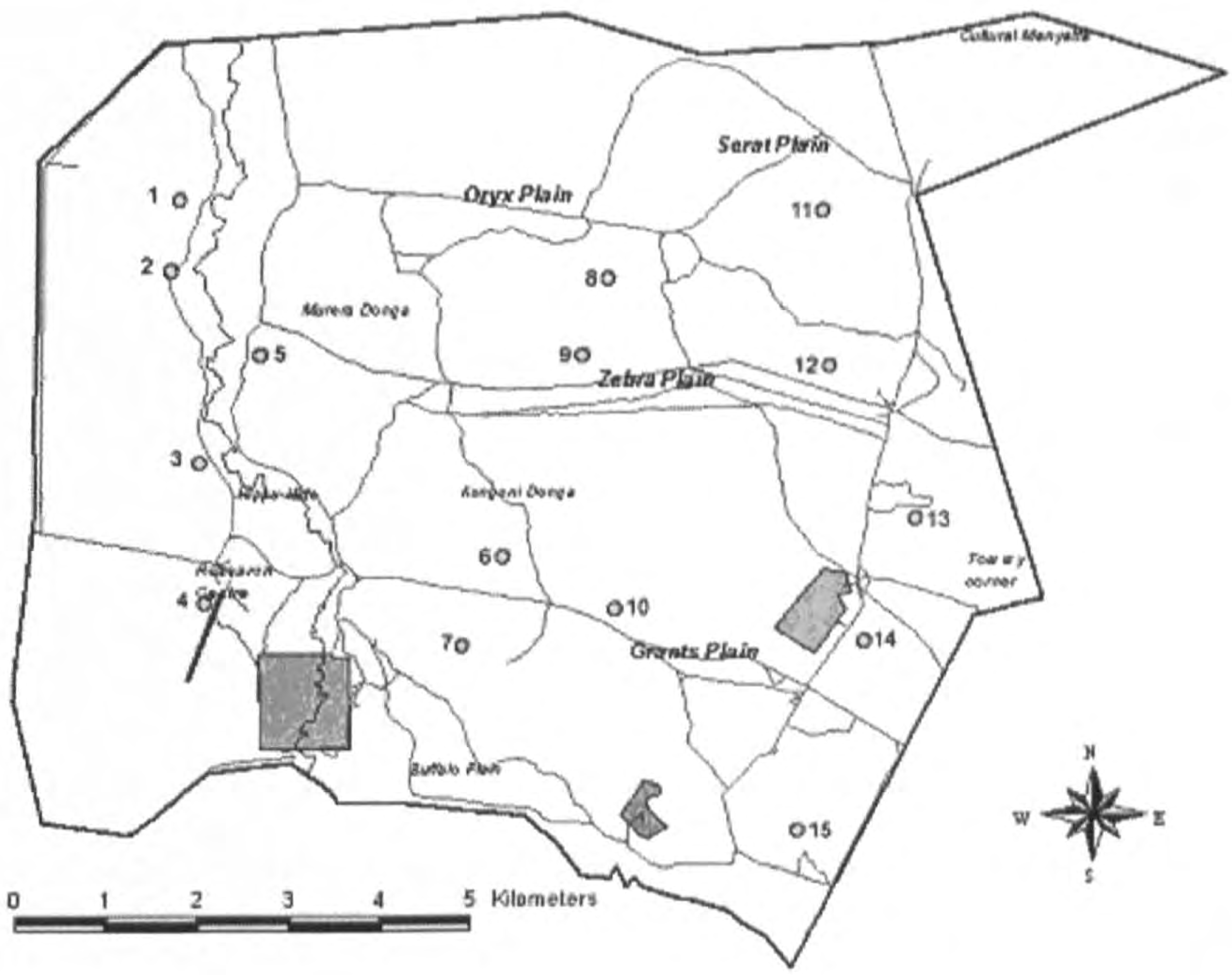


Figure 4.1: Map of Sweetwaters and monitoring plots
Locations of the 15 monitoring plots in Sweetwater Game Reserve, Kenya.
Map courtesy of Ol Pejeta Conservancy

Rhino density	***Habitat Type***				
	Acacia	Mixed Acacia Dominant	Mixed Euclea Dominant	Mixed	Riverine
High	11, 14	13	7	10	
Medium	6	8	1	12	2
Low	9	4	5	15	3

Table 4.1: Rhino density and habitat
Habitat Type and Rhino Density for each Plot

- 50x20m belt (1000m²)
  From the GPS point, measure 50 metres south. This forms the centre line. Measure 10 metres either side of the end of that line and mark the corners of the belt. Survey the vegetation and dung within that area.

- Nested square plots (*Krebs, 1999*) (100m² vegetation survey)
  10 x10m square plot, within a 25x25m square plot, within a 50x50m square plot
  From the GPS point, measure 10 metres north and mark that corner. Then measure 10 metres East to mark the next corner, then 10 meters South to mark the final corner. Survey the vegetation within that block. To complete the method, extend the plot to 25 x 25 metres, and 50 x 50 metres from the same GPS point (dung survey only in these plots)

- 20m diameter circular plot (314.2m²)
  From the GPS point, fix the tape measure to the point and measure 10 metres. Survey the vegetation and dung in a 10m radius from the central point.

- Plot less sampling (*Krebs, 1999*)

  - T squared (T²) &Ordered distance (OD) (3 most common tree species)
    T²: From the GPS point, measure the distance from that point to the nearest tree (e.g.*A. drepanolobium*). Then measure the nearest neighbour (other *A. drepanolobium*) to that tree (providing the second tree is angled at > 90° from the orientation of the GPS point to the first, nearest tree) Repeat this for *E. divinorum* and *S. myrtina*
    OD: Measure the distance from the GPS point to the third nearest tree (for *A. drepanolobium, E. divinorum and S. myrtina*)
    For both methods to increase the sample size, once the GPS point has been surveyed, measure 10m North and repeat the survey, then 10m East for a third survey, finishing by measuring 10m South for a final survey, thus recording 4 surveys at each of the 15 GPS sites.

  - Point quarter
    At the GPS point, face North and divide the area around the point into four quadrants (North West, South West, South East, North East). Measure the distance to the nearest tree from the point in each quadrant. Repeat this 20 metres North and then East from the GPS point, thus surveying 3 points per location.

- Point intercept transects (*Krebs, 1999*)
  From the GPS point walk West using the GPS and an compass to maintain bearing, for a set distance recording and surveying each tree and dung pile directly on the transect line. Note every 100 metres completed

Figure 4.2: Survey methods
Variety of vegetation survey methods used by students to assess browse on the 15 monitoring plots

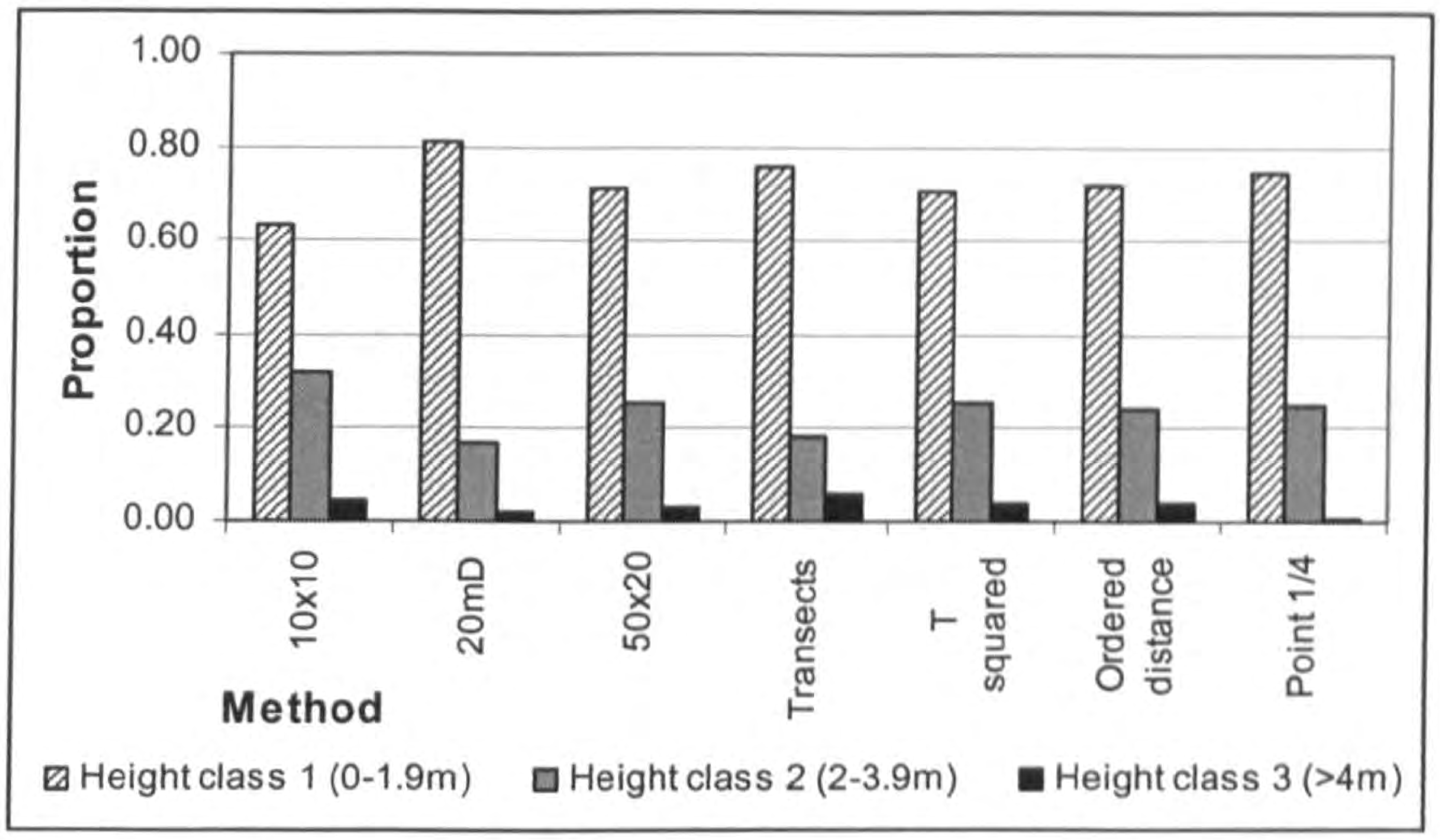


Figure 4.3: Trees in each height class
Proportion of trees in each height class for each method

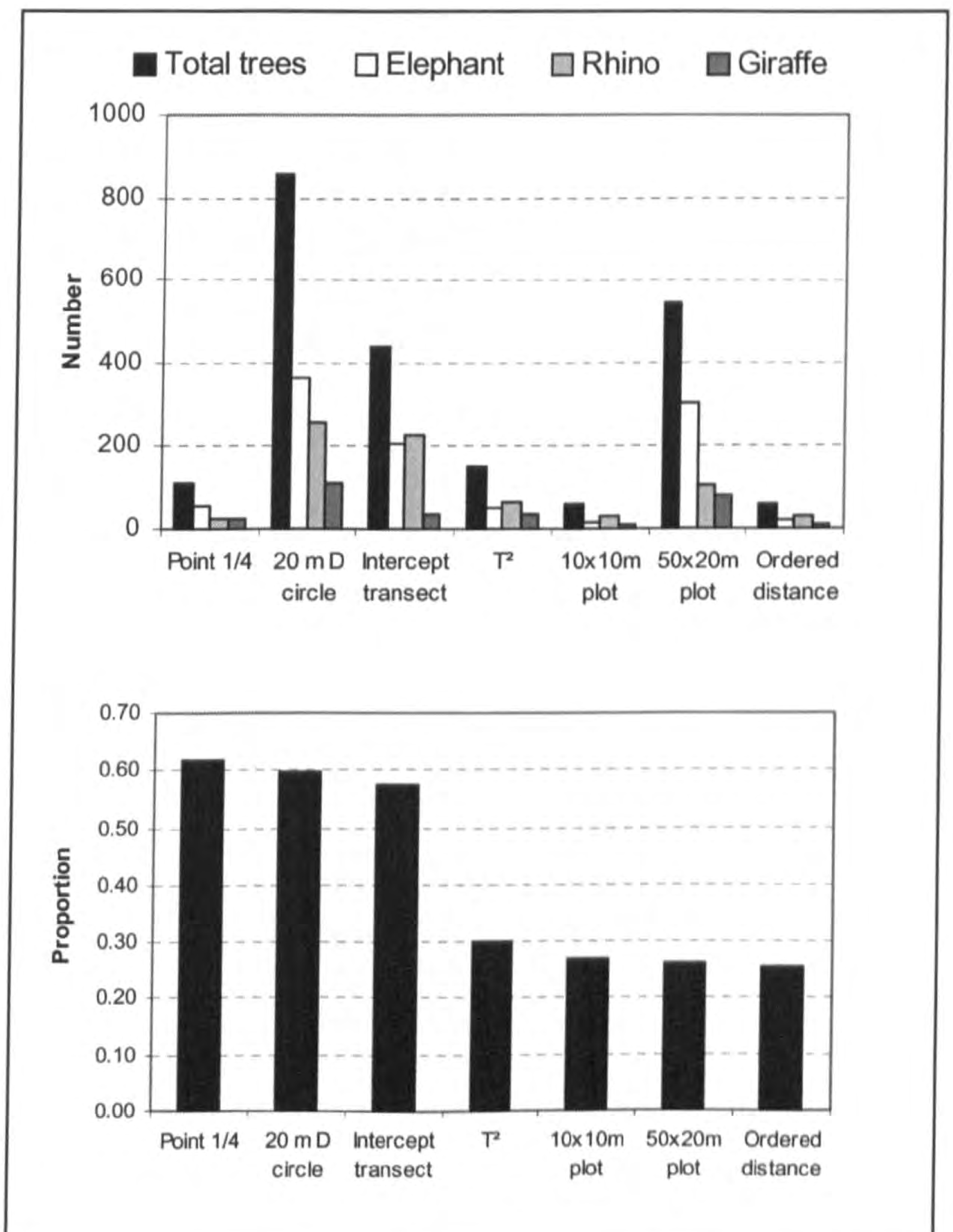


Figure 4.4: Number and Proportion of trees damaged
Number of trees damaged as a total and by each browser and the total proportion of trees surveyed as damaged on the 15 survey points by each method

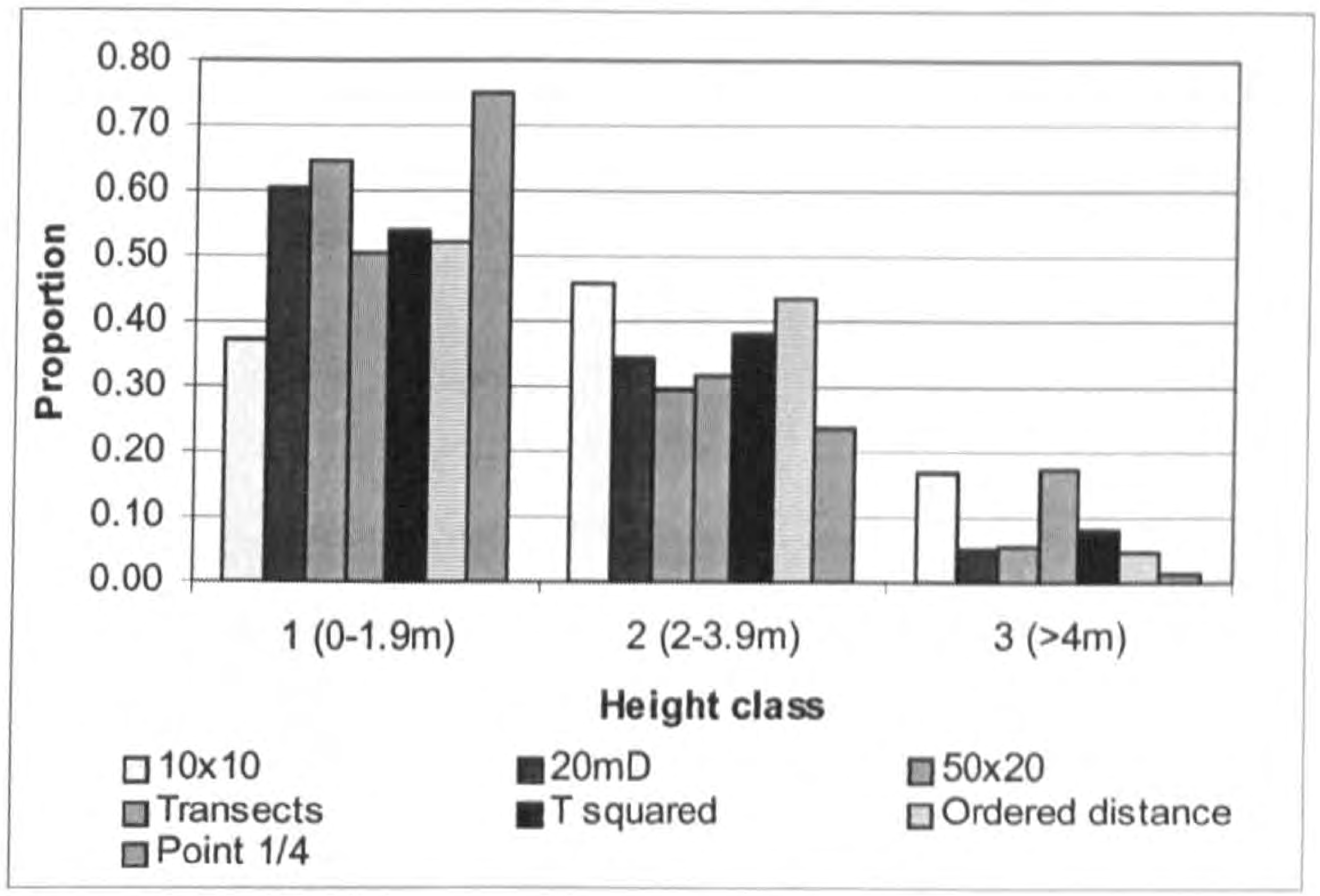


Figure 4.5a Elephant browse per height class

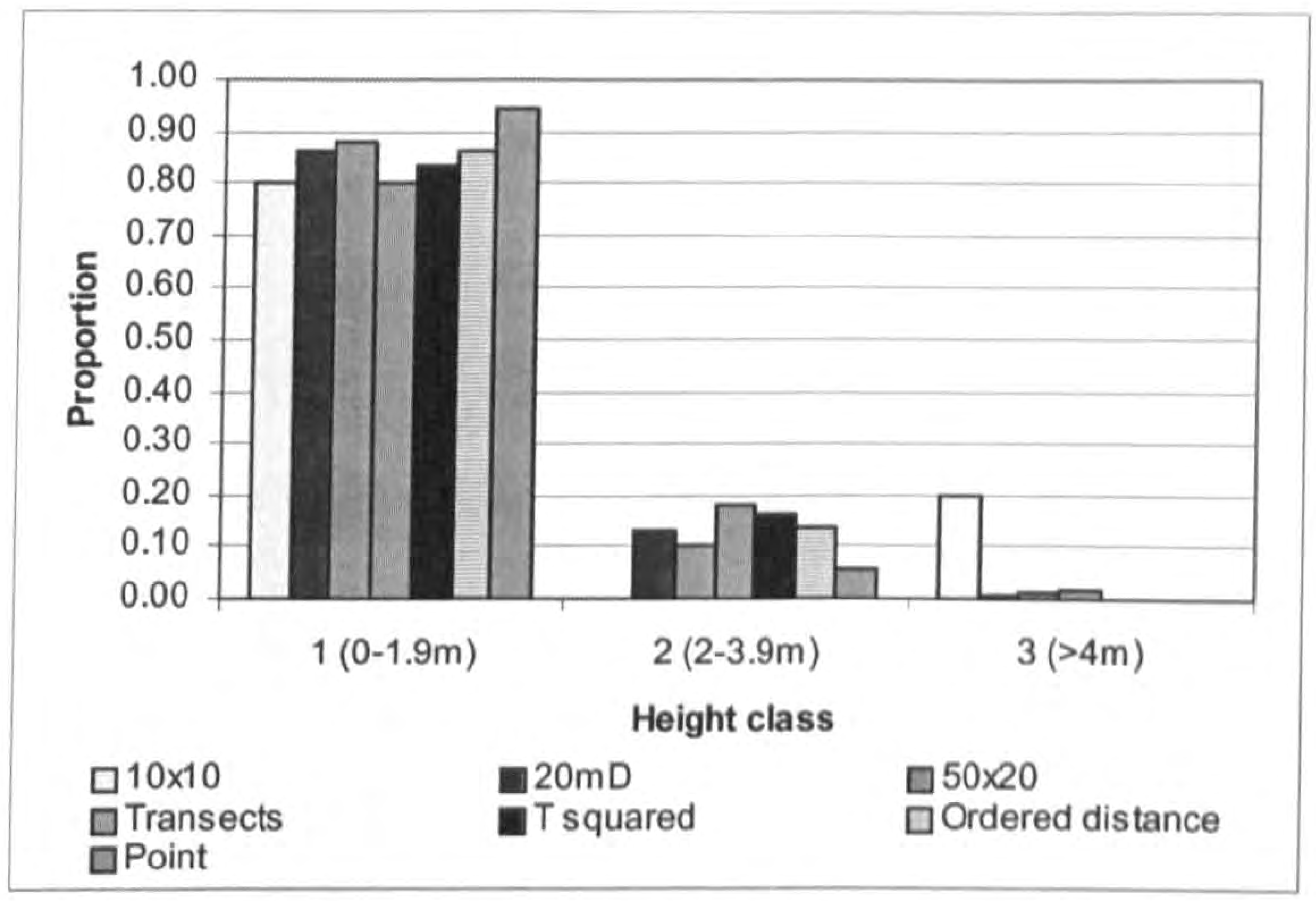


Figure 4.5b: Rhino browse per height class

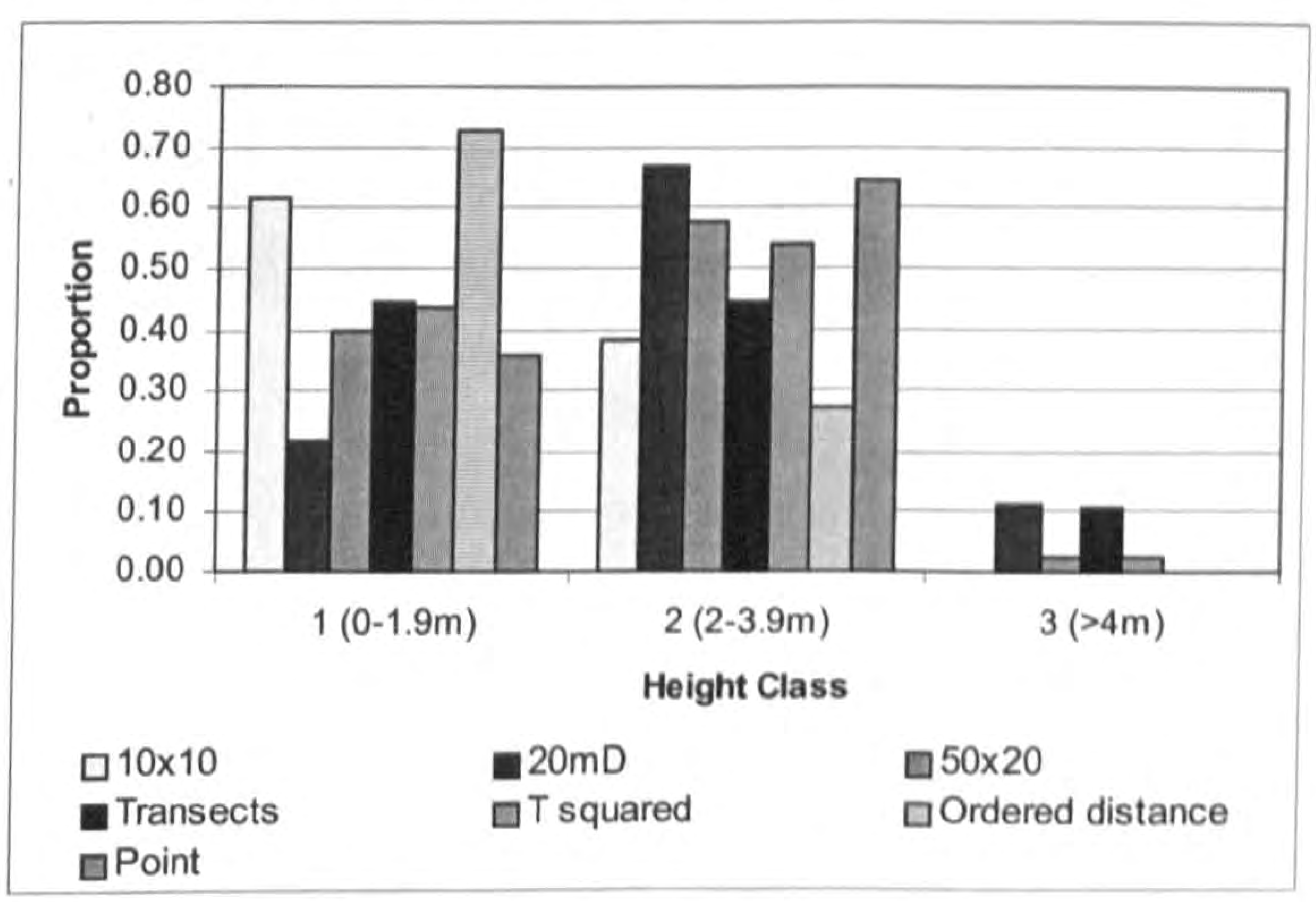


Figure 4.5c: Giraffe browse per height class

Figure 4.5 a, b, c: Elephant, rhino and giraffe browse per height class
Distribution of browse across height class (1: 0 – 1.9m, 2: 2-3.9m, 3: >4m) for all damaged trees for elephant (a), rhino (b), giraffe (c)

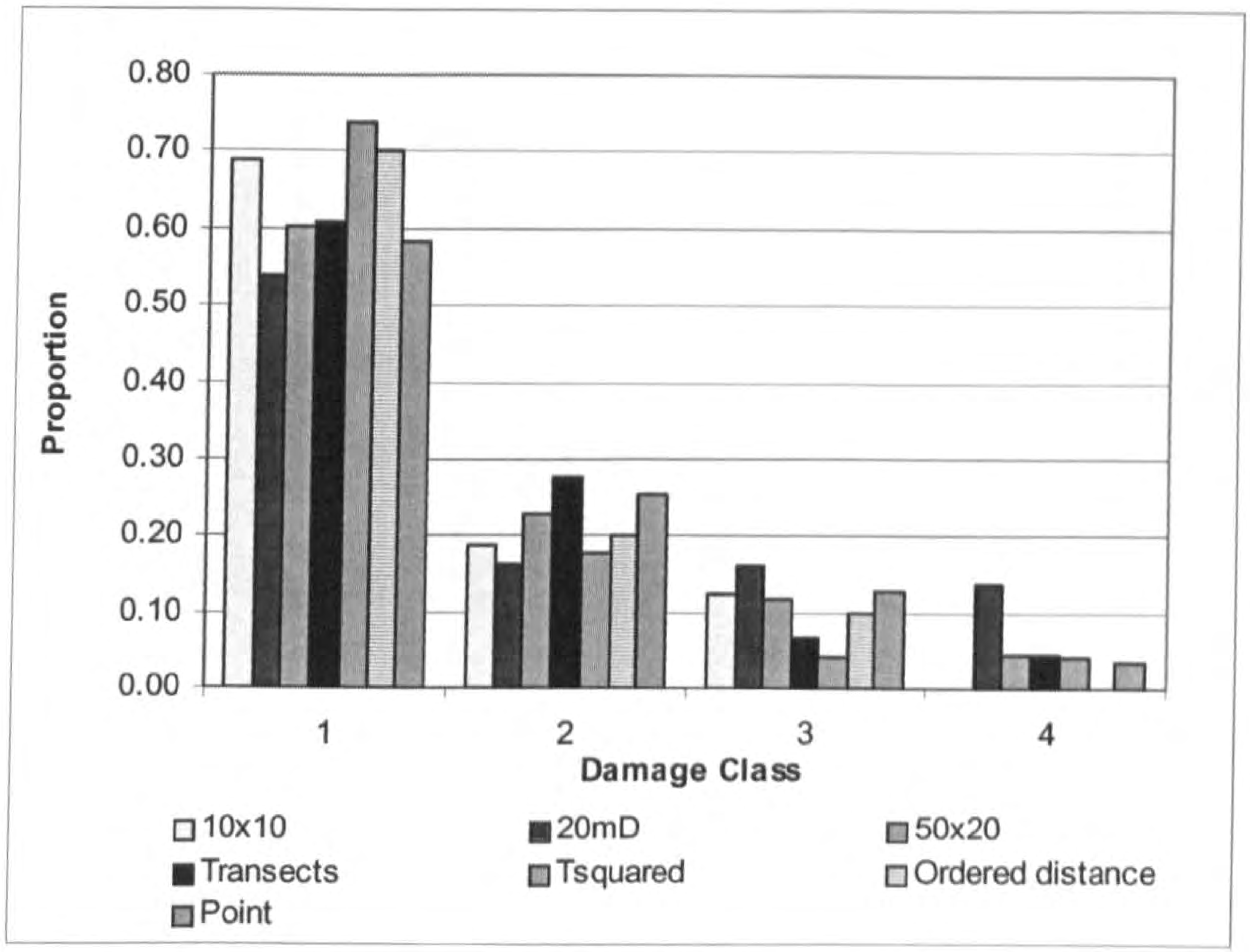


Figure 4.6 (a) Elephant browse damage class

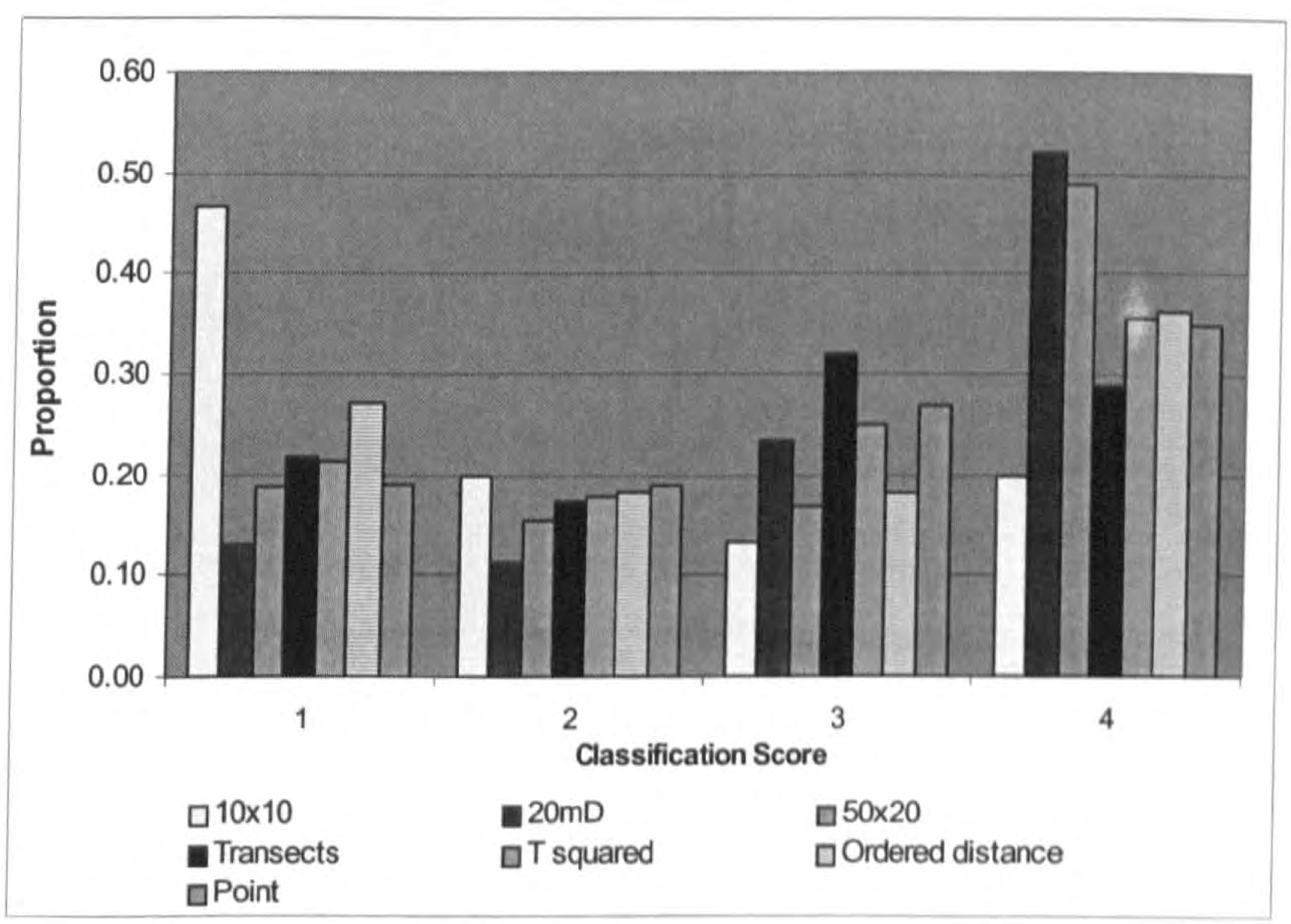


Figure 4.6 (b) Elephant browse main stem class score

Figure 4.6 a, b: Elephant browse severity

Proportion of Elephant browse in each Damage Class (1 = <25%, 2= 26-50%, 3=51-75%, 4= >75% canopy broken) (a) and Main Stem Class Score (1 = <0.25, 2= 0.26 – 0.50, 3= 0.51-0.75, 4= >0.75 proportion of main stems

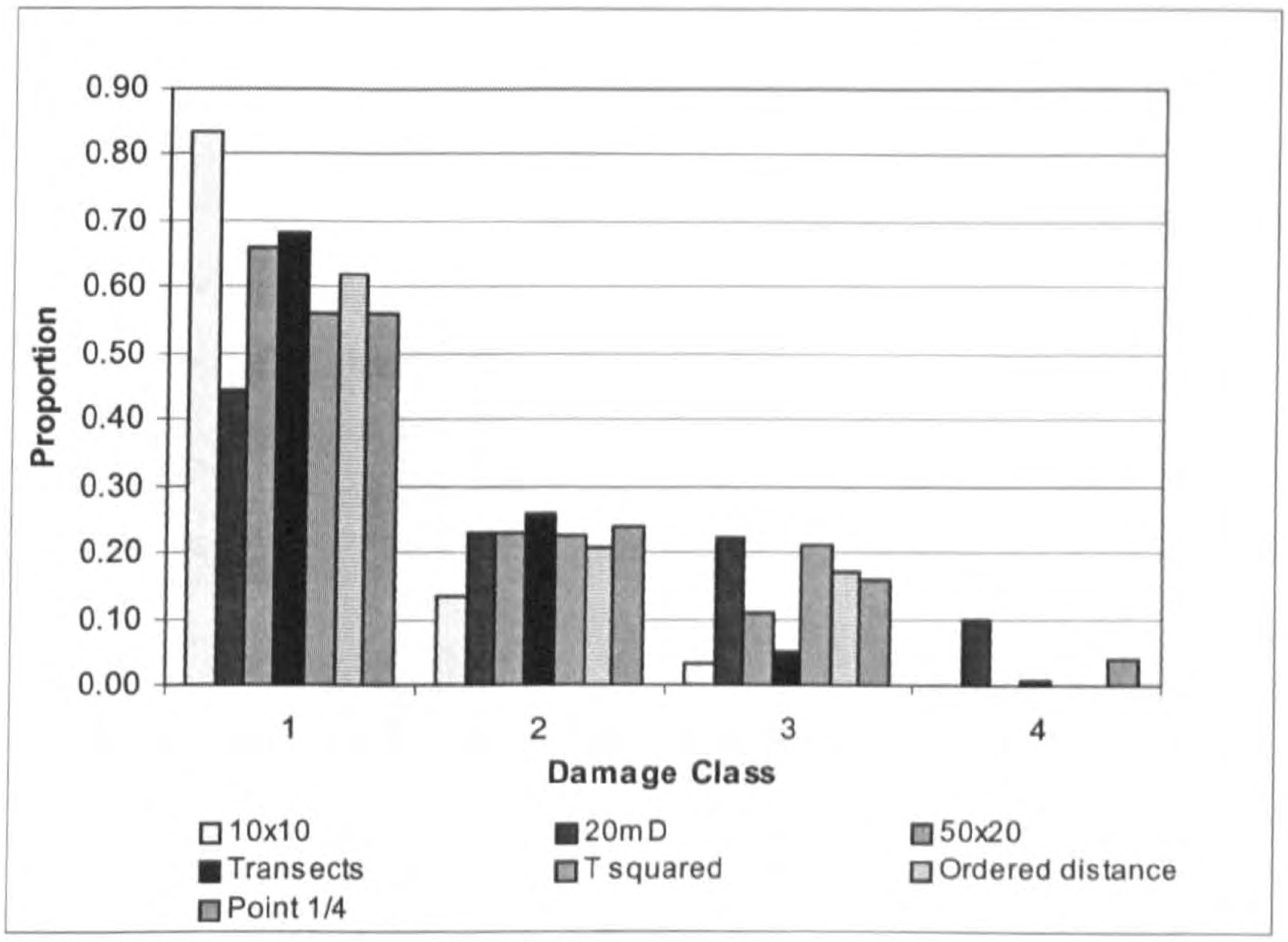


Figure 4.7 (a) Rhino browse damage class

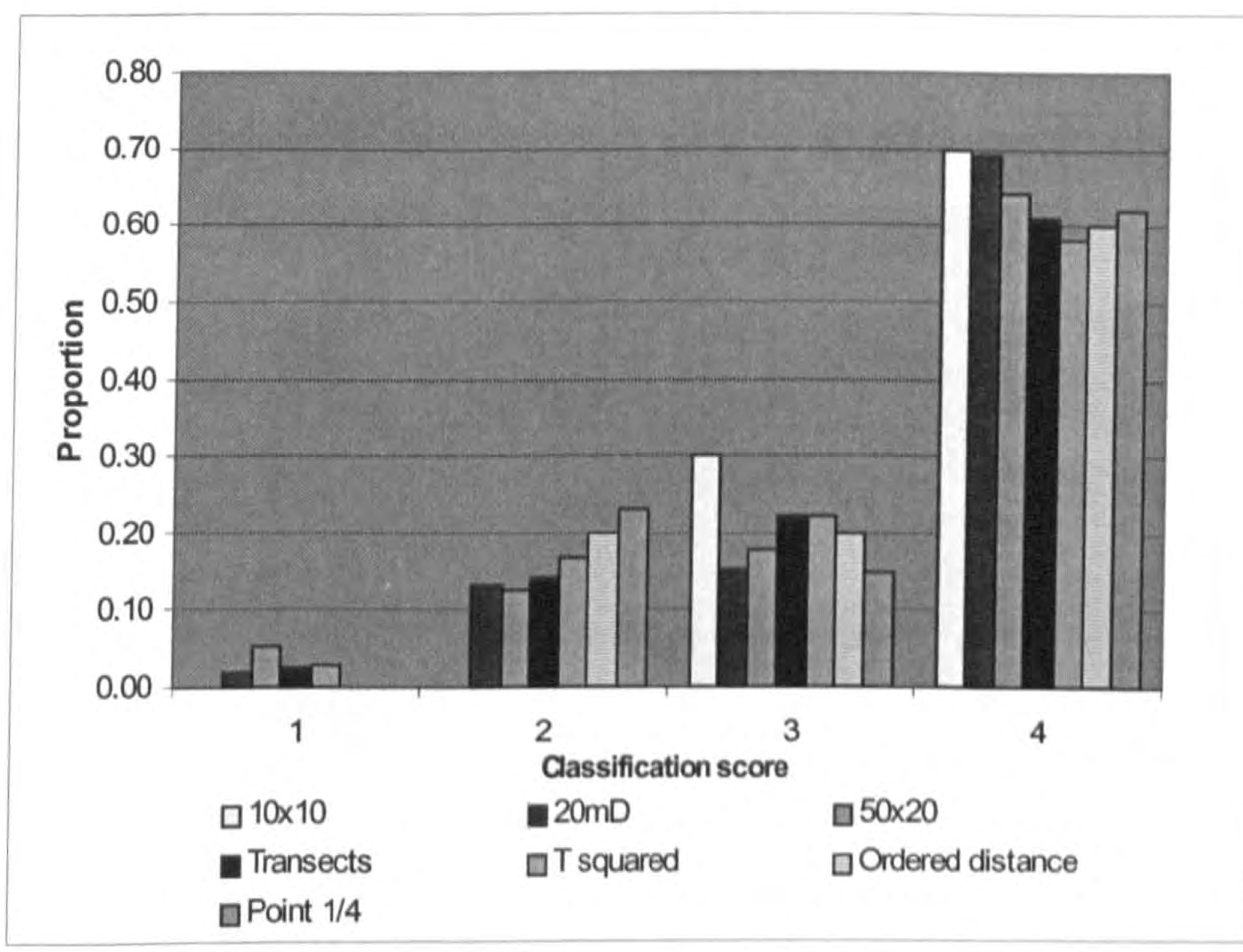


Figure 4.7 (b) Rhino browse main stem class score

Figure 4.7 a, b: Rhino browse severity

Proportion of Rhino browse in each Damage Class (1 = <25%, 2= 26-50%, 3=51-75%, 4= >75% canopy broken) (a) and Main Stem Class Score (1 = <0.25, 2= 0.26 – 0.50, 3= 0.51-0.75, 4= >0.75 proportion of main stems

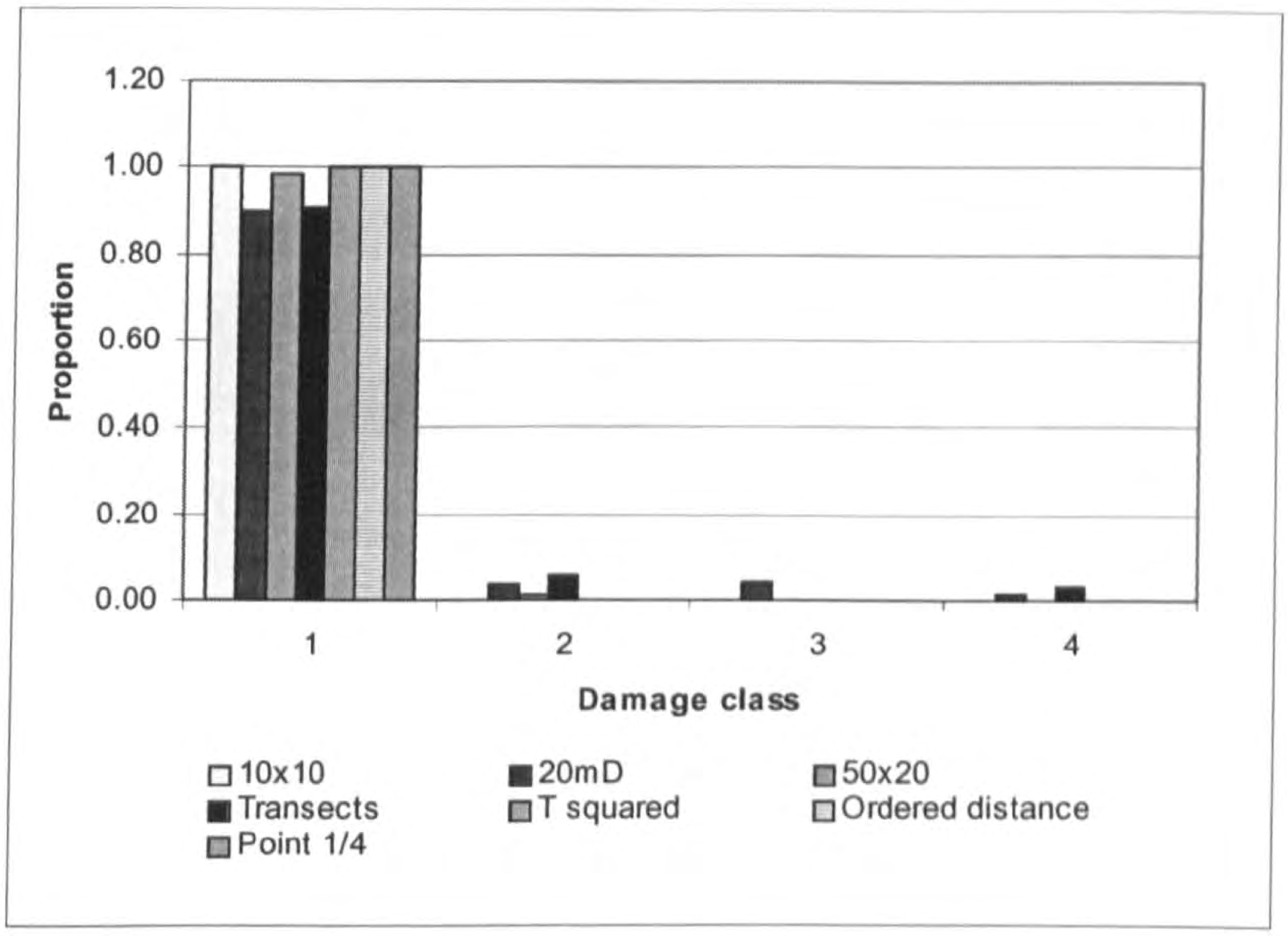


Figure 4.8 (a) Giraffe browse damage class

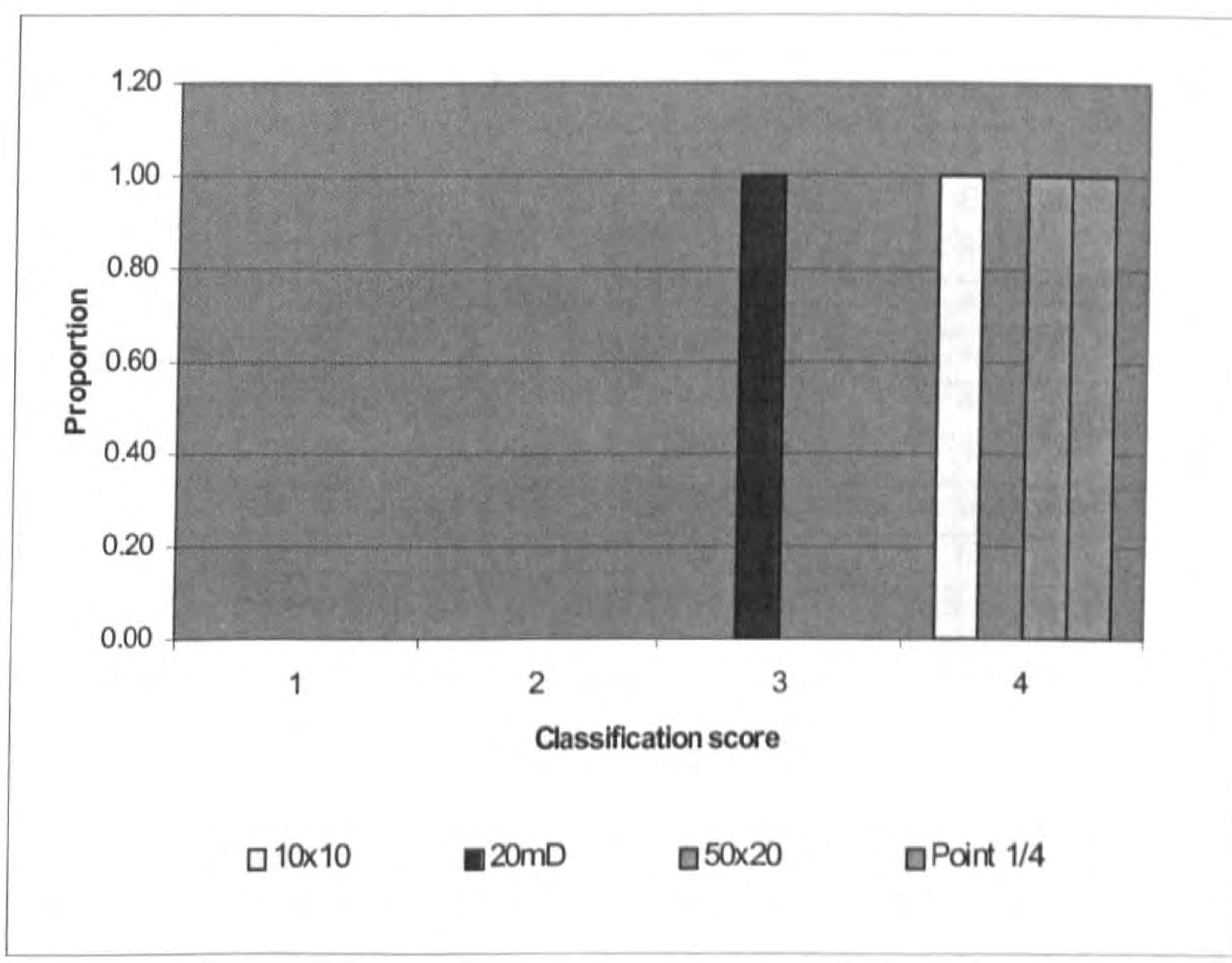


Figure 4.8 (b) Giraffe browse main stem class score

Figure 4.8 a, b: Giraffe browse severity
Proportion of Giraffe browse in each Damage Class (1 = <25%, 2= 26-50%, 3=51-75%, 4= >75% canopy broken) (a) Main Stem Class Score (1 = <0.25, 2= 0.26 – 0.50, 3= 0.51-0.75, 4= >0.75 proportion of main stems broken) (b)

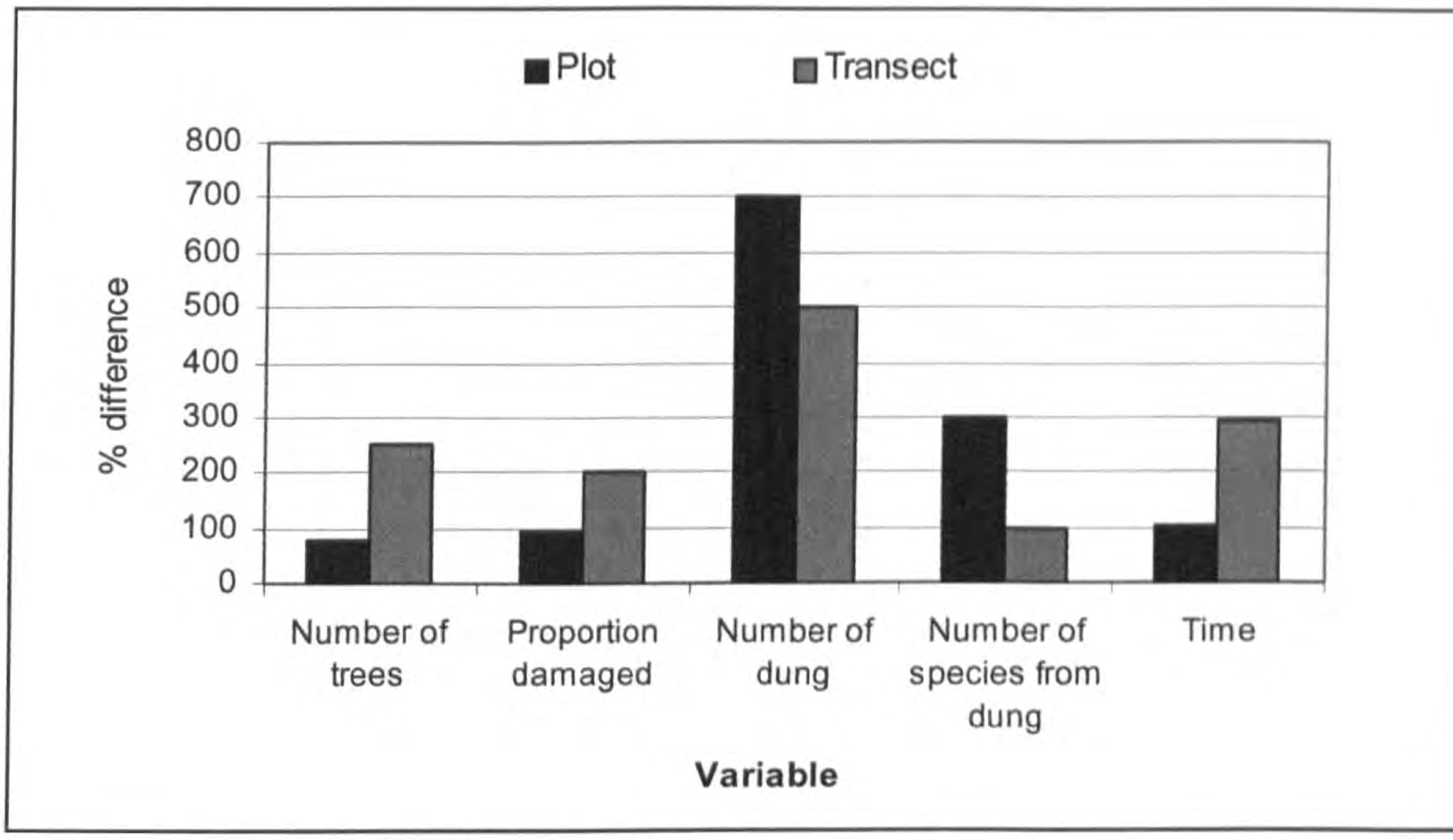


Figure 4.9: Difference between surveyors on test transect and plot
Percentage difference between the highest and lowest recording for each variable within the transect and plot

Survey	Surveyor	Total trees	r	Damage						Dung				Time (min)	r
				Trees	*Proportion*	*r*	*E*	*R*	*G*	*Total*	*r*	*Species*	*r*		
Plot	1	28	3	20	0.71	3	8	7	2	3	8	3	5	30	6
	2	31	2	26	0.84	1	12	5	3	6	4	4	1	42	2
	3	26	4	16	0.62	6	9	6	1	8	1	3	5	45	1
	4	23	5	10	0.43	8	7	2	0	8	1	4	1	26	8
	5	20	7	14	0.7	4	10	2	1	4	6	3	5	22	9
	6	20	7	16	0.8	2	11	5	5	4	6	1	8	35	4
	7	32	1	22	0.69	5	13	9	0	1	9	1	8	40	3
	8	23	5	10	0.43	8	2	3	4	8	1	4	1	29	7
	9	18	9	10	0.56	7	8	0	0	6	4	4	1	33	5
	Mean	*24.6*		*16*	*0.6*	*4.9*	*8.9*	*4.3*	*1.8*	*5.3*		*3*		*33.6*	
	SD	*5*		*5.7*	*0.1*	*2.6*	*3.3*	*2.8*	*1.9*	*2.5*		*1.2*		*7.7*	
Transect	1	6	3	6	1	1	5	2	2	12	7	5	2	51	1
	2	8	2	7	0.88	4	4	2	5	21	2	6	1	31	2
	3	4	8	4	1	1	2	1	1	24	1	5	2	17	6
	4	6	3	2	0.33	9	2	0	0	15	6	5	2	24	3
	5	4	8	3	0.75	5	0	2	2	20	3	5	2	13	8
	6	6	3	4	0.67	6	3	4	0	8	8	3	9	17	6
	7	5	6	5	1	1	2	2	2	4	9	4	8	13	8
	8	5	6	3	0.6	7	0	1	2	17	4	5	2	21	5
	9	10	1	5	0.5	8	3	2	0	17	4	5	2	24	3
	Mean	*6*		*4.3*	*0.7*	*4.7*	*2.3*	*1.8*	*1.6*	*15.3*		*4.8*		*23.4*	
	SD	*1.9*		*7.1*	*0.2*	*2.7*	*4.1*	*2.3*	*1.6*	*6.4*		*0.8*		*12*	

Table 4.2: Survey results for test plot and transect
Results from plot and transect survey for each surveyor. r = rank score (highest to lowest), St Dev = standard deviation from the mean.

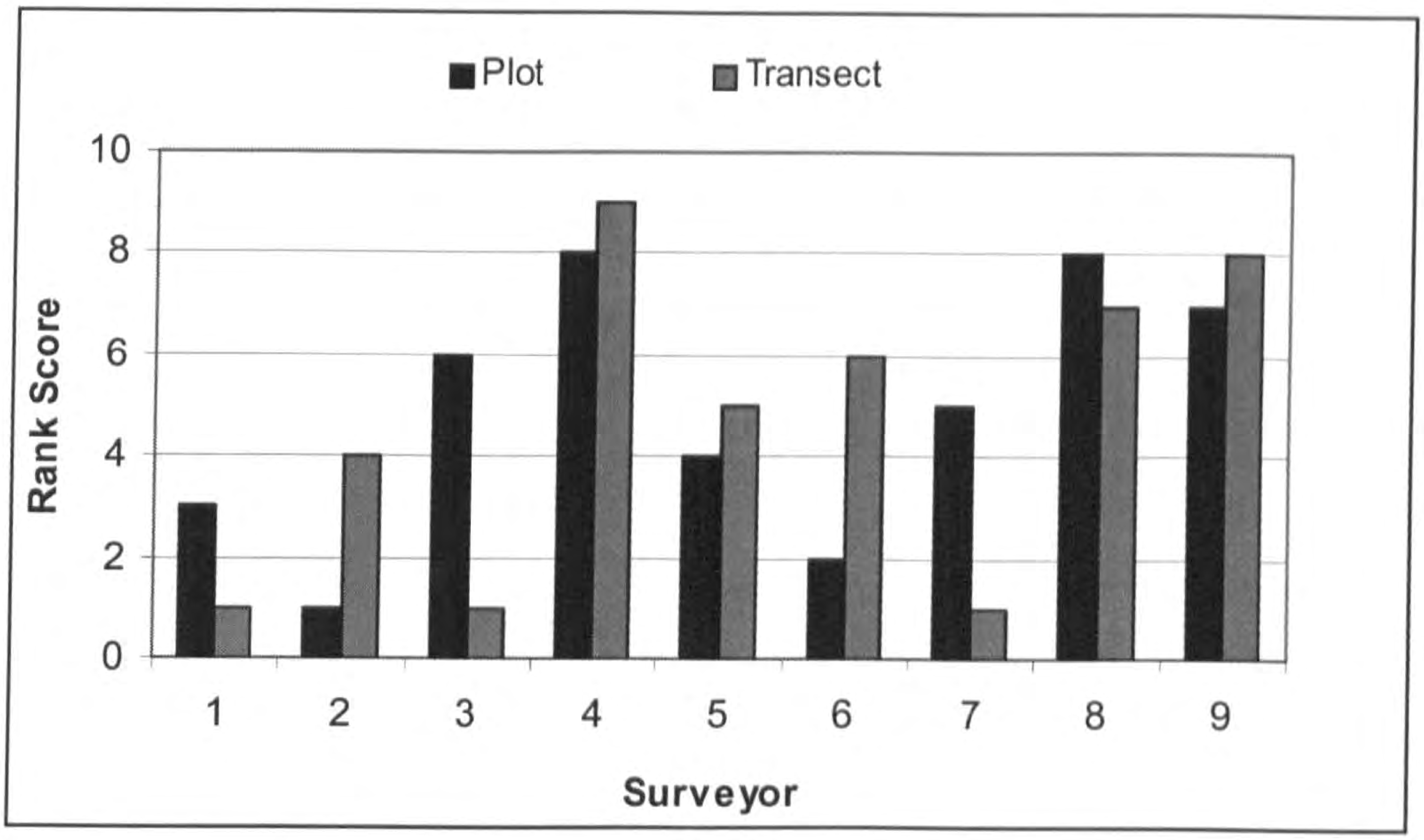


Figure 4.10: Rank scores for test plot and transect
Individual rank score per surveyor for the proportion of trees surveyed as damaged
(***rank 1 – 9 = highest to lowest proportion of trees recorded as damaged***).

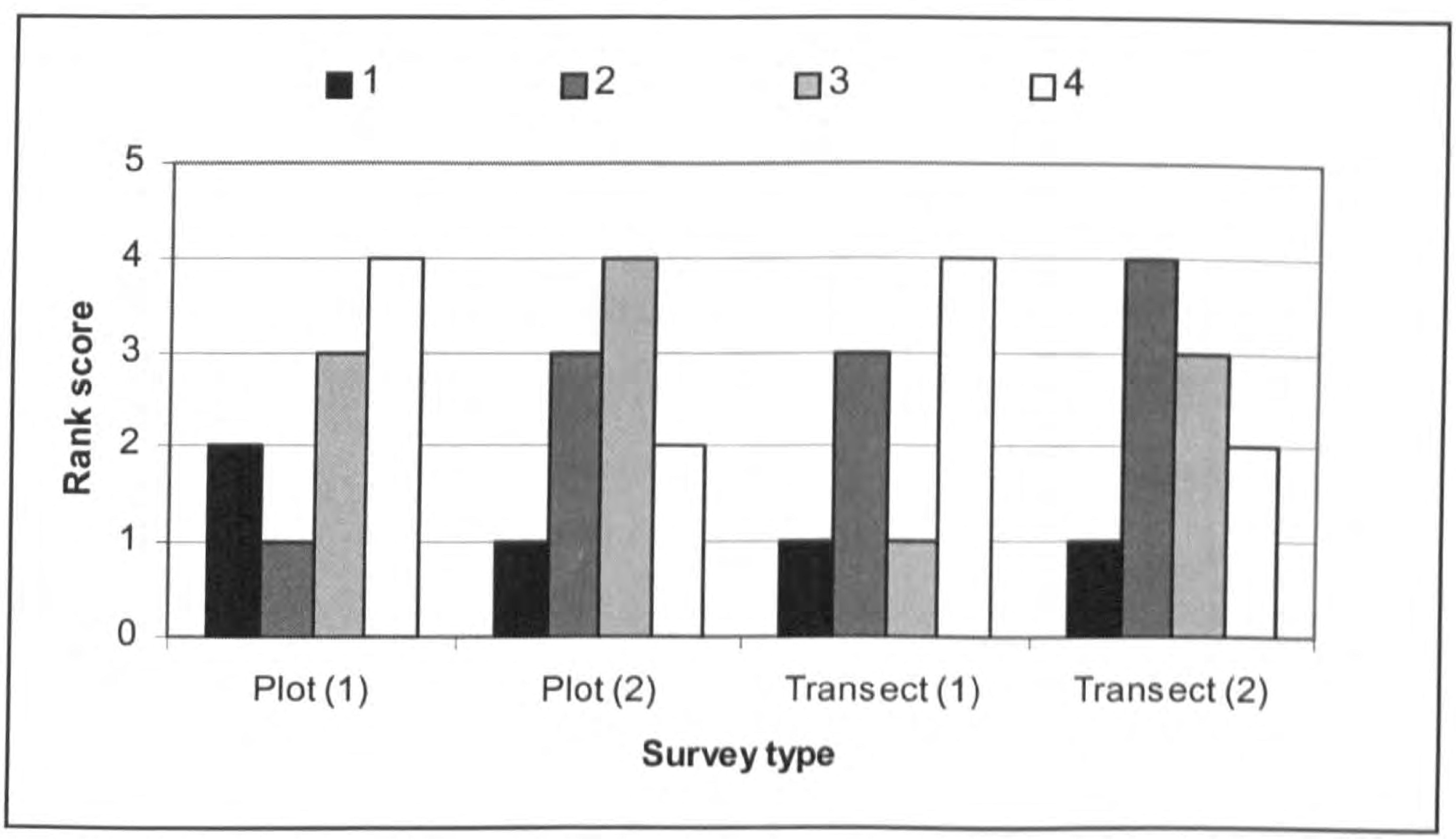


Figure 4.11: Surveyors rank scores for repeated plot and transect
Individual rank score per surveyor for the four surveyors recording proportion of trees damaged in the repeated plot and transect.

Variable	Plot			Transect		
	t	p	df	t	p	df
Number of trees	-1.9	0.14	3	-1	0.41	3
Number of trees damaged	-0.4	0.68	3	-2	0.14	3
Number of dung	-2.7	0.07	3	7	0.01	3
Number of species from dung	-2.4	0.09	3	5.2	0.01	3
Time	-0.7	0.54	3	1.2	0.31	3
Elephant browse	0.36	0.745	3	-7.1	0.006	3
Rhino browse	3.15	0.051	3	-5	0.02	3
Giraffe browse	-0.77	0.495	3	0.68	0.547	3

Table 4.3: T test results for repeat sampling
Paired t test results for the four surveyors on the repeated plot and transect.

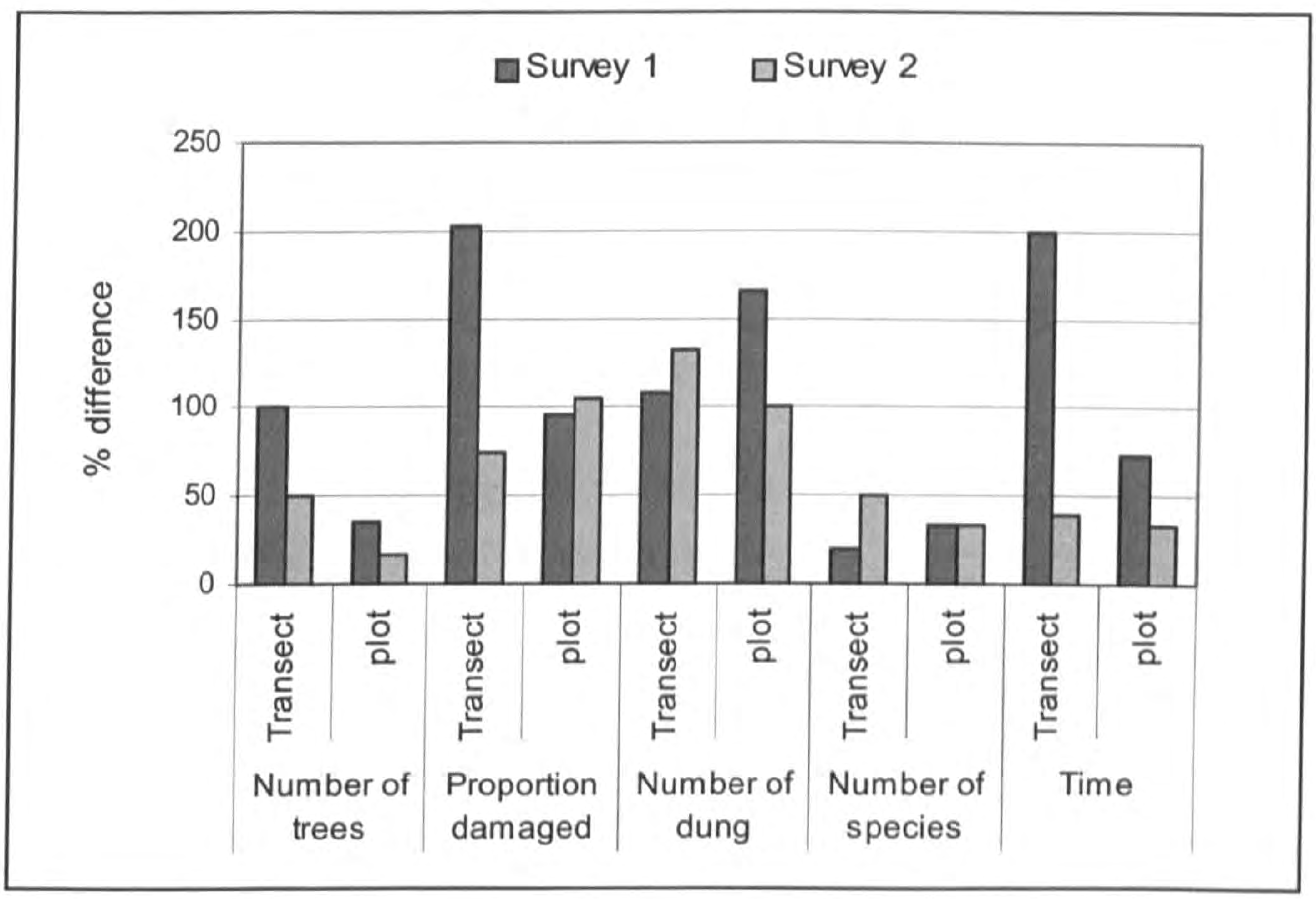


Figure 4.12: Difference between surveyors on repeated transect and plot
Percentage difference between the highest and lowest recording for each variable within the first and second survey of the transect and plot

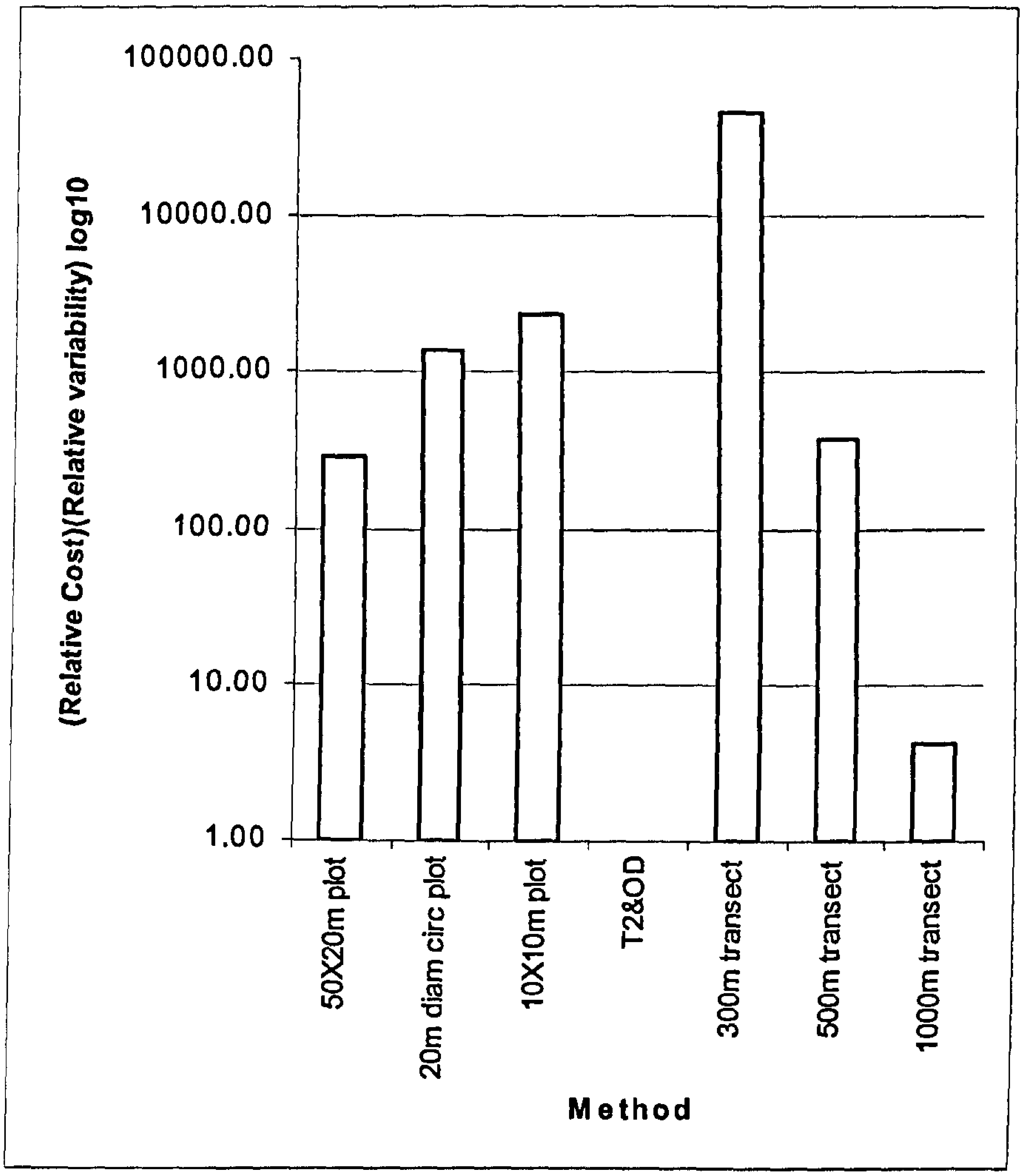


Figure 4.13: Determining optimal quadrat size: mean number of trees
Weigarts (*Krebs, 1999*) product numbers (log^{10} scale) for the mean number of trees surveyed per method

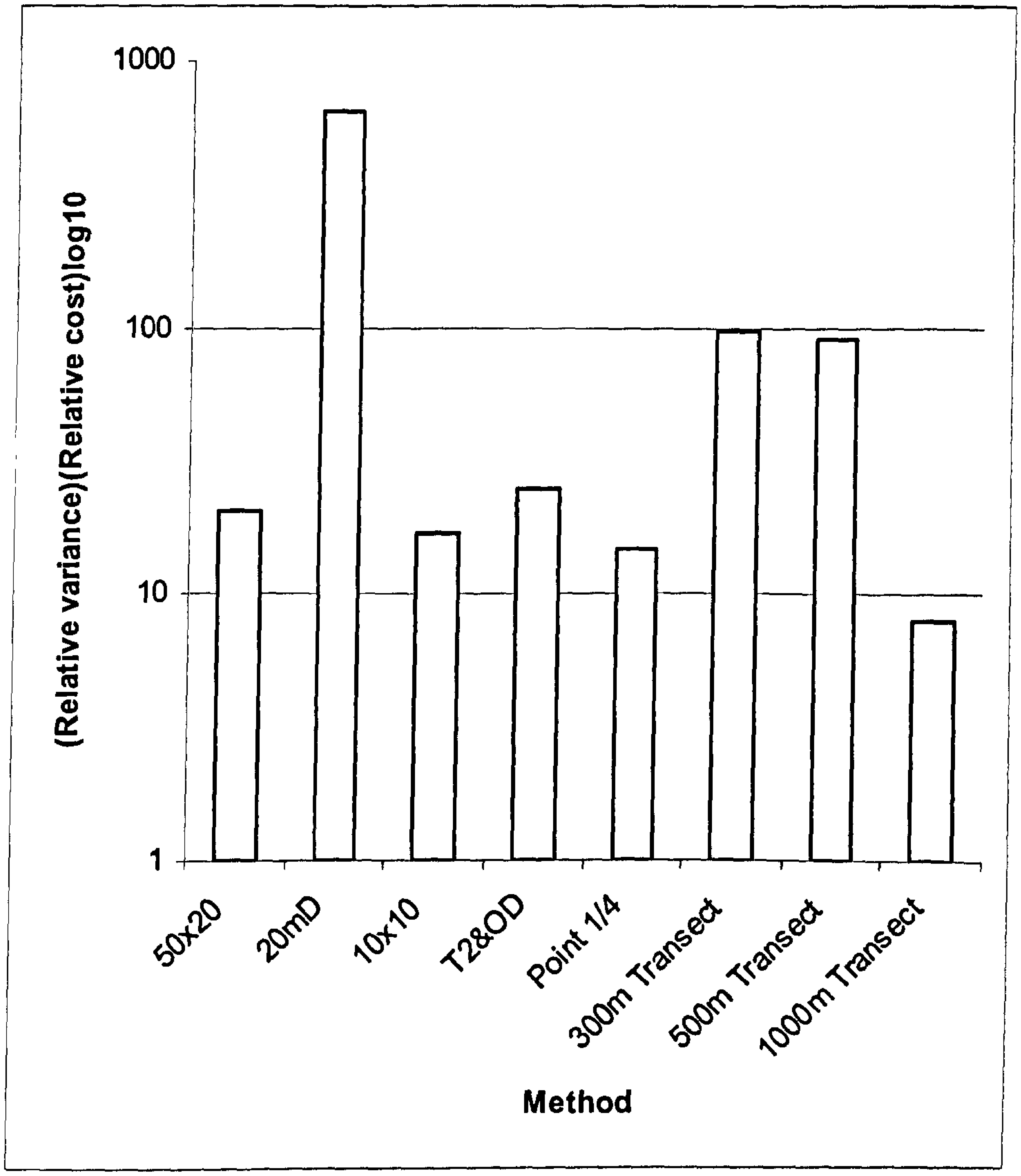


Figure 4.14: Determining optimal quadrat size: mean number of damaged trees
Weigarts (*Krebs, 1999*) product numbers for the number of trees recorded as damaged per method

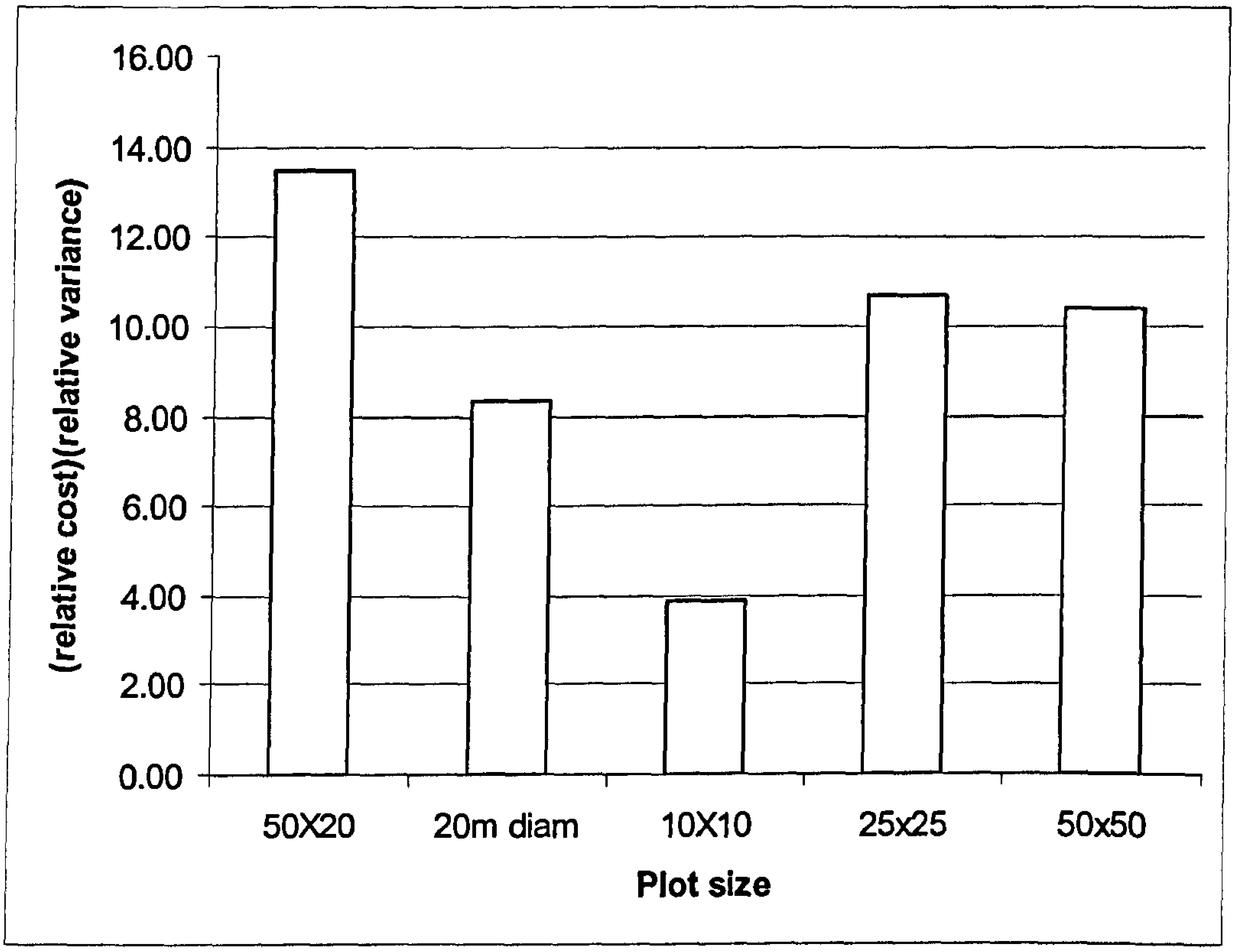
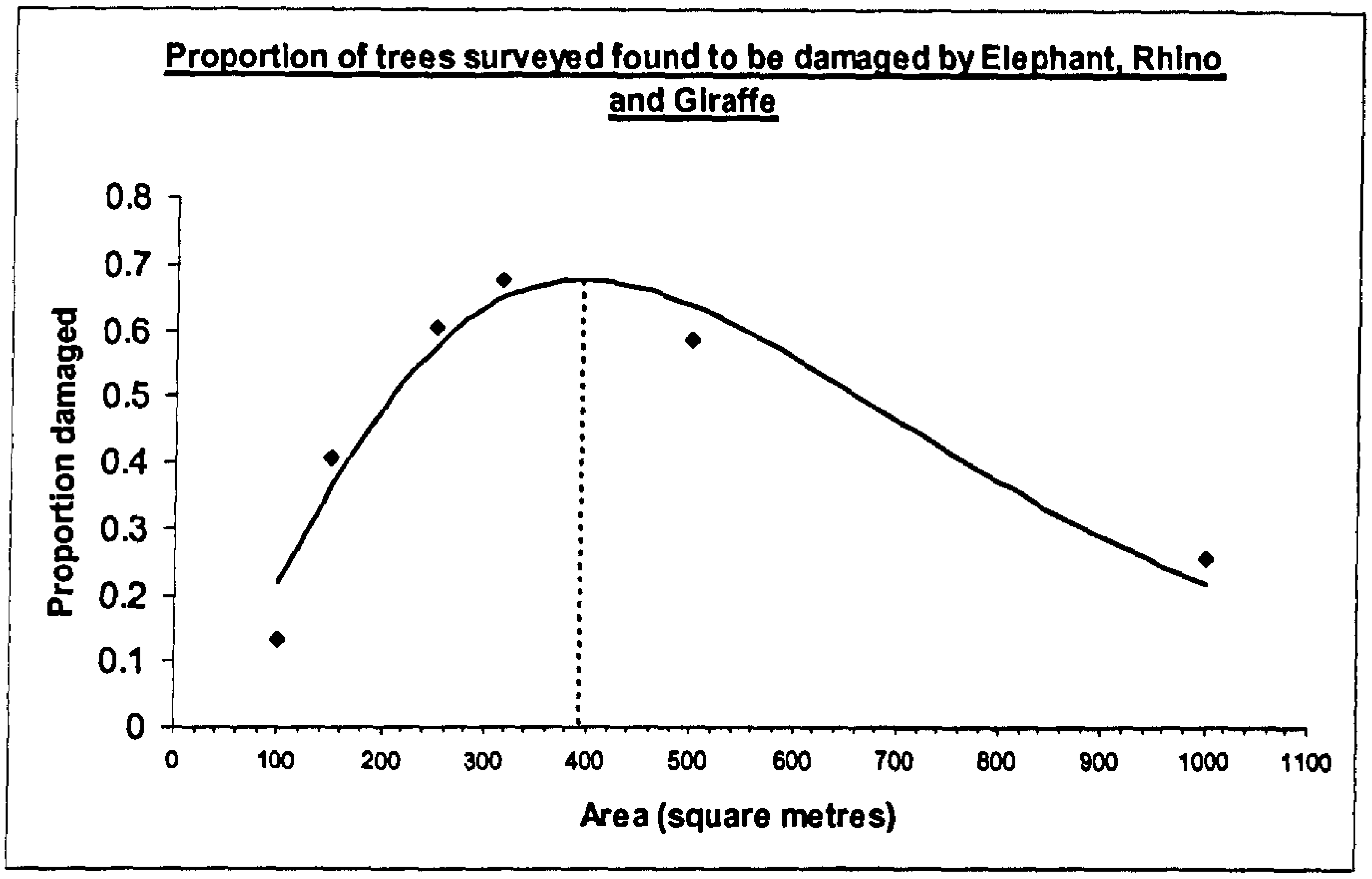
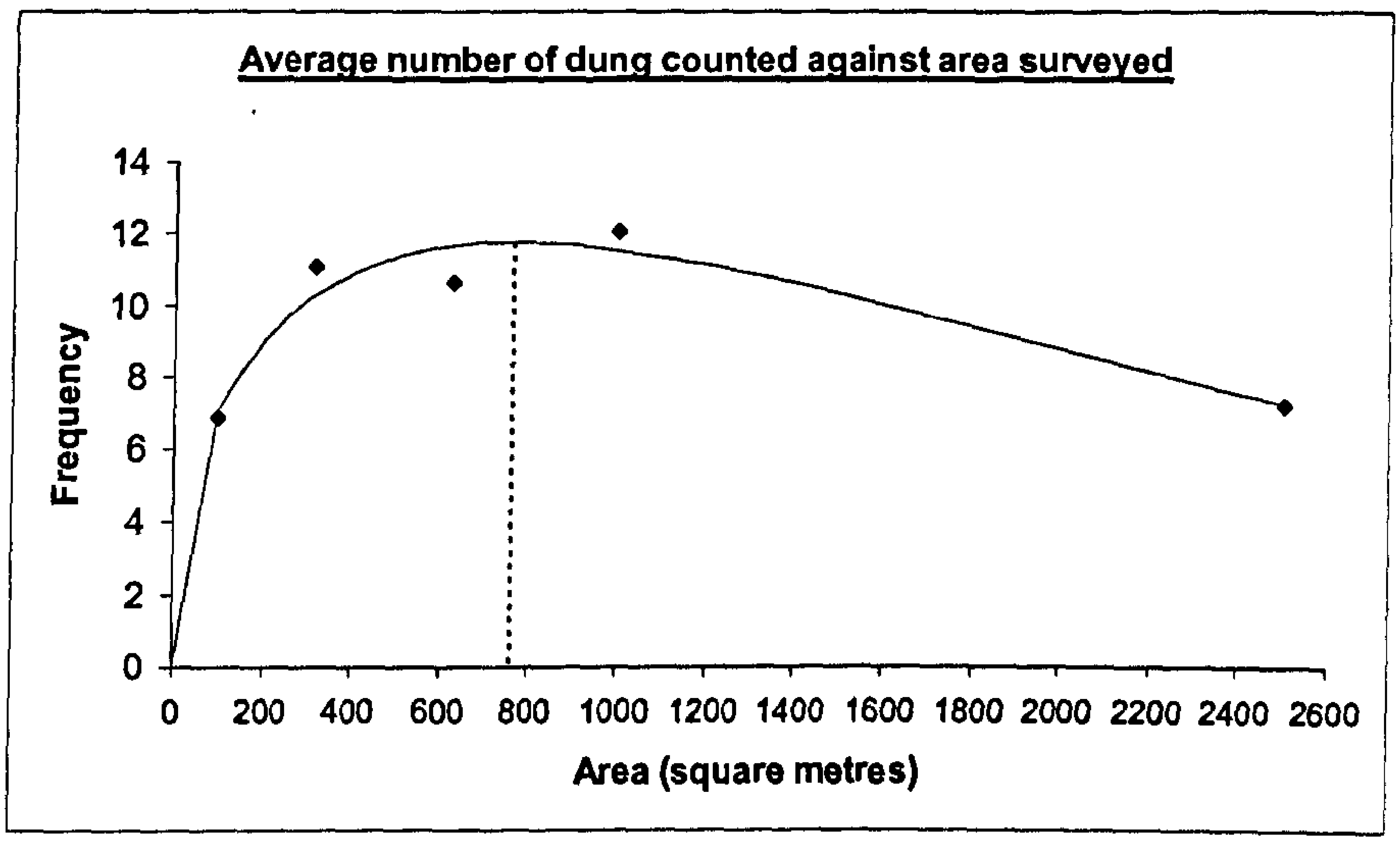


Figure 4.15: Determining optimal quadrat size: mean amount of dung recorded
Weigarts (*Krebs, 1999*) product numbers for the number (amount) of dung recorded per method.

4.16a



4.16b



4.16c

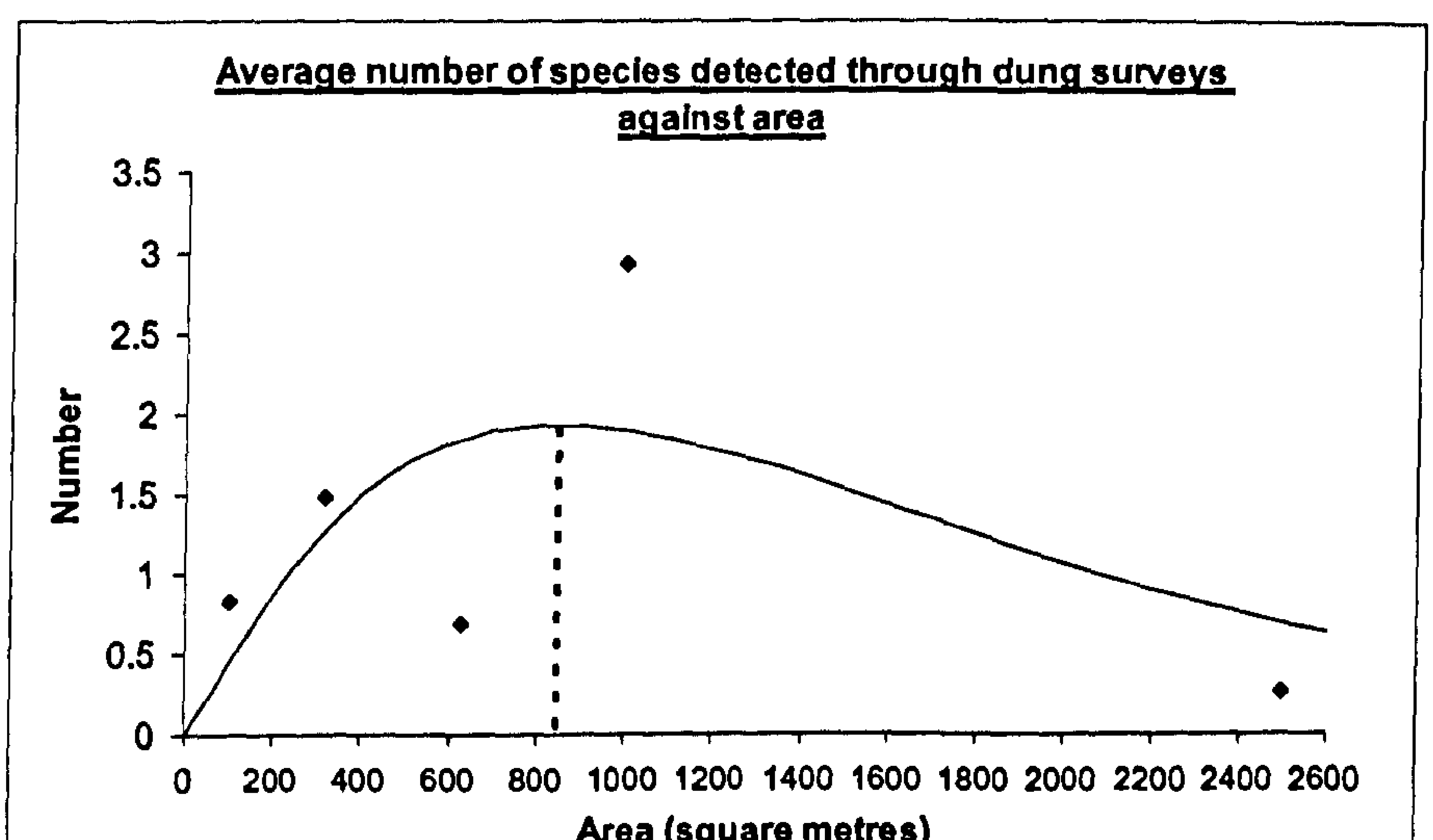


Figure 4.16 a, b, c: maximum information versus area covered
maximum information by area for detecting (a) proportion of damaged trees (b) average number of dung (c) average number of species from dung.

Trees	Number of trees surveyed	50x20m plot (1000m^2) = optimal method
	Number of trees surveyed as damaged	Point quarter and 10x10m (100m^2) plot = optimal methods
	Proportion damaged	400m² = optimum area
Dung	Amount of dung surveyed	10x10m (100m2) = optimal method
		800m² = optimum area
	Number of species identified from dung	10x10m (100m2) = optimal method
		800m² = optimum area

Table 4.4: Results summary
Summary of results from optimal quadrat calculations and optimal area charts.

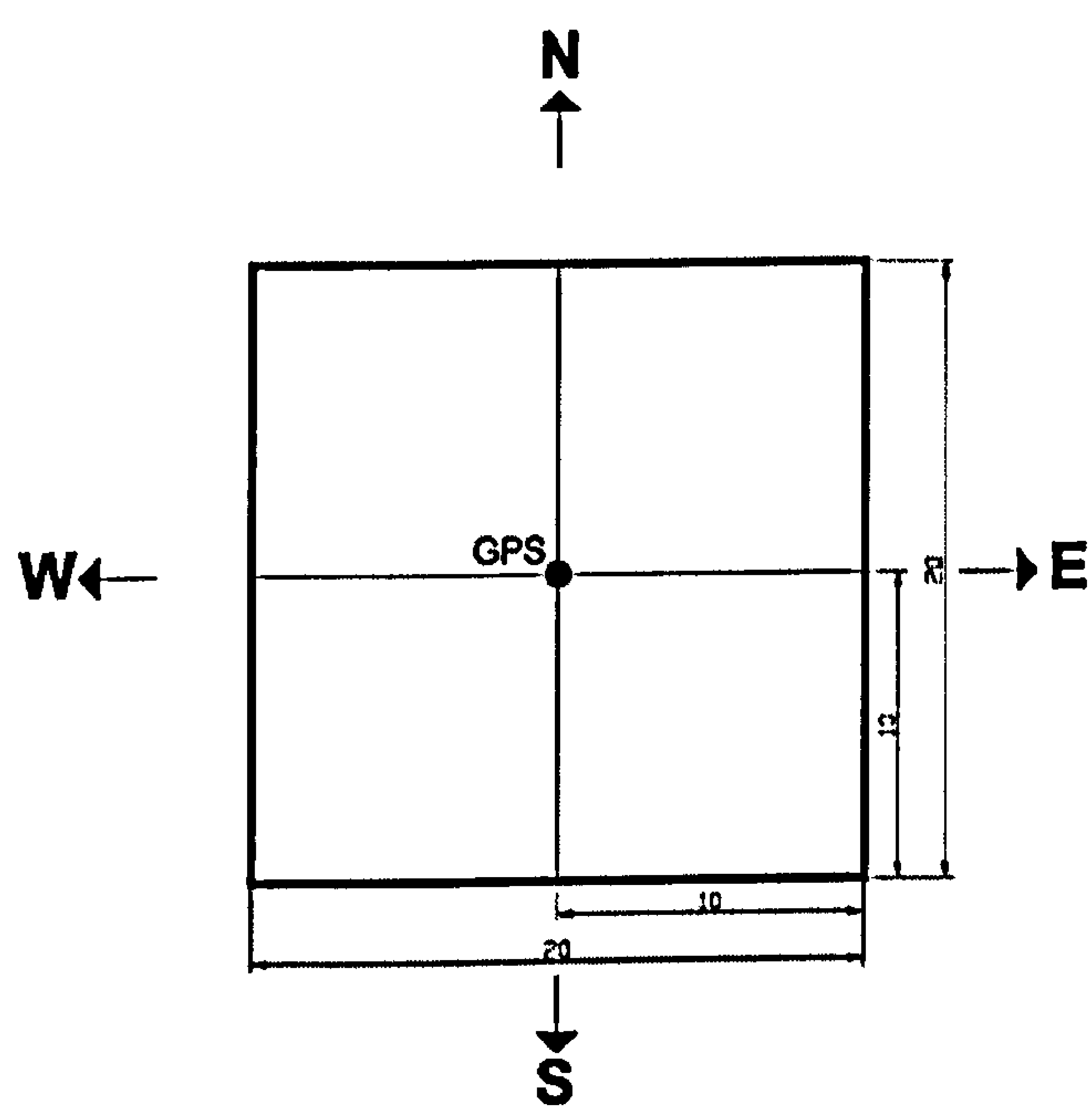


Figure 4.17: Optimal field survey design
Designed survey technique diagram based on optimal method and area results

Tree			*Elephant*			*Rhino*			*Giraffe*			*Other damage*		
TS	HT (m)	NMS	EDC (1-4)	EMS	F	RDC (1-4)	RMS	F	GDC (1-4)	GMS	F	ODC (1-4)	OMS	F

Plot information:
- Number of trees per plot
- Number of trees damaged per plot
- Number of trees damaged by Elephant, Rhino, Giraffe and Other (ERGO) per plot
- Number of trees with main stem damage per plot
- Total damage product number per plot

Tree Information:
- Number of trees in each height class
- Number of trees damaged in each height class
- Number of each tree species in each height class
- Number of each tree species per plot
- Number of each tree species damaged per plot
- Number of each tree species damaged by ERGO per plot (total)
- Number of each tree species with main stem damage per plot (total)
- Total damage product number per tree species

Specific damage information:
- Number of trees in each damage class for ERGO
- Number of trees in each main stem class score for ERGO
- Total damage product number for ERG

Figure 4.18: Data collection format
Vegetation data collection format and list of summary statistics to be compiled.
Key to data sheet: TS = tree species, HT = height in metres, EDC = elephant damage class, EMS = elephant main stem damage (number), F = fresh, RDC = rhino damage class, RMS = rhino main stem damage, GDC = giraffe damage class, GMS = giraffe main stem damage.

$$DPS = \frac{\sum DPN}{N}$$

DPS = damage product score
DPN = damage product number (DC + CS)
(DC = damage class (1-4), CS = main stem class score (1-4))
N = total number of trees in survey/plot/per tree species

Figure 4.19: DPS formula

Tree species	*n*	% of total trees surveyed	% damaged	% of damage which is to the main stem
A. drepanolobium	456	43.4	47.8	47.7
E. divinorum	2	21.9	52.6	43
P. punctulata	7	20.5	11.6	80
S. myrtina	1	3.9	75.6	38.7
R. staddo	4	3.7	74.4	17.2
R. natalensis	230	2.8	72.4	85.7
G. similis	12	1.1	33.3	100
M. senegalensis	5	0.9	66.7	66.7
A. xanthophloea	9	0.7	57.1	100
M. triphylla	215	0.5	100	100
C. edulis	29	0.4	75	100
A. africana	39	0.2	50	100
B. glabra	41	0.1	100	100

Table 4.5: Trees species damaged
Species composition and % damage, and % of which is main stem damage, per species.

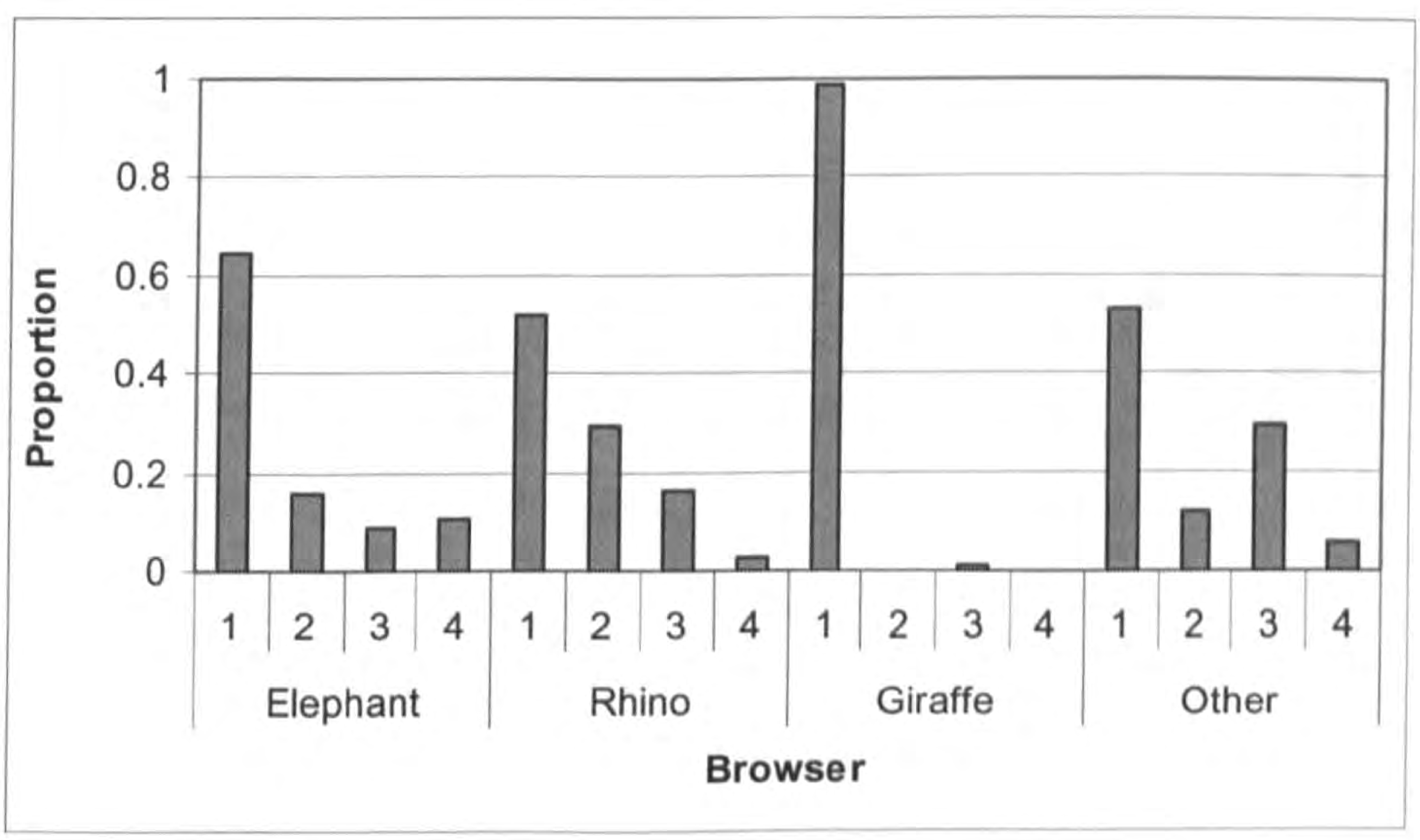


Figure 4.20: Proportion of browsing in each damage class
proportion of the total amount of elephant, rhino, giraffe browse and other damage that achieved a damage class of 1 (<25% broken), 2 (25-50%), 3 (50 – 75%) and 4 (>75%).

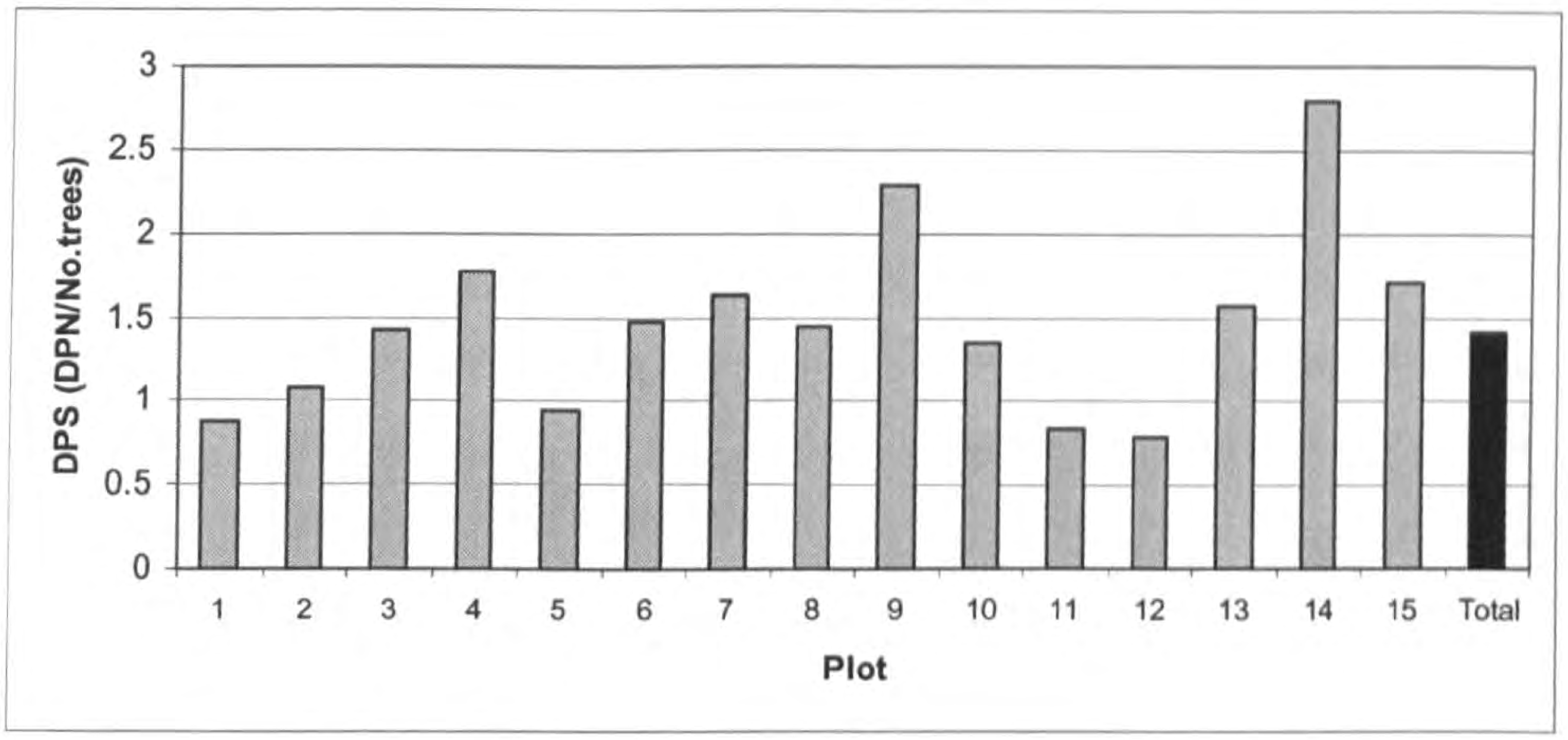


Figure 4.21: Damage Product Score (DPS) for the monitoring plots
calculated Damage Product Score (DPS) for each monitoring plot and as a total for 2006
(DPS = ∑DPN / total number of trees in each plot, or for total DPS, all plots combined)

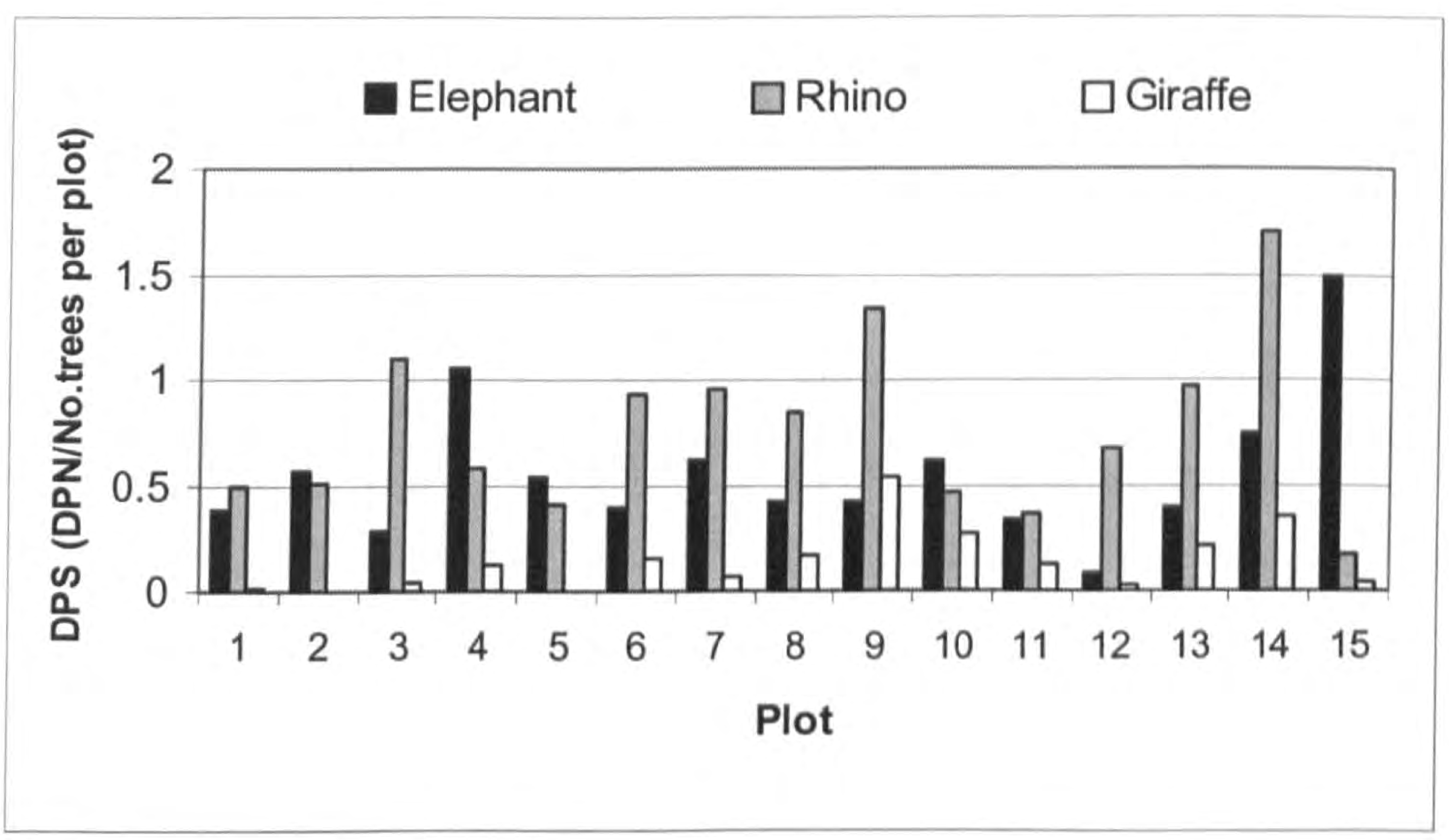


Figure 4.22: DPS per browser per plot
calculated Damage Product Score (DPS) for each browser in each plot
(DPS = ∑ browser DPN / total number of trees in each plot)

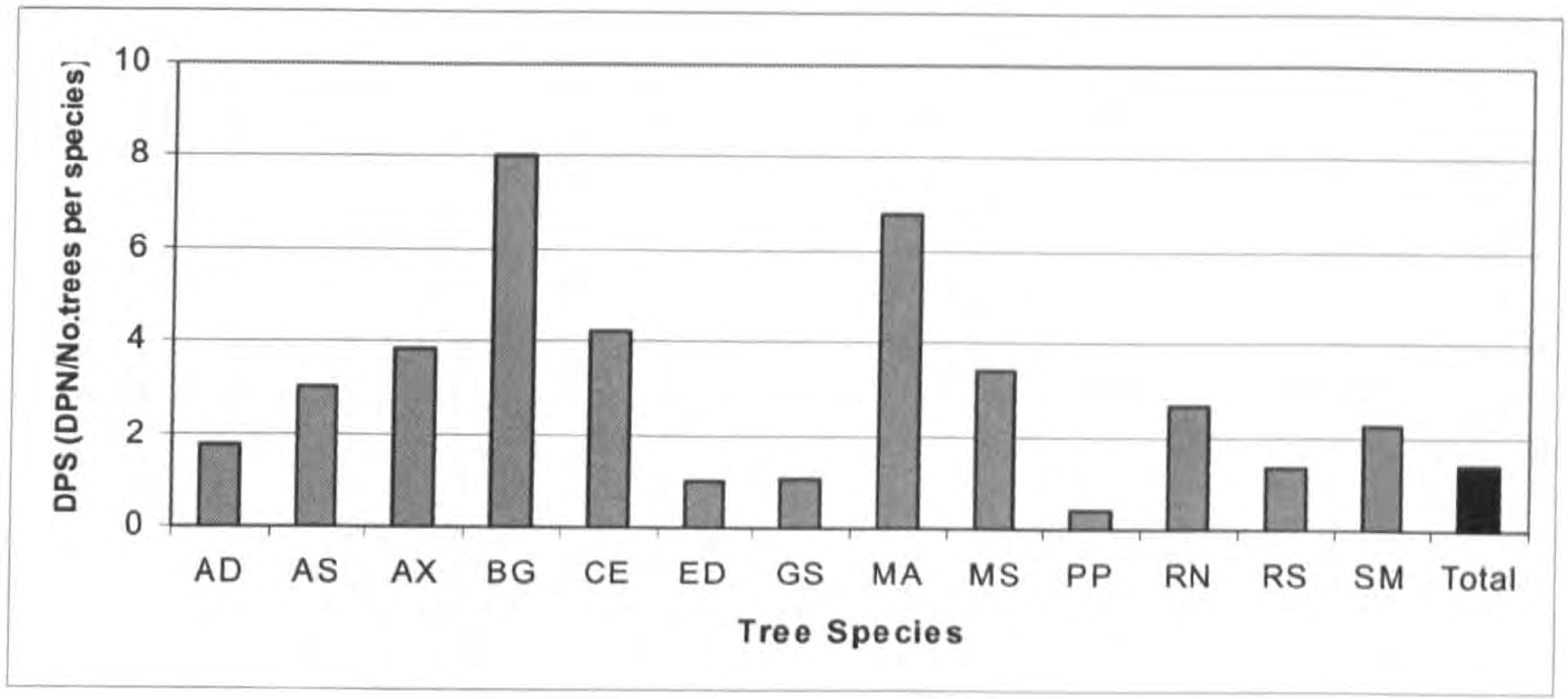


Figure 4.23: DPS per tree species
calculated Damage Product Score (DPS) for each tree species
(DPS = ∑ tree species DPN / total number of trees per species)

Key: AD: *A. drepanolobium*, AS: *A.africana*, AX: A. *xanthophloea*, BG: *B. glabra*, CE: *C.edulis*, ED: E.*divinorum*, GS: *G. similis*, MA: *M.triphylla*, MS: *M.senegalensis*, PP: *P.punctulata*, RN: *R. natalensis*, RS: *R. staddo*, SM: *S. myrtina*.

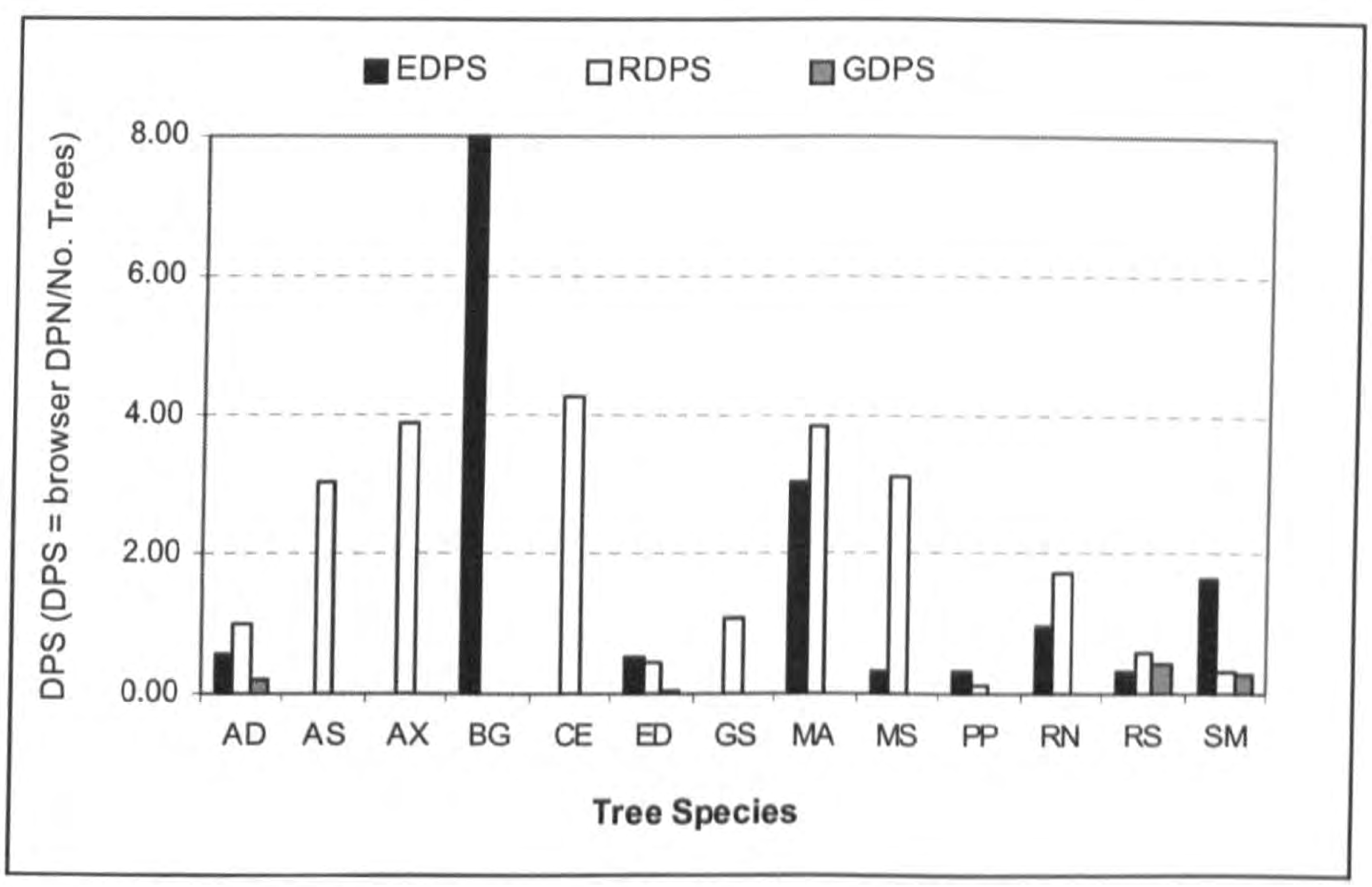


Figure 4.24: DPS per browser, per tree species
calculated Damage Product Score (DPS) for elephant, rhino and giraffe
for each tree species (DPS = ∑ browser DPN / total number of trees per species)

Key: AD: *A. drepanolobium*, AS: *A.africana*, AX: A. *xanthophloea*, BG: *B. glabra*, CE: *C.edulis*, ED: E.*divinorum*, GS: *G. similis*, MA: *M.triphylla*, MS: *M.senegalensis*, PP: *P.punctulata*, RN: *R. natalensis*, RS: *R. staddo*, SM: *S. myrtina*.

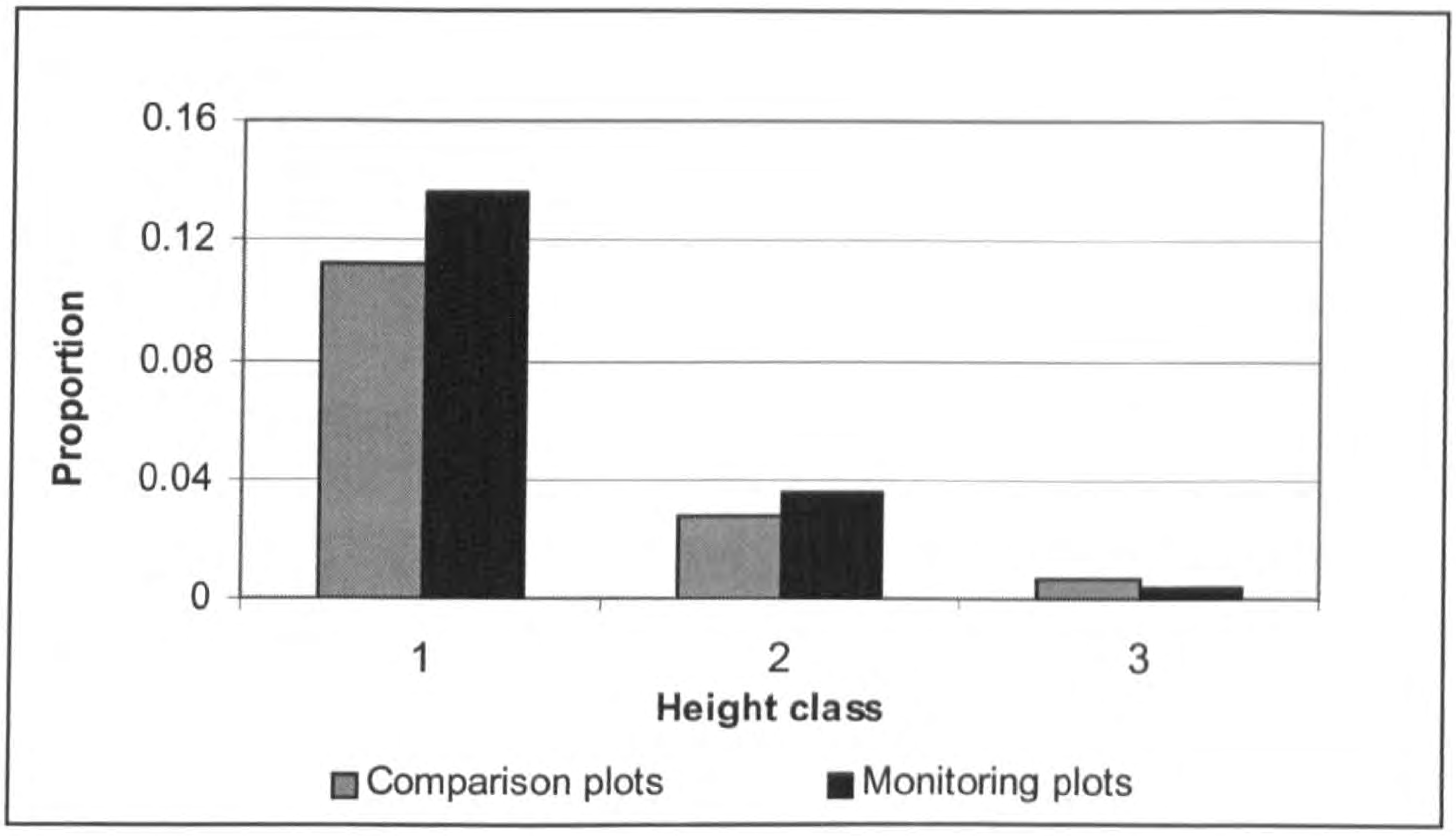


Figure 4.25: Tree height by area surveyed
number of trees in each height class (1: <2m, 2:2-4m, 3: >4m) in proportion to total area surveyed (m^2).

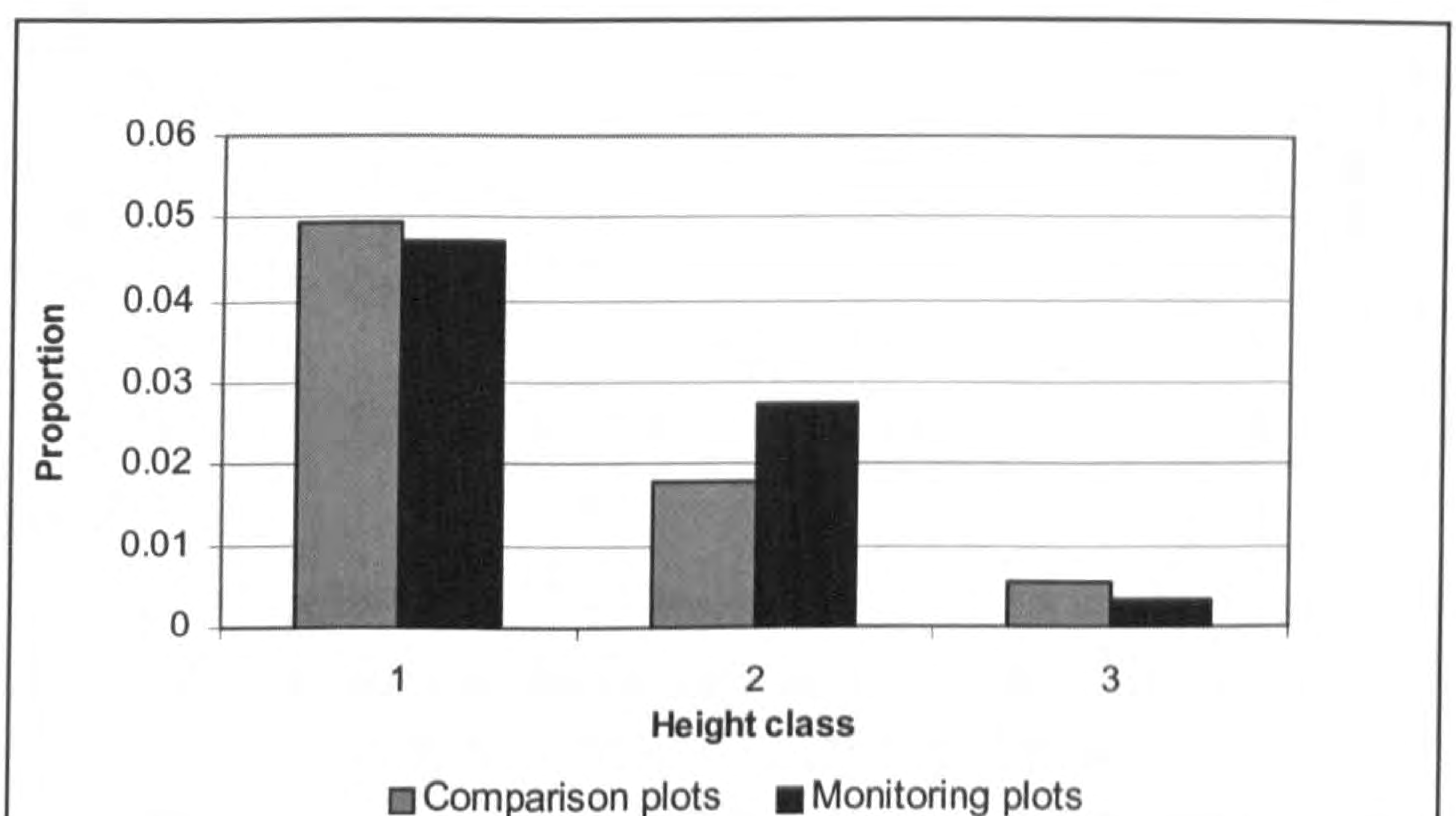


Figure 4.26: Damaged trees by area surveyed
number of trees damaged in each height class (1: <2m, 2:2-4m, 3: >4m) in proportion to area surveyed (m^2).

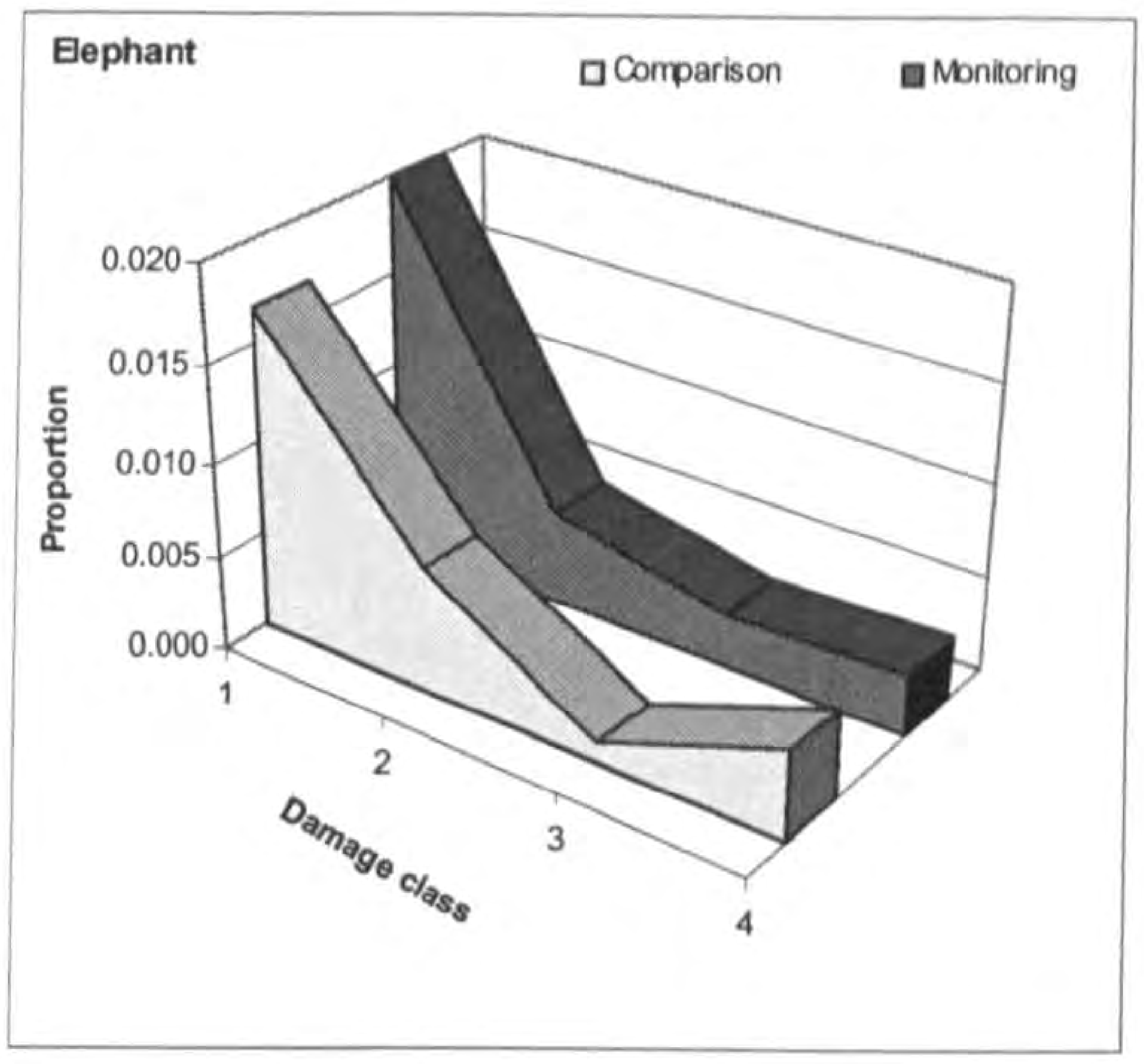


Figure 4.27:a(i) elephant damage class in proportion to area for monitoring and comparison plots.

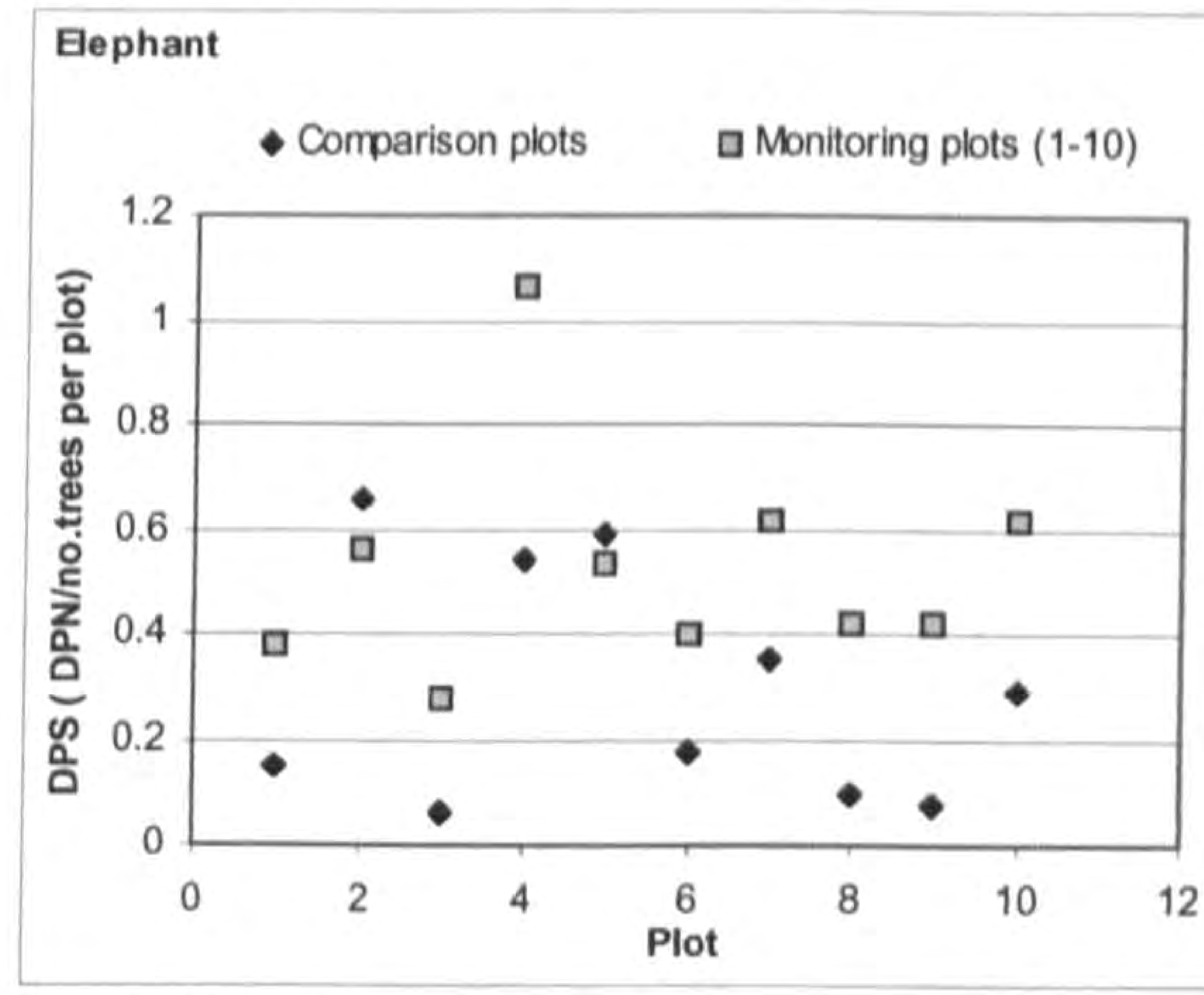


Figure 4.27:a(ii) elephant damage product score (DPS = elephant DPN/no. trees per plot) for monitoring and comparison plots.

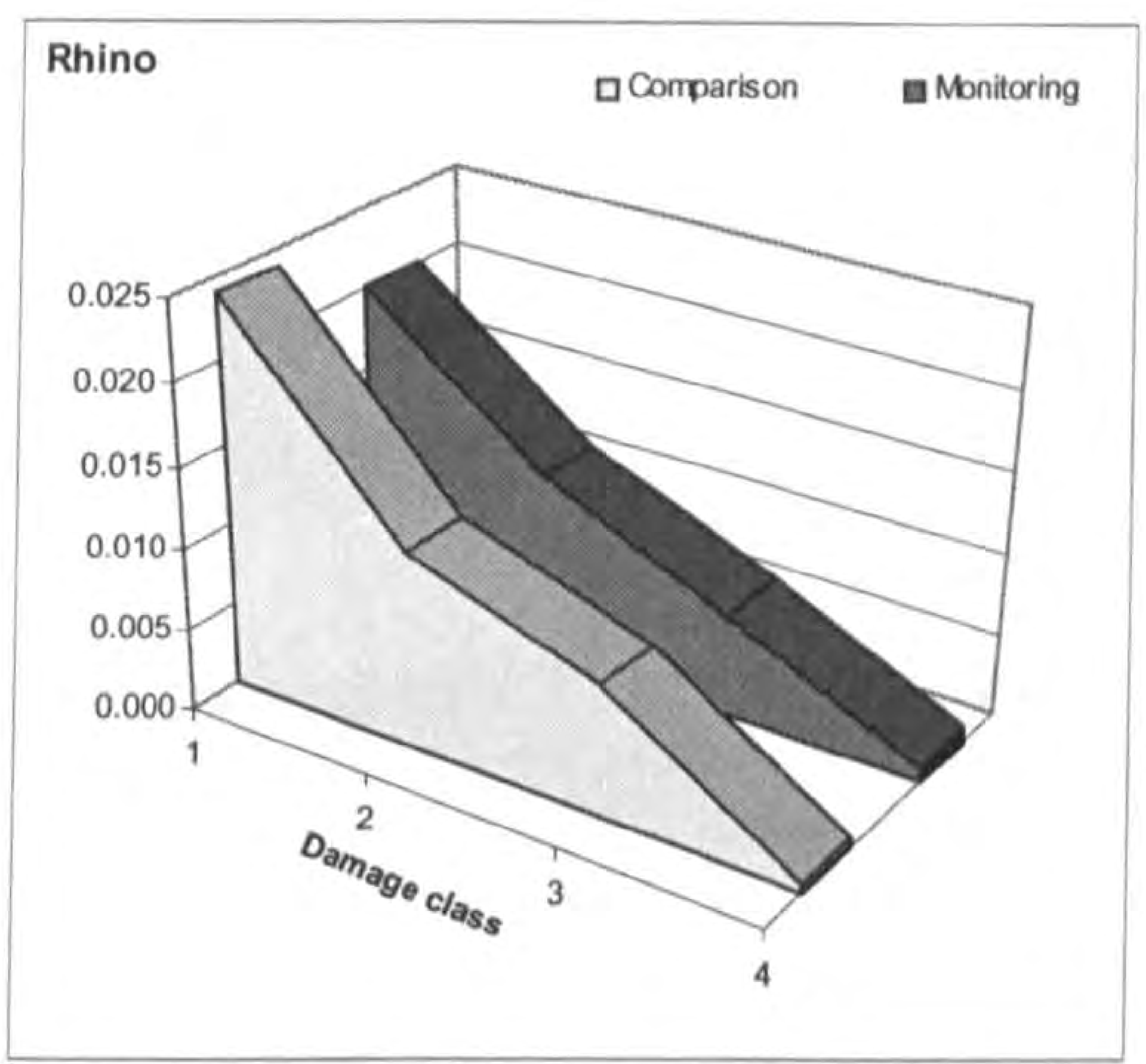


Figure 4.27:b(i) rhino damage class in proportion to area for monitoring and comparison plots.

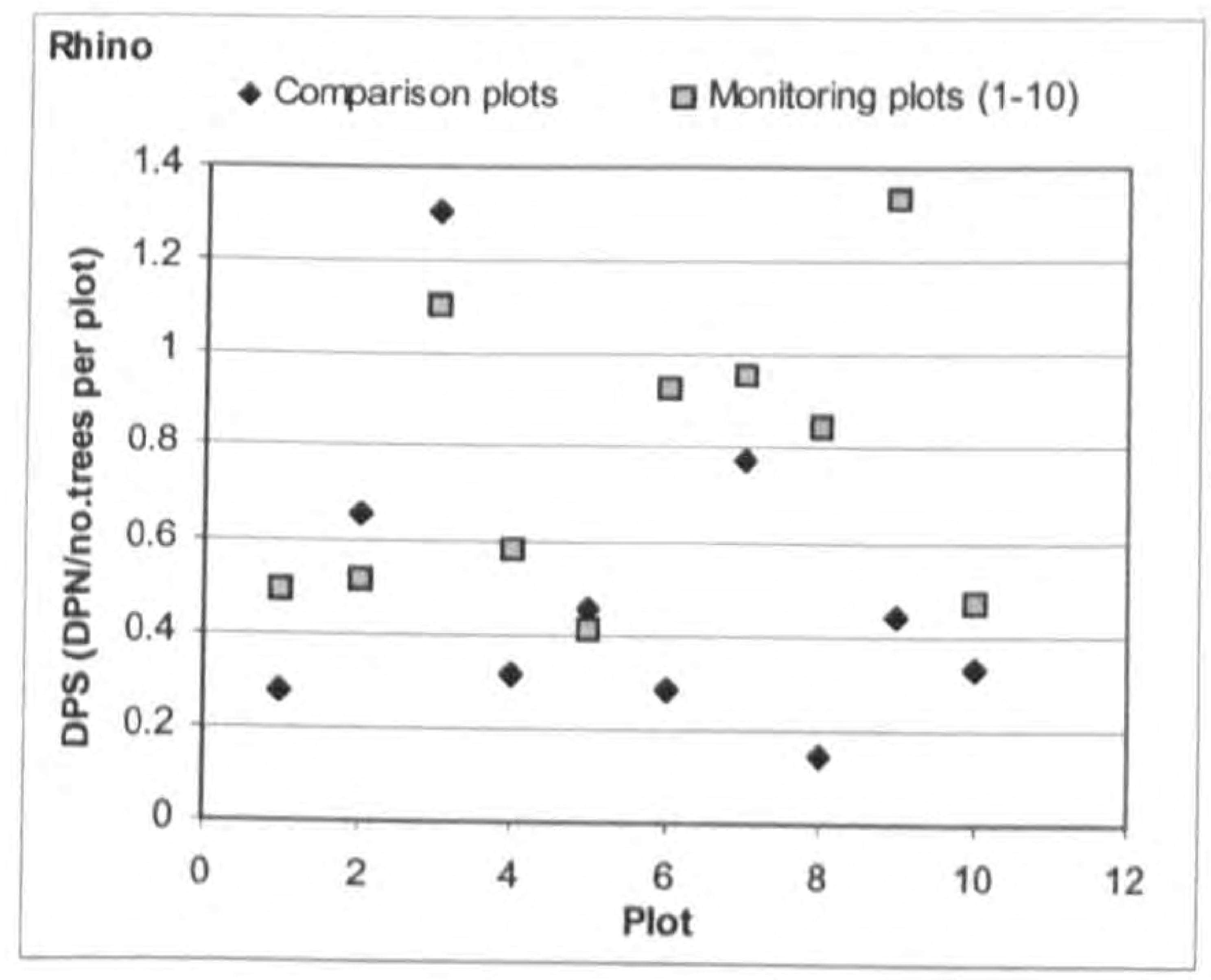


Figure 4.27:b(ii) rhino damage product score (DPS = rhino DPN/no. trees per plot) for monitoring and comparison plots.

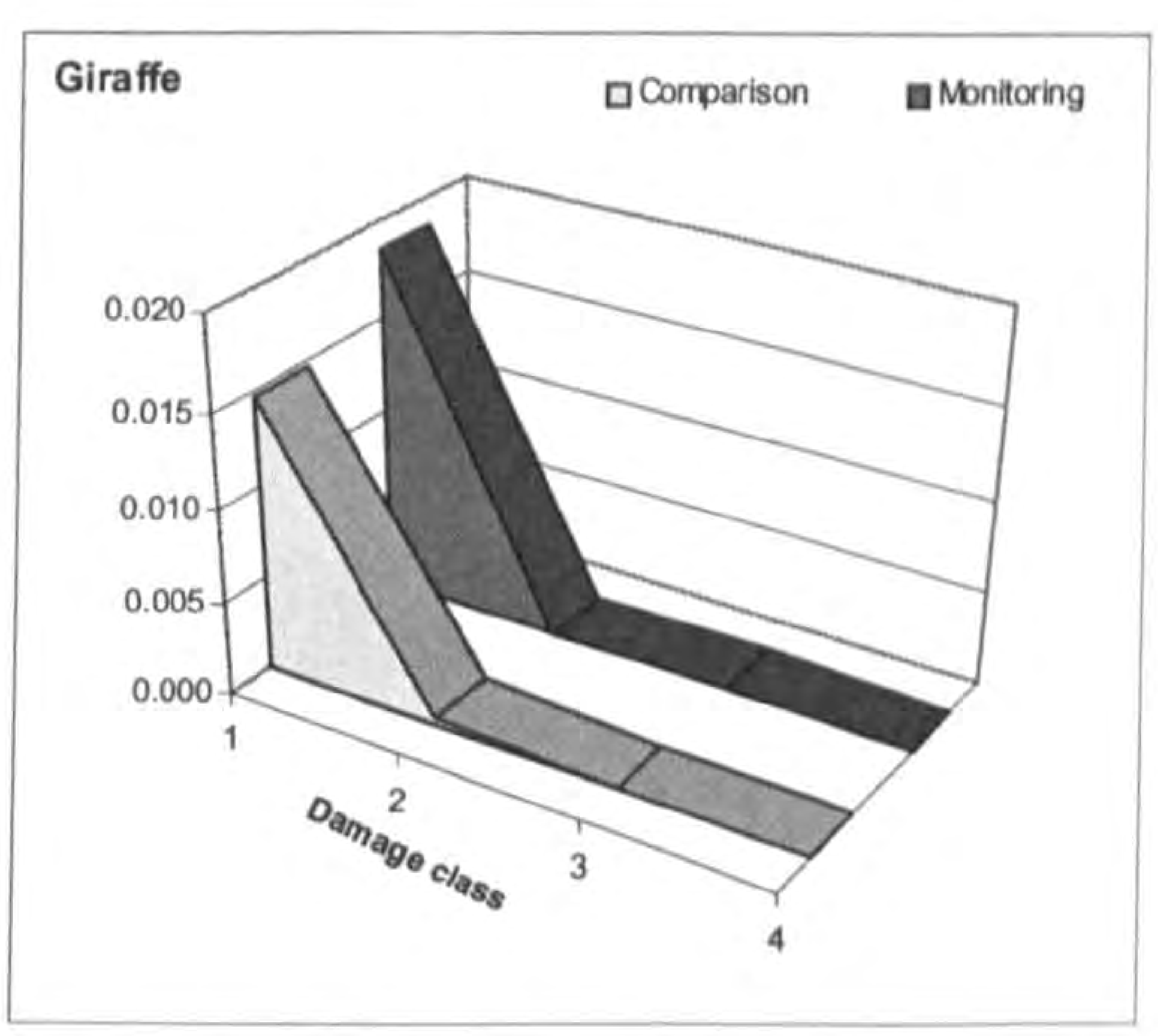


Figure 4.27:c(i) giraffe damage class in proportion to area for monitoring and comparison plots.

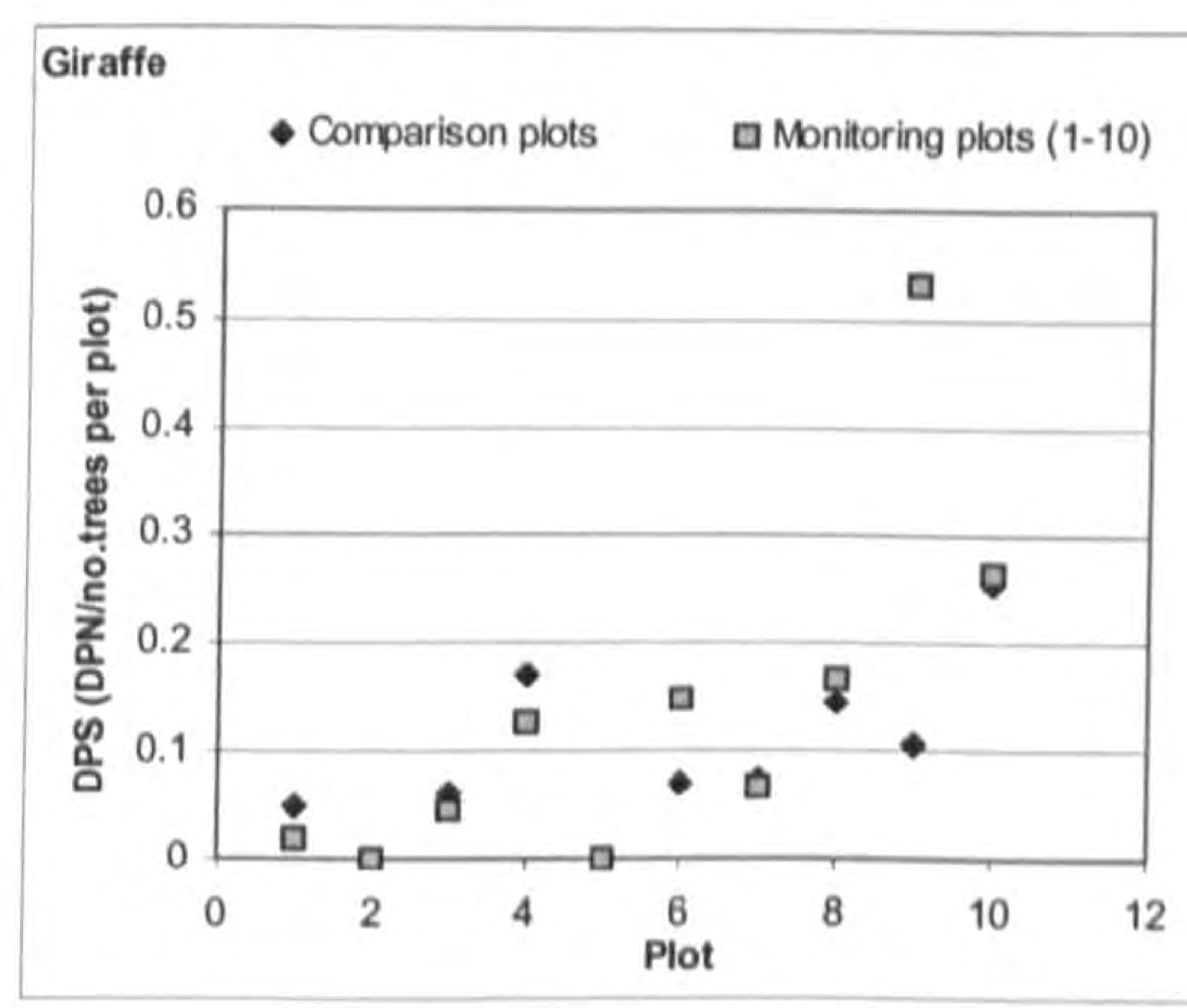


Figure 4.27:c(ii) giraffe damage product score (DPS = giraffe DPN/no. trees per plot) for monitoring and comparison plots.

Figure 4.27 a(i), (ii), b(i), (ii), c(i) (ii): browser species damage class and DPS for monitoring and comparison plots.

Plot Type	Surveyor	Time (min)	Number of trees	Damage				Dung	Total DPS
				Trees	*Elephant*	*Rhino*	*Giraffe*		
Subdivided	X	43	64	42	26	16	10	33	1.8
	X	30	73	54	29	8	28	37	2.26
	X	36	113	68	39	16	25	31	2.27
	X	31	94	55	29	6	31	32	1.76
	Y	47	84	42	17	23	12	34	1.19
	Y	34	73	53	27	18	21	36	2.27
	Y	34	105	76	41	25	23	31	2.3
	Y	37	103	61	33	18	26	39	1.94
mean		***36.5***	***88.6***	***56.4***	***30.1***	***16.3***	***22***	***34.1***	
Full	X	30	69	44	28	10	15	30	1.39
	X	32	102	52	37	5	19	21	1.71
	X	31	74	26	17	3	12	23	1.26
	X	36	100	51	35	8	17	33	1.91
	Y	41	94	49	25	13	13	32	1.52
	Y	38	104	61	38	21	18	33	1.95
	Y	27	84	38	20	14	10	23	1.35
	Y	33	97	45	29	15	17	30	1.52
mean		**33.5**	**90.5**	**45.8**	**28.6**	**11.1**	**15.1**	**28.1**	

Table 4.6: Control plot results

Survey data for control plot grid, with calculated means.

Anova: two way						
	Plot type		*Surveyor*		*Interaction*	
	F	P	F	P	F	P
Time	1.22	0.291	1.03	0.331	0.01	0.928
No.trees	0.05	0.824	0.7	0.42	0.04	0.847
No.trees damaged total	3.25	0.096	0.49	0.497	0.02	0.884
No.trees damaged elephant	0.13	0.723	0.09	0.768	0	1
No.trees damaged rhino	6.68	0.024	22.35	<0.001	0	0.951
No.trees damaged giraffe	5.18	0.042	0.5	0.495	0.08	0.777
No.dung	8.13	0.015	1.14	0.306	0.06	0.816

Table 4.7: ANOVA of control plots

Anova: two way to identify significant differences in time taken, the number of trees included and recorded as damaged in total and per browser and the number of dung recorded, in both subdivided and full plots and by each surveyor.

	Subdivided plots		Full plots	
Variable	***Surveyor X***	***Surveyor Y***	***Surveyor X***	***Surveyor Y***
Elephant browse	30.75	29.5	29.25	28
Rhino browse	11.5	21	6.5	15.75
Giraffe browse	23.5	20.5	15.75	14.5
Dung	33.25	35	26.75	29.5

Table 4.8:Browse and dung mean values from control plots
Mean values for surveyors and plot types per variable

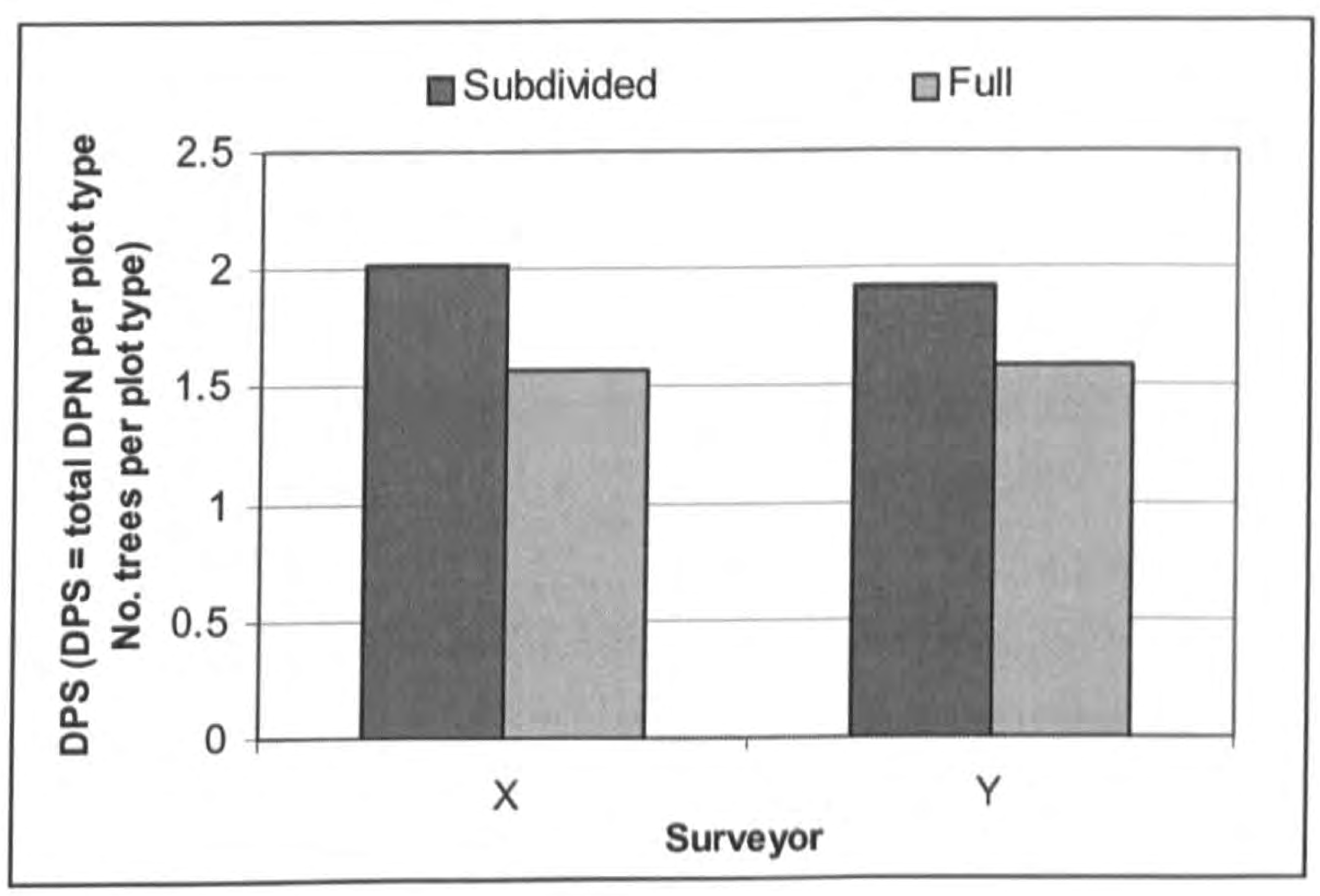


Figure 4.28: Control plot DPS
total DPS for subdivided and full plots, per surveyor

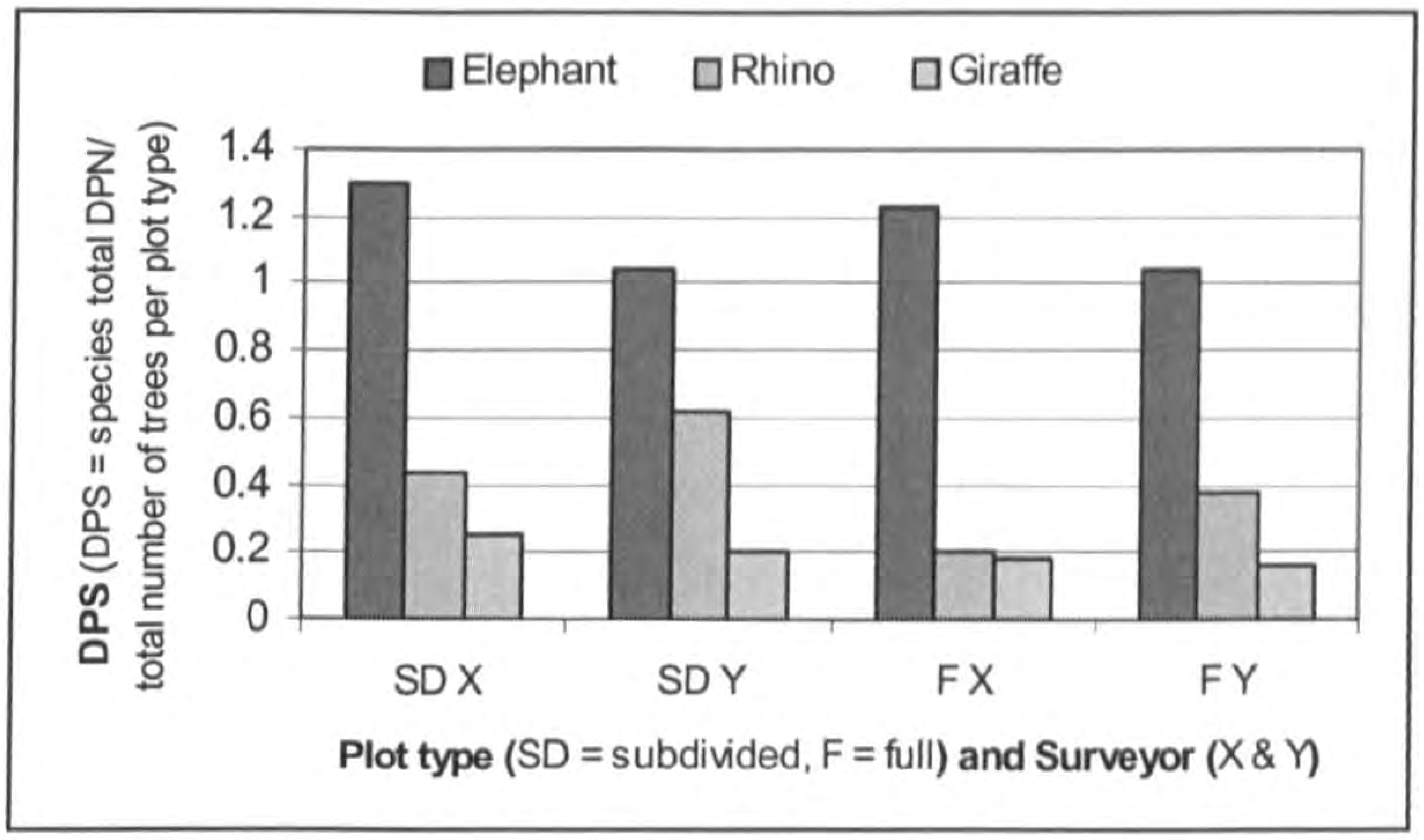


Figure 4.29: Control plot DPS per browser
DPS for elephant rhino and giraffe per plot type and per surveyor

% change	*Number of significant runs (P=<0.05)*
5	0
10	0
15	0
20	0
25	0
30	0
35	11
40	70
45	100
41	**76**
42	**84**

Table 4.9: Power simulation results: number of damaged trees 2006
significant values following 100 simulations at 5% change increments. A powerful technique = >80%

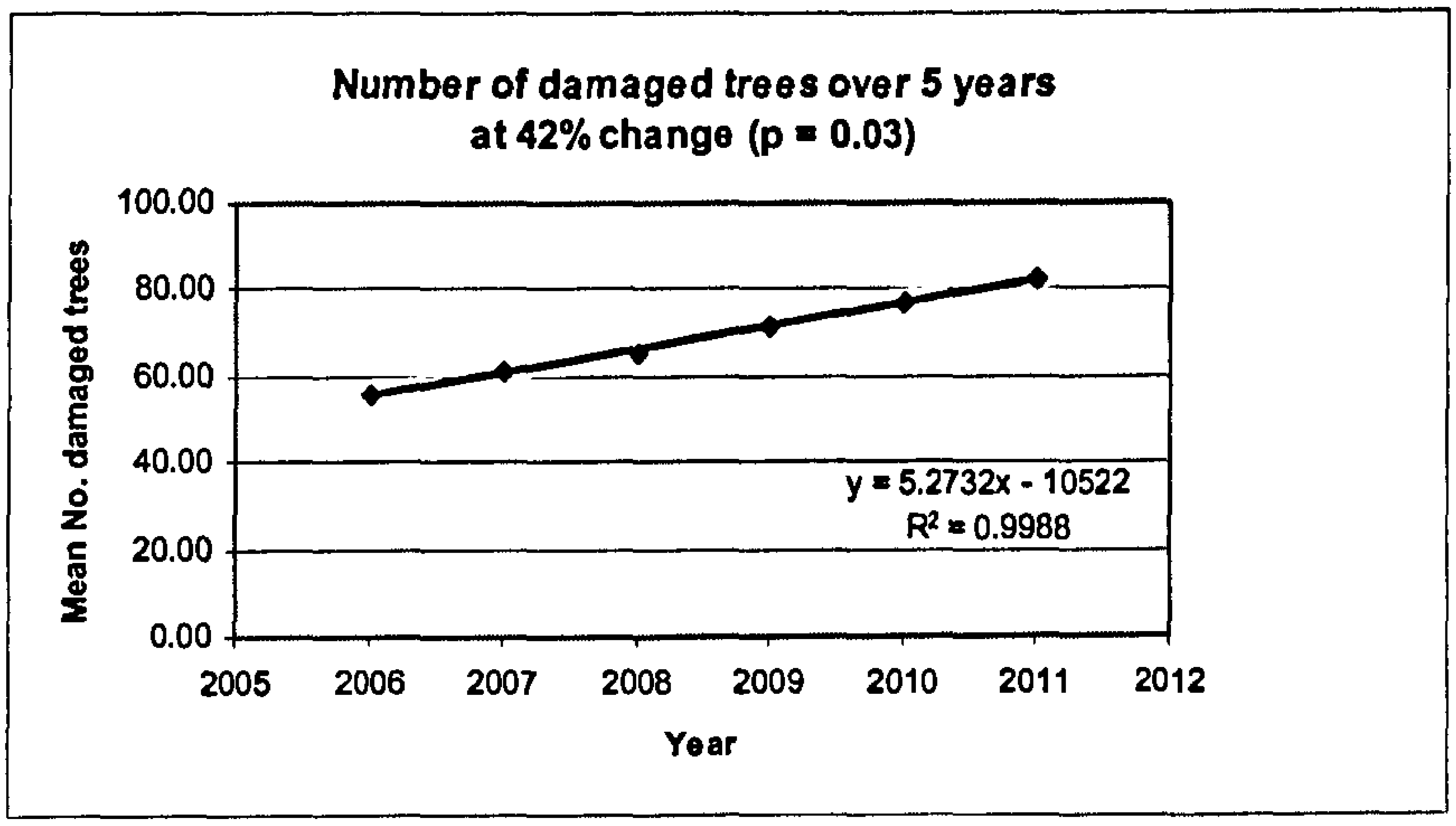


Figure 4.30: Regression of damaged trees simulated over 5 years
Example regression for 42% change in number of damaged trees over a five year time scale.

% Change	*Number of significant runs (p=<0.05)*
5	0
10	0
15	0
20	0
25	33
30	95
27	72
28	**91**

Table 4.10: Power simulation results for DPS 2006
significant values following 100 simulations at 5% change increments. A powerful technique = >80%

Main results	2006	2007
Total		
Total number of Trees recorded (No.Trees)	1050	1891
Total number of trees damaged (No.Trees D)	469	1343
Proportion of trees damaged (Proportion D)	0.446667	0.710206
Percentage damaged (% D)	44.66667	71.02062
Total Damage Product Number (Total DPN)	1486	2541
Total Damage Product Score (Total DPS)	**1.415238**	**1.343733**
Elephant		
Number of trees damaged by elephant (No.T D Ele)	187	376
Proportion of total number of trees (Propn of no.T)	0.178095	0.198837
Percentage of total number of trees (%)	**17.80952**	**19.88366**
Proportion of total number of trees damaged (Propn of D)	0.398721	0.27997
Percentage of total number of trees damaged (%)	39.87207	27.99702
Rhino		
Number of trees damaged by rhino (No.T D Rhi)	233	606
Proportion of total number of trees (Propn of no.T)	0.221905	0.320465
Percentage of total number of trees (%)	**22.19048**	**32.04654**
Proportion of total number of trees damaged (Propn of D)	0.496802	0.451229
Percentage of total number of trees damaged (%)	49.68017	45.12286
Giraffe		
Number of trees damaged by giraffe (No.T D Gir)	112	156
Proportion of total number of trees (Propn of no.T)	0.106667	0.082496
Percentage of total number of trees (%)	**10.66667**	**8.249603**
Proportion of total number of trees damaged (Propn of D)	0.238806	0.116158
Percentage of total number of trees damaged (%)	23.8806	11.61579
Other		
Number of trees with other damage (No.T D Other)	17	383
Proportion of total number of trees (Propn of no.T)	0.01619	0.202538
Percentage of total number of trees (%)	**1.619048**	**20.25383**
Proportion of total number of trees damaged (Propn of D)	0.036247	0.285182
Percentage of total number of trees damaged (%)	3.624733	28.51824
Main stems		
Number of trees with Main Stem Damage (No.T MS D)	233	434
Proportion of total number of trees (Propn of no.T)	0.221905	0.229508
Percentage of total number of trees (%)	**22.19048**	**22.95082**
Proportion of total number of trees damaged (Propn of D)	0.496802	0.323157

Table 4.11: Results from field season 2006 and 2007

The main result figures for the 15 monitoring plots in total, for 2006 (testing the technique field season) and 2007 (monitoring workshop)

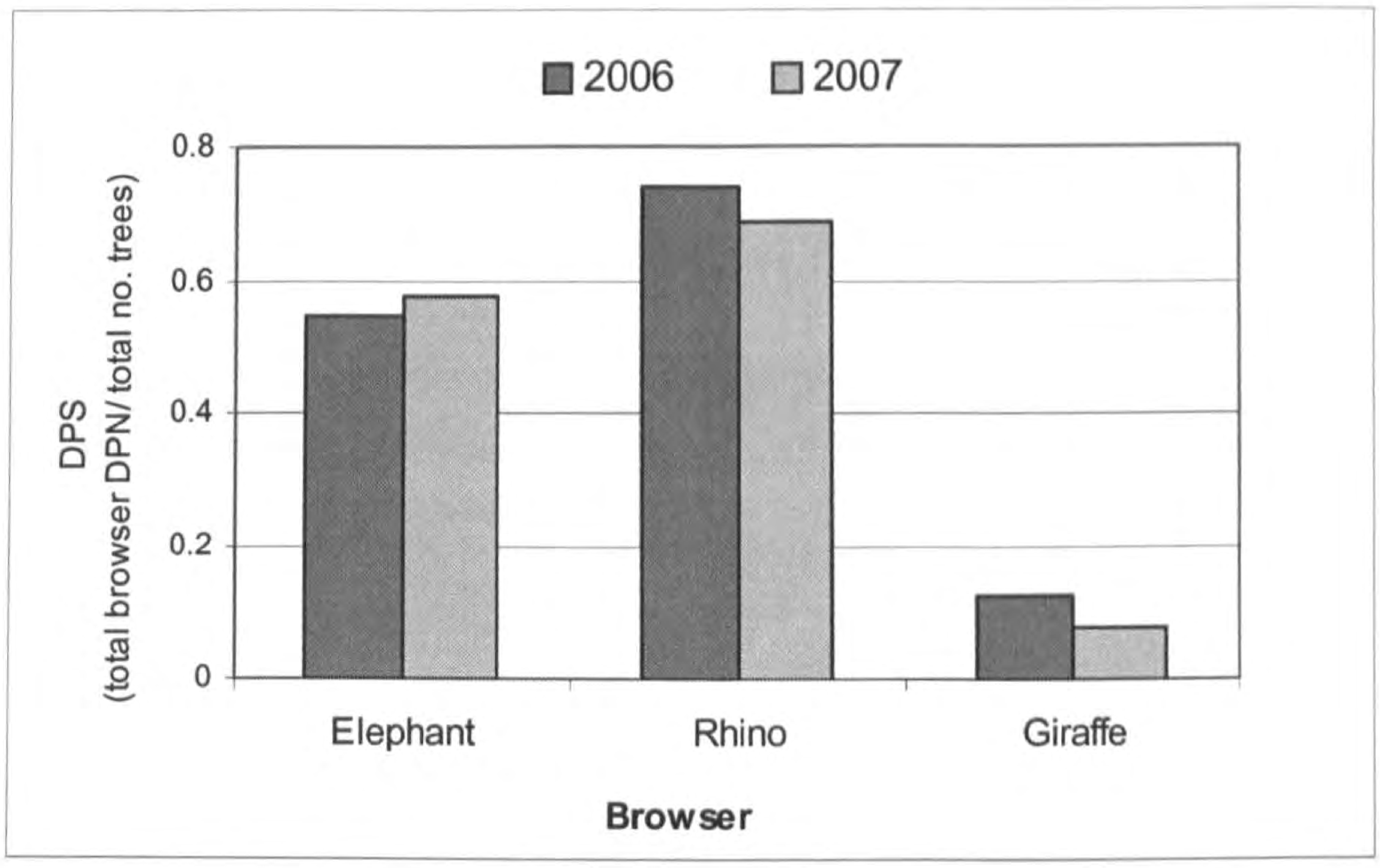


Figure 4.31: DPS per browser, 2006 and 2007
DPS per browser, per year (DPS = total browser DPN / total no. trees)

CHAPTER FIVE: DISCUSSION - MANAGEMENT, MONITORING, AND THE CONSERVATION OF ENDANGERED SPECIES

5.1 Pre Amble

5.11 Research goal

Underpinning management and monitoring programmes is an understanding of the broad geography of endangerment and the specific threats that endanger species. Identifying such information for a sample of species, determining which have management and monitoring programmes and identifying attributes which make such systems successful, will provide useful information. This can be used to help in targeting conservation action and develop programmes which effectively protect increasingly vulnerable species.

The goal of this research was to evaluate the role of management, research and monitoring in the conservation of endangered species. Would it be possible to identify how widely used management and particularly monitoring programmes are and to judge their effectiveness for example against a species status and trend? Also could characteristics of a well monitored species in particular be identified, and do conservation ambassadors actually benefit from their 'notoriety'? Zoos are very popular and many species are represented in captivity, and some have captive breeding programmes. Does this type of species management have a global conservation role, and how successful is it in the conservation of endangered species? Monitoring may form the back bone of conservation, as without it, key management decisions would be badly informed. Would it be possible to determine how common monitoring programmes are for a sample of threatened species, and importantly, to identify key attributes of successful monitoring? Also, as funding is always an issue, and cost efficiency paramount, would it be possible to design a monitoring system which is both ecologically and cost effective? Attempting to answer such questions formed the principle aims of this research

5.12 Key research outcomes

The global analysis revealed that the majority of the 153 critically endangered and endangered terrestrial mammals under study occurred in Asia. Most of the species also have a range of only 1 country, and the majority rely in part, or solely on forest habitat. The most common threats to these species were found to be habitat loss and degradation, and hunting and harvesting. There were a further 5 threats identified as affecting more than 10% of the study species: accidental death, change in native species dynamics, alien species, persecution and intrinsic range restriction. It was clear that threats combine to increase extinction risk.

Analysis revealed that a critically endangered species may receive more conservation action, particularly research and monitoring than one which is 'only' endangered. Those species which also have research and monitoring were more likely to have an improved trend. Characteristics of critically endangered species were those with declining or stable trends. Endangered species were more likely to be found in Africa and South America. The study also identified the need for basic information about endangered species, in particular the need to quantify their population trends.

The danger of allocating conservation action based on geographic location has been indicated, with the theory of conservation hotspots potentially acting to create 'black spots'. A Random Forest classification analysis was able to detect relationships between extrinsic variables and status, trends and level of research. The novel use of this analysis highlighted areas requiring more focused conservation action and indicated characteristics of good research and monitoring.

The presence of species management and research and monitoring was shown to be positively associated with species population trends. Research and monitoring was found not only to be associated with a higher status, but also with species suffering visible threats, which are easy to study and where there may be an obligation to do research (with legal protection and/or in a protected area). Better research and monitoring was also associated with more charismatic species, although species management was not.

The most effective species management programmes were those which also incorporated a re-introduction programme. Both common and species specific management actions were found to be equally important, but must be used synergistically to be wholly effective: with the plethora of threats affecting species. This study highlighted that it is often the acute and specific threats which act to undermine conservation work. In monitoring programmes, commonly used techniques are incorporated to answer specific management questions, and it is the basic, mostly indirect, techniques which will continue to form the basis of monitoring. It is also not the number of techniques which are used but the consistent use of one or two effective techniques which is important in good monitoring. Techniques which have been identified as having current use and future potential for many species include satellite technology, GIS, scat detection dogs, photography, laboratory techniques and community monitoring.

In the four, more detailed case studies it was collaboration and co-operation, a fast response and secure funding which were identified as the basic requirements for good management and monitoring. The criteria also identified secure funding as a key indicator for the presence of good management and monitoring. Other key indicators included a positive response of a species to management, availability of ecological and demographic information, and a statement that monitoring is being carried out. A gold standard of monitoring is achieved when a system has good foundations (is well planned, tried and tested) and there are clear goals and secure funding. Techniques should be sustainable, flexible, robust and easy to use, and designed to collect broad data allowing for post refinement to answer management questions. Information gained over a long time period is better than unstable, hasty information which is used to make decisions in the management of an endangered species.

From this information a flow diagram was suggested which was designed to guide through 'initiation', 'mobilisation' and 'implementation' of a monitoring system. This model was used to develop a system to monitor the impact of elephant, rhino and giraffe browse within a black rhino sanctuary in Kenya. The survey was designed to be the best statistically (collecting the optimal level of information for a given area and powerful enough to detect true trends), ecologically (collect specific browsing data to answer management questions) and logistically (using basic equipment, easy to use and low cost (time)). The vegetation data collection technique was shown to be effective and calculation of the DPS provided one measure of browse incorporating both presence and severity. The subdivided plot design stratified the data collection and helped to maintain motivation and orientation, meaning that fewer data were 'missed'.

Important findings were that, although the monitoring plots were found to be representative of the reserve, browsing is not uniform and variability (particularly with fine scale data) should always be expected. Also, even with thorough training and consistent field conditions, if different surveyors are used the potential for variability is high. Therefore, to achieve the best monitoring standards, data should be collected by the same surveyor for the entirety of the programme, and pre training and testing surveyors to identify the most consistent is recommended. The monitoring system is able to detect true trends and monitor long term vegetation changes, but if incorporated into the newly expanded conservancy, the number of plots should be proportional to the total area and that of each habitat type.

5.2 Successful management and monitoring

5.21 Threatened species

It is clear that the abundance and diversity of the world species is under threat and the current extinction crisis is both evidential and unprecedented, with the greatest threat to biodiversity undoubtedly being human induced change (Baillie et al 2004, Mooney and Cleland, 2001, Phillips and Shine, 2004, Purvis et al, 2000, Magin et al 1994, Myers et al, 2000). It is widely accepted that the two most prevalent threats are habitat loss and degradation, and hunting and harvesting (Baillie et al, 2004). This is further supported by the results of the global analysis. Of growing concern is the current and future effect of climate change (Dang et al, 2007, Pimm et al, 2006, Stachowicz et al, 2002), not only on existing resources for endangered species but in its effect on the integrity of already protected areas and habitats – with nowhere else for many species to go.

Also recognised and supported by this study is the fact that threats act together to increase a species' vulnerability to extinction, and the more insular a population becomes due to range restriction the more susceptible they are to other threats. (Beissinger, 2000, McLaughlin et al, 2002). What is also clearly indicated is that there may well be common threats which affect many species and require similar action to be taken across the globe, but it is the specific and acute threats which may be confounding efforts, and which require concerted and specific management action. It is these threats which ultimately may be reducing a species resistance to broader extinction processes. Examples of this are the Iberian lynx and the black rhino: the random forest analysis identified both the lynx and black rhino as having characteristics better suited to an endangered status than a critical one. The discrepancy may be a result of threats which are certainly specific and acute - poaching for the rhino and road accidents for the lynx (in particular the Doñaña population). Other problems for the lynx include accidental death, range restriction, lack of prey and disease, all of which are acting synergistically to endanger the species. By targeting and managing each threat individually, species populations will be given the best chance to recover in situ. While such acute threats remain un-managed for any vulnerable species, the effectiveness of other conservation action (e.g. habitat protection, re-introduction of individuals) is undoubtedly compromised.

5.22 Defining the attributes for success

Key precedents for effective management and monitoring were identified as: 1. collaboration and co-operation, 2. fast response (threat removal and first generation re-introduction), 3.secure and reliable funding. Without co-operation and contact between interested parties effective management is not possible: openness is needed with dissemination of results and communication to aid decision making and progression. At the time of the case study interview, there had been problems with collaboration involving Iberian lynx conservationists, and the hindrance generated by this was evident. In conserving wide ranging species which often cross geographic boundaries, such as the tiger and snow leopard, or for species which are maintained in patches within different countries, such as the wild dog and black rhino, such collaboration is essential to manage scattered populations as a whole.

Fellowes et al (2009) state that conservation involves many people, and of those people it is the officials in charge of protected areas which may be regarded as the most important. There is a danger in that often, such managers have limited scientific background, and consequentially, without ecological advice, could make well intentioned decisions which are harmful to biodiversity (Fellowes et al, 2009). They also state that it is only with improved collaboration, and the pooling of knowledge, perspectives and skills, that many real world conservation problems can be addressed.

A fast response, particularly to removing or managing threats is a common sense approach. It must be the first step for many species especially where the clear impact of removable threats are seen, such as fishing debris for the seal and sea lion species, and road accidents for the Iberian lynx. Where threats are more difficult and controversial, but there is a clear issue where work can be targeted to alleviate such pressure, this should be the first point of action. For example it is clear that there must be greater international efforts and pressure to prevent poaching of the tiger, snow leopard and all rhino species for the supply of Traditional Chinese Medicine. Of course, all conservation action, whether at ground level or international, relies on financial support.

A conservation success story which has incorporated all three precedents is the Californian channel island fox, and by doing so the conservation work has saved the species from almost certain extinction. The speedy response was vital, with threat removal and a short captive breeding timescale which saw original members and first generation offspring released back into the wild – thus minimising any loss of survival skills. Effective monitoring since then has shown increases in all released populations. Although rightly regarded as a conservation success, an undoubted contribution has been the fact that the fox, for the most part, is isolated from human settlement and disturbance. The most important attribute therefore, is the absence of humans, and if this was the case for many study species, it is highly likely that most, if not all would not be threatened in the first place.

Information from the four case studies was used to identify the criteria which indicate good management and monitoring and these were applied to the 20 monitored species. Most of them scored well, which would be expected (they were originally chosen as they had monitoring programmes). In particular the greater Indian one horned rhino scored just as well as the 4 case study species on which the criteria were based, and for which more information was known. This is interesting as due to successful management and monitoring, the status of this species has improved (appendix 6), and as a result this rhino has been downgraded from endangered to vulnerable (Talukdar et al, 2008).

Some of the criteria indicate good management just from the nature of the type of information needed to meet them (e.g. a statement that monitoring is in place, the presence of ecological and biological data and evidence of a positive species response to management). The presence of secure funding is also an indication that there is the opportunity to have specialist staff and resources. By simply finding basic information as suggested by the criteria in this study, the potential for the presence of good management and monitoring programmes for endangered species can be indicated.

5.23 Effectiveness of management and monitoring

5.23.1 Species management

The effectiveness of ex situ and captive breeding programmes is arguable, and they are regarded as a last resort by some, and a useful conservation tool for vulnerable species by others (Snyder et al 1996, Tenhumberg et al 2004, Earnhardt 1999). More than half of the study species had some form of species management. An ex situ population with captive breeding but without re-introduction did not seem to contribute to effective conservation, although these may not of course be causal relationships. It is possible that re-introduction is not feasible because threats in the wild have not been controlled causing any positive effects of management to be undermined. It makes sense, however, that the most effective management is that which directly supports in situ conservation by making sure re-introduction is both possible and achieved. In situ conservation should always be given greatest prominence in any management programme. Even vulnerable wild populations may still be far more viable than captive populations and if captive propagation is used, without re-introduction, conservation breeding is a failure (Balmford et al 1996, Ebenhardt 1995, Snyder et al, 1996).

Following successful breeding in captivity, there were two species in particular which would seem to require re-introduction to be established - the giant panda and the Iberian lynx. The genetic diversity of the captive panda population is low and the one re-introduced panda which was trained for 2 years before release was found dead in 2007 after its release 10 months earlier (Ran et al, 2009). For the Iberian lynx, there is a danger that the current captive breeding successes will garner the attention, funding and efforts, causing in situ work to become secondary. There are so many threats affecting the lynx that concerted effort to minimise these is vital. Habitat protection and restoration, rabbit population recovery, disease research and prevention, and the co-operation with landowners to reduce hunting impacts and to prevent road accidents must be dealt with quickly so that a re-introduction programme can be initiated, thus avoiding the ultimate failure of the captive breeding programme. For the black rhino, the support of suitable captive breeding initiatives is part of the African rhino action plan (Emslie and Brooks, 1999, appendix 7), but as with the findings here, it must carried out in direct collaboration with in situ conservation and re-introduction measures should be developed as an inherent part of the programme, other wise captive breeding is purely for captive gains.

The risks involved with re-introduction are recognised (Breitenmoser et al, 1999, Earnhardt 1999, Griffin et al, 2000, Mathews et al, 2005, Parsons, 1999, Rees, 2001, Smith, 1999), and reasons for failure are well documented (Griffin et al, 2000, Mathews 2005, Shepardson 1994, Snyder et al 1996). Many issues are likely to be exacerbated the longer individuals are kept, and/or the more generations pass by, in captivity, essentially expanding the gap between individuals and their wild ancestors. Also by not adequately assessing release site, providing adequate training, or by creating stress in a sudden movement and release, the process of reintroduction will likely fail. Therefore to be successful, programmes must be well informed and developed in synchronisation with in situ management, threat removal and in accordance with the needs of the individuals to be released.

It is recognised that species management techniques, such as those discussed here, should only be employed only when other viable techniques are unavailable (Snyder et al,1996). For all species, in situ conservation is of paramount importance, and habitat protection is vital, as highlighted by the 20 monitored species in this study. A priority action for many of them is habitat protection and better management of reserves and their boundaries. Consideration of habitat changes are a small focus within the African rhino action plan (Emslie and Brooks, 1999). This study has supported the requirement for a greater emphasis on habitat conservation in the work to conserve threatened species. There needs be a continuation of, or the development of, a 'sanctuary' attitude for the conservation of the black rhino, and protected areas cannot afford to be compromised by other management focuses. For species such as the Javan rhino, habitat conservation is crucial. There is no ex situ population and in any case, following Snyder (1996), this is one population which is extremely vulnerable but which may be more viable with improved management in situ. With increased habitat availability, the Javan rhinos demographic viability has the potential for improvement without the incorporation of captive propagation.

The presence of species management (ex situ, captive breeding and re-introduction) does have an effective role in global conservation, with measurable associations with an improved species trend. However, it is in taking the extra step to re-introduce species which has the most impact. It is not suggested that the numbers of reintroduced individuals are dramatically increasing species trends, but it may be that in having such a high profile conservation programme, and in taking the measures to control threats to make it viable to re-introduce individuals, the whole in situ population is then supported. The need to control threats is evident also for the black rhino. Major threats for this species are traditional Chinese medicine and ornamental dagger handles – both causing poaching for rhino horn. The action plan states the need for cultural sensitivity (Emslie and Brooks, 1999) and at the time of publication (1999), the action plan stated there had been 'some progress' in interested parties recognising the need for exploration of limiting medicinal uses and in 'exploring the potential of farming'. Demand for rhino horn is intensifying, so this approach is clearly not working. There needs to be increased action at the source of the problem and intense pressure to curb the demand, possibly by having more conclusive evidence of the lack of medicinal properties in comparison to other keratin rich materials. Cutting the demand will ultimately result in little or no poaching. This is true for many endangered species suffering the same threat.

5.23.2 Research and monitoring

Monitoring is an essential pre-requisite for effective conservation management as it provides the data on which to base management actions, achieve conservation targets, and set priorities, and a thorough grounding in theory and practice is essential (Battersby and Greenwood, 2004, Harris and Yalden 2004, Joseph et al, 2006, Nichols and Williams, 2006, Smart et al, 2004, Smith et al, 2006, Vasarhelyi and Martin, 1994). Monitoring system development is widely regarded as complex, with issues in choosing the best methods, the need for financial support and in clearly defining its purpose (Caughlan and Oakley, 2001, Joseph et al, 2006, Landsberg & Crowley 2004, Smyth and James, 2004, Watson & Novelly 2004). Monitoring also requires long term consistency and a significant past to be of any value (Watson and Novelly, 2004). It is for these reasons that for a species to achieve the best research and monitoring grade in this study (RMG = 5), a monitoring system had to be in place alongside evidence of all types of research.

This study found the presence of research and monitoring to be associated with a positive species trend. Unfortunately, the allocation of research and in particular monitoring for the 153 study species was not widespread. With mammals supposedly one of the best studied and understood classes (Magin et al 1994, Baillie et al 2004), the low occurrence of research and monitoring was surprising, and it is worrying to think of the level of research underway for other members of the animal kingdom. Such a low occurrence of research supports the identified requirement for more information, particularly about basic trends and especially for the endangered species.

Research and monitoring is expensive and there is growing pressure for cost efficiency within conservation, where there are limited funds, conflicts of interest and inherent financial costs of conservation action (Lindsey et al, 2005, Main et al, 1999, Rondinini and Boitani, 2007, Shogren et al, 1999). The assimilation of information and the identification of true trends will always be a basic requirement of species protection, it is the most simple and indirect techniques (e.g. sign surveys) which are most economically viable, and will continue to form the backbone of monitoring species. Some simple, although innovative, techniques are also playing an increasing role (community monitoring, scat detection dogs), and technological techniques (e.g. satellite monitoring, genetic analysis, GIS) gain useful insights into species' ecology, and may become viable for use with almost all threatened species. It may seem advantageous to use such technology where funding and expertise is available, but potential advances in knowledge must be balanced against the risks, for example in using techniques which involve trapping or darting the animal. Each individual of an endangered species is extremely valuable and the risks involved with using anaesthesia, and the stress or ill effects it causes, should never be underestimated.

Identifying associations between species characteristics and the level of research and monitoring in place could be useful: species with characteristics found to be associated with high levels of research, which are not currently studied, could be highlighted, or the information could be used to better target research towards species with other characteristics which are less understood. Variables associated with good research and monitoring in this study included species protection (legal/protected area), open habitats (grass land/ shrub land), limited dispersal, human/species conflicts and change of native species dynamics. Such associations may reflect patterns in the ease of study (open habitats) or greater research interest/obligation (hunted/persecuted species). There may also be other obligations to carry out research, for example to keep funding bodies responsible for legal protection and protected areas status informed of progress. More funding and greater access to legitimate protected areas may be available, and such work may be deemed more attractive (presence of the study species is almost guaranteed, and there may be facilities provided for research and monitoring work).

Any research and monitoring of endangered species should aim to be effective and through the best practice list developed from the responses of conservation scientists and managers, it is revealed that many attributes of monitoring are broadly recognised in practice. Such information has been combined and supporting literature (e.g. Caughlan and Oakley, 2001, Evans and Hammond, 2004, Regan et al, 2008, Schwartz et al, 2006, Smyth and James, 2004, Watson & Novelly 2004) has been used to confirm the suggested set of requirements for a good standard of monitoring. By following such basic requirements, effective monitoring can be readily achieved.

5.24 Execution of monitoring design

5.24.1 Model comparison

Following the definition of attributes of good monitoring, the flow diagram suggested by this study (chapter 3) was designed to be simple. It was also designed with a relatively small scale requirement to monitor the vegetation of a reserve, but, as discussed, it incorporates similar features identified in other large scale assessments of monitoring design issues. The model identifies a process which is similar to other models or stages developed for the purpose of designing monitoring systems. Most notably it is similar to the framework for building and operating a cost-effective programme developed by Caughlan and Oakley (2001). Their framework describes a 3 stage process of design, testing and implementation and which is based on budgeting with each stage requiring justification of the costs involved. In comparison, the flow diagram appears to split the design stage of their framework in half (initiation followed by mobilisation), and so identifies the need for monitoring and the desired outcomes prior to the issue of funding within the mobilisation phase. It is suggested that by bringing budgetary constraints in too early, in monitoring conception, then a much needed system may never be given consideration.

Both systems recognise the importance of carrying out a pilot study. A difference between the two models is that strategic planning takes place at a later stage in this study's flow diagram. During the development of the monitoring system in this study, it was within the strategic planning stage that most data analysis was carried out, the field work procedure was refined, optimisation and power of the system was considered, data storage and analysis techniques were set and logistical plans for monitoring fieldwork were made. It is therefore suggested that it may be more cost and time effective to have piloted techniques, established the minimum sample size required and then secured funding and resources, prior to strategic planning to avoid wasting funds, time and resources.

Evaluation and feedback are important elements of both models. A final major difference between the flow diagram and the framework suggested by Caughlan and Oakley (2001) is the consideration given in the flow diagram to training after strategic planning. An important element of the list of best practice, on which the flow diagram was based, was consistency and standardisation through the provision of a training programme. System designers may not be the ones collecting the data, and so training has to be an integral part of monitoring design and any system has to be communicable.

The effectiveness of any system design is reliant upon specific conditions and management issues on site. Both suggested models are developed from a different basis: one is designed around the achievement of cost effectiveness, the other, on the opinion of practical conservationists of what makes a good monitoring system. What is achieved in this study is the practical application of the flow diagram for designing a monitoring system.

5.24.2 Successful application

The conservation strategy for the Black rhino in Kenya recognises that there is a requirement for the assessment of vegetation status (Okita-Ouma et al, 2007). In places like Sweetwaters (now Ol Pejeta Conservancy (OPC)) priority is given to the black rhino and the maintenance of favourable habitat conditions. It is stated that enclosed areas are susceptible to major fluctuations in the populations of a variety of species, potential over-browsing of favoured black rhino diet species, habitat changes caused by elephants, disturbance of black rhino, and the pressure for both fence and water maintenance (Okita-Ouma et al, 2007). The need for a monitoring system which is appropriate to enclosed systems is clear, as habitat changes can affect the carrying capacity for black rhino (Okita-Ouma et al, 2007).

In response to legitimate concerns about the alteration of vegetation in response to browsing within the then enclosed Sweetwaters black rhino sanctuary (Birkett, 2002, Birkett and Stevens-Wood, 2005, Gitchohi, pers.comm), the conceptual model was applied (2005 – 2007) to design a system capable of monitoring such vegetation change. During system development, there were some interesting findings, most notably with the potential effects of using a variety of surveyors to collect the data, which will be discussed later. Another finding was that subdividing a plot benefited the field technique: subdivided control plots yielding higher means for most variables, and there was motivation to finish each block without feeling overwhelmed. It was also clear which trees had been included and which had not, therefore disorientation was considerably reduced. Subdivision may also have added benefits: full plot data can be divided into smaller sections for comparative analysis and there is flexibility to survey each block differently if required, e.g. to monitor the effect of different land management practices on a control area.

Overall the system designed in this study appears to be effective in that the 15 monitoring plots were found to be representative of the reserve. Also the survey was found to be powerful enough to detect an 8.4% change in the number of damaged trees, and a 5.6% change in the damage product score (DPS) per year. An almost 10% change in the number of damaged trees may not seem to be a useful measure, as this appears to represent catastrophic damage – it must be remembered that this survey can record a damaged tree that has one nibbled branch. In fact the majority of browse recorded qualified in the least severe damage class where less than 25% of the canopy was damaged. Therefore the methodology is sensitive. It can be argued that monitoring change in the DPS score would be more useful, as the calculation of this score combines a measure of browse presence with a measure of its severity, therefore if DPS increases this represents an increase in presence and/or severity of browse.

This study has shown the successful progress through initiation, mobilisation and implementation of the suggested development model, and has designed what could be an effective monitoring system. Problems with deciding which methodology to use (Joseph et al, 2006) were overcome in the mobilisation phase of the model through the testing of a variety of techniques. In response to literature (e.g. Carlson and Schmeigelow, 2002, Caughlan and Oakley, 2001), the concept of optimisation and power were incorporated into strategic planning and final method design. The plot design suggested in this study has been thoroughly tested and its concept, design and data collection technique has foundations within other scientific literature (e.g. Abella and Covington, 2004, Afolayan, 1975, Barnes,1983, Ben-Shahar, 1993, Birkett, 2002, Buechner and Dawkins, 1961, Krebs, 1999, Lunney et al, 2000, Parrikh and Gale, 1998, Shuman and Ambrose, 2003, Walpole et al, 2004). To complete the application of the model, the training programme with the research department of OPC was successful, with the field methodology, data entry, storage, and analysis techniques translating well. This is the point at which OPC can enter the monitoring cycle, continuing to use and evaluate the system if they choose.

Other habitat monitoring procedures specifically for the black rhino have been developed, with training provided to park personnel. One such technique involves visually assessing rhino browse and assigning a browse availability score: the percentage to which browse-able plant canopies fill the 0-2 metre tall space over a site

(Adcock, 2005, Adcock pers.comm, 2006). The methodology is quick and easy to use in the field and is effective in giving an accurate estimate of the ecological carrying capacity for black rhino in a given area (Adcock pers.comm, 2006, Okita-Ouma et al, 2007). What this method does not include is a measure of the presence and severity of browse by rhino and other species which may compete for resources such as elephant and/or giraffe. It is therefore proposed that the damage assessment developed in this study could be combined with the assessment of browse availability. During a Southern African Development Community (SADC) training programme (2006) at OPC to assess the carrying capacity of the new area becoming available to rhinos, the accepted browse availability methodology combined well experimentally with this studies vegetation assessment technique. The two techniques therefore have great potential to be synergised, effectively providing a measure which would balance browse availability with current resource pressure.

As previously stated, there needs to be a greater emphasis placed on habitat management and monitoring within the African rhino management plan. Ultimately, to state the obvious, if there is no habitat or the habitat is poor quality there can be no species. There is a danger in increasing black rhino populations within enclosed reserves (i.e. through breeding and translocations) without intensive pre-habitat assessment and continuous monitoring. Such monitoring is essential to avoid potential catastrophic demographic collapse. It is stated in the management plan for rhinos that monitoring the population is the first line of defence against poaching (Emslie and Brooks, 1999), as such work will enable quick detection of a problem – the same is true for the habitat and its resources. Within an enclosed reserve, it is vital that 100% of the area must be 'available' and of sufficient quality for rhino, in order to maintain the optimum carrying capacity, genetic diversity and overall demographic stability. It is hoped that with the development of the conservation strategy for the black rhino in Kenya, that there may be a greater habitat focus. This study has developed a methodology which works and which is also adaptable, the issue of variability has also been incorporated and will be discussed.

5.24.3 Variability

The potential affect of using different surveyors to collect data within an ecological monitoring project was highlighted by this study through results from the test plot and transect in the pilot study, and from the control plot when testing the designed field method. Although the same broad conclusions would have been made, particularly following the designed field method, variability increased for finer scale data, and for some important variables, there was a large range of results from the different surveyors in the initial test plot and transect.

There are many organisations (e.g. Operation Wallacea, Greenforce, Frontier, Earthwatch) which incorporate the use of volunteers to collect large amounts of ecological data which is then analysed to inform management decisions. Although this is undeniably the most effective way of producing a large amount of information over a short time scale, this study highlights the potential dangers of making important decisions based on such data, particularly for endangered wildlife. An additional point is that the surveyors involved with this study have a scientific background and were studying conservation-based courses, attributes potentially not acquired by expedition volunteers.

This study did find that variability decreased with experience, suggesting the importance of adequate training and most importantly, practice. Also where some surveyors were found to be consistently positively or negatively biased, a suggestion is to identify the most consistent and middle ranking surveyor, and for that person to collect the data for the entirety of a monitoring programme. It is of course recognised that this may not be possible. At the very least, it is important to recognise that the potential for variability when using a range of surveyors is high, and that training, practice and experience is essential.

There is no evidence that the reliability of data collected by programmes incorporating volunteers on a large scale has been assessed. Designing a data collection technique which cuts down potential variability is key to the reliability of such projects. In their study, Birkett and Stevens-wood (2005) used data collected by Earthwatch volunteers, but their method involved recording information from individually marked and number trees, and data collection did not depend on previous experience. Such methodologies therefore may be more stable, and inherently take into account potential variability. Even so, before decisions are made, important findings from data such as that collected by volunteers, should at least be verified, or the level of error calculated and results corrected, before they are acted upon.

5.3 Allocation of conservation action

5.31 Ambassadors

The Iberian lynx was voted the most charismatic species in a small survey grading critically endangered mammals and this indicates its potential as a flagship species. On the whole, the carnivores received the highest mean score. There may well be cause to suspect that charismatic species receive more conservation action, particularly research and monitoring as the best levels were associated with higher charisma scores. It is clear that charismatic species have flagship potential and that they have a role in raising public awareness, sympathy and finance, and that captive individuals can become ambassadors for their wild counterparts (Balmford et al 1996, Dietz et al 1994, Rabb and Saunders, 2005, Snyder et al 1996). For these reasons zoos have an obvious role in global conservation of endangered species. Good zoos also importantly provide support for in situ work through running their own projects or by raising financial support (*WAZA, 2005*). Species management (ex situ, captive breeding and re-introduction) was not found to be associated with charisma score therefore there are broad indications that its allocation is based on need. Charismatic species may not only have a valuable role as a flagship for their own kind, they are potentially supporting other species, by raising awareness of conservation and generating funds which are spread across projects for many species.

5.32 Status and Hotspots

Resource allocation in species conservation is often based on an assessment of threat (*Master,* 1991). The effectiveness of the IUCN classification system in providing impetus for action for the highest status has been demonstrated. It has been shown with the sample of terrestrial mammals that species with a higher status are more likely to receive conservation action, in particular more research and monitoring. It may be that there is more motivation to work with a critical species, and probably that funding is more likely to be available. More is known about the critically endangered species in comparison to the endangered ones, and a clear need for information about the lower status species has been highlighted. Without up-to-date data about a species, true assessments of their situation cannot be made and ultimately conservation action cannot be effective.

Studies have associated many species characteristics with a potential increased risk of extinction (e.g. Beissinger, 2000, Owens and Bennett, 2000, Purvis et al 2000a, Purvis et al, 2000b). Much of their work has concentrated on biological correlates, and assessed why certain species may be more susceptible to extinction. A related and possibly more useful approach is to identify which species may be miss-classified (particularly if they are more threatened than is currently thought) and/or predict which species may become more threatened in the future. There are clear advantages of developing a system which can predict the vulnerability of a species from extrinsic data sources such as represented in this study. Here such data has been incorporated into a Random Forest analysis which is ideally suited to cope with the wide range of variables which affect endangered species. Although limited to 153 mammals from four orders, the potential for the use of such analysis has been shown. Not only did the analysis identify variables which distinguished a critically endangered from an endangered species, but it showed its potential to predict values for unknown categories. Potentially it could be a powerful tool with a global application as it provides a system which combines data, such as that represented here, with other extrinsic data such as measures of human development, alongside new and existing biological data.

It is important to balance conservation action and target species most in need, by not restricting the basis of action solely on geographical location or biological information. An analysis such as used here can identify potential areas where conservation needs to be improved, but it is not suggested as the only method to use. Instead it is proposed as an additional tool for conservation planning which could facilitate better progress and help make improved decisions in the allocation of much needed resources. Currently conservation action allocation is based on assessments of threat (e.g. IUCN red list) and on theories such as the hotspot theory (Myers et al, 2000). The danger of relying upon one theory to assign conservation value is recognised (Ceballos and Ehrlich, 2006, Cardillo et al, 2006), and Myers (2003) does state that the 'hotspot' theory is not designed to neglect other areas. However in recognising existence of the hotspots, conservation decision makers may inherently favour them.

Based on species distribution maps (IUCN red list, 2008) of the 20 monitored species included in this study, the ranges of 6 species fall within the boundaries of a number of conservation hotspots suggested by Myers et al (2000) (Sumatran rhino and Javan rhino: Sundaland hotspot, greater Indian one horned rhino: Indo-Burma hotspot, Iberian lynx: Mediterranean basin hotspot, Hawaiian monk seal: Polynesia/Micronesia hotspot, and golden lion tamarin: Brazil's Atlantic forest hotspot). For 6 species, the hotspot boundaries possibly incorporate some of their range (snow leopard, tiger, black rhino, California channel island fox, giant panda, Mediterranean monk seal). For the remaining 8 species, the hotspot boundaries appear to entirely miss their range (Eastern mountain gorilla, Western lowland gorilla, Grevys zebra, Northern steller sea lion, African wild dog, Ethiopian wolf, red wolf, Arabian oryx). Therefore, if conservation action was to be based solely upon the geographical hotspot theory, 40% of the monitored species would not be conserved, and a further 30% would only have part of their current range protected. This is only small sample of species, even so allocation of conservation action restricted within hotspots would fall short of what is required.

This study has shown that focusing on recognising which species are at risk and concentrating on solutions is successful: species can be successfully managed and monitored, with a higher and more species specific input resulting in the greatest success. One undeniable factor for conservation success is the availability of funding and whether conservation action is species specific or based on theories, its success will always be reliant upon financial support. All case studies highlighted the importance of funding, with the most successful case study (channel island fox) located within a developed country and with no funding issues. The others, especially the panda and black rhino, are supported internationally. In comparison to the species specific approach, the conception and utilisation of broad scale theories to direct conservation resources internationally is financially cheap to do, but the most cost effective approach will always be the one that is most successful in achieving its goal.

5.4 Further research

Information analysed in the global analysis part of this study can be re-assessed on a five yearly basis. Predictions following Random Forest Analysis can be tested by looking at changes in IUCN categories in the future. Such work can also be expanded to include other species and orders. Are their fluctuations in the patterns and process, and if so how extensive are the changes? Can trends in management, research and monitoring be identified? Does such work improve or for most species does it stagnate over time? For species with changes in status, can changes in the level of conservation action and protection be identified, and over what timescale? Can successful management action be greater refined? Such research would support collaboration in the field of conservation and would clearly identify areas and species in need of resources.

Extrinsic and intrinsic data, including human factors, can be combined and the effectiveness of Random Forest Analysis in identifying associations and identifying areas for targeted action for all threatened species can be assessed. Can such analysis effectively target species most in need of conservation resources? Of those species identified, does field work corroborate the requirement? Results from such research has great potential in helping to guide decision makers to allocate conservation resources based on species specific assessments.

The application and effectiveness of management and monitoring across other groups within the animal kingdom can be assessed, this may be most useful for groups which are not as well known as mammals. How widespread is management and research across the animal kingdom? Have programmes been more effective for some groups than others and if so are their attributes identifiable and comparable i.e. are attributes for good management universal or specific? The usefulness in assessing and evaluating how effective conservation action has been in protecting vulnerable species is vital to its progress. Also by compiling such information, opportunities for identifying and refining successful techniques, and collaborating across the conservation network are enhanced.

The potential for variation in volunteer based data and its effect on the results of programmes incorporating volunteers can be assessed. Such work can be targeted at making such data collection more reliable and could also evaluate the potential impact of action taken based on the outcomes of such programmes. Have actions been successful regardless of potential data variability? Are there identifiable areas for improvement? Is the snap shot provided by such programmes sufficient or is greater refinement and accuracy of information required?

The designed monitoring system can be used and expanded across OPC. Is the programme effective in monitoring browse over a set time period (e.g. 5 years)? Does the research department find the system useful and flexible enough to incorporate other data collection? Only with longevity can a monitoring system be truly evaluated.

5.5 Summary

The aims and objectives presented at the start of this study have been met, and the questions which formed the goal of this study have been answered:

- *Are management and monitoring programmes widely implemented?*

  - 54% of the study species have some form of species management.
  - Only 12% have species management which includes a re-introduction programme.
  - 41% of the species have some form of research.
  - Only 16% of species have a monitoring programme.

More than half of the species analysed (Chapter 2) have some form of species management (ex situ, captive breeding, reintroduction), but far less have species management which involves re-introduction.

The majority of study species have no evidence of research or monitoring, and very few have evidence of an established monitoring programme.

Species management appears to be widely implemented, it may be more desirable that it is not, i.e. that more funds are allocated to in situ conservation. Research and particularly monitoring is not widely implemented, but there is a clear need to quantify trends, particularly for lower status species. This study found that higher status species (critical rather than endangered) are more likely to receive research and monitoring, therefore its implementation is uneven.

- *Are management and monitoring programmes effective in protecting species which are vulnerable to extinction?*

The presence of management and research and monitoring has a positive affect on population trend, therefore they appear to be effective in stimulating an increasing population.

Species management is most effective when re-introduction is involved (chapter 3). It may be that high profile management such as re-introduction raises funds, awareness and the level of protection for the species in situ therefore causing a positive effect on overall species trend.

In situ, common and specific management actions are important, with particularly acute threats needing concerted management (chapter 3). It is these specific, acute threats which can threaten the viability of conservation action e.g. Iberian lynx, black rhino

Monitoring is effective where it is implemented, there is clear a need for more. Where monitoring does exist, it is most effective where 1-2 techniques are used consistently (Chapter 3). The basic and indirect techniques (e.g. sign surveys) will continue to provide baseline monitoring. New and innovative techniques (e.g. satellite technology, GIS, community monitoring, scat detection dogs) having great potential for future monitoring but risks must always be assessed.

In comparison to broad conservation theories used in the allocation of resources (e.g. the hotspot theory) a species specific approach is more effective, and more likely to succeed, therefore is more cost effective in the long term

- *Can characteristics of well monitored species be identified?*

Random Forest analysis (chapter 2) has examined extrinsic variables associated with extinction risk and identified important variables in the data set, indicated associations between them, and identified characteristics of well researched and monitored species.

The best level of research and monitoring is associated with species which trends are known and also which:

- have a high status (e.g. critical)
- suffer visible and acute threats (e.g. direct human impact, natural disaster, change of native species)
- are easy to study (e.g. open habitat types, limited dispersal)
- are researched as part of management (e.g. legal protection, protected area)
- are charismatic

- *Do conservation ambassadors benefit from their notoriety?*

The presence of research and monitoring was found to be associated with species charisma, however species management was not. Therefore charismatic species may well receive more conservation action in the form of research, but species management appears to be based on need.

In their potential role as flagship species, charismatic species not only raise awareness and funds for their own kind but may also raise support for in situ conservation of many other species.

- *Can attributes of successful management and monitoring be identified?*

Important attributes for effective management (Chapter 3) include: collaboration and co-operation, a fast response and secure funding.

The Californian channel island success story achieved all of these attributes and in addition, fox recovery is, for the most part, also attributed to the absence of humans.

Indicators (Chapter 3) from basic information that effective management and monitoring may be in place include:

- The presence of secure funding
- A positive species response to management efforts (e.g. population increase)
- Availability of up to date ecological and demographic information
- A statement that monitoring is under way
- The species is regarded as an ambassador (e.g. flagship, umbrella)
- The species has legal protection or is in a protected area.

To achieve a 'gold standard' of monitoring (Chapter 3) a programme must:

- Have good theoretical and practical foundations
- Have secure funding
- Have clear goals
- Be technically robust, sustainable, flexible and incorporate training
- Collect broad data for later refinement
- Be easy to implement, evaluate and communicate,
- Be designed with longevity in mind.

In addition (chapter 4) for the best standards of monitoring, a programme should ideally identify the most consistent surveyor/s and use the same surveyor/s for its entirety. Where different surveyors have to be used, account for variability and adjust for error or verify results before action is taken. The monitoring system should also incorporate cost effectiveness and power into its design

- *Can a monitoring system be designed to be both ecologically and cost effective?*

The flow diagram (chapter 3) provided a systematic way to develop a monitoring system to assess the level of elephant, rhino and giraffe browse within Sweetwaters black rhino sanctuary, Kenya.

A vegetation survey technique was designed, a range of methodologies tested, the effect of different surveyors explored, the concept of optimisation included in methodology design, one measure of damage occurrence and severity was suggested and the power of the 15 monitoring plots to detect a true trend assessed (Chapter 4).

Ecologically (2006, Chapter 4 part B), 45% of trees were recorded as having some form of browsing damage. Most damage occurred to trees less than 2 metres tall, in accordance with abundance, and for all forms of browse, the majority did not cause severe damage. The most common browse was rhino browse.

The 15 monitoring plots were found to be representative of the whole Sweetwaters area, but browsing is not uniform and variability between plots should be expected (Chapter 4, part B)

In terms of cost, the methodology uses basic equipment and the plots are quick to survey (14- 33 minutes (mean = 26 minutes)), and plot subdivision is effective in maintaining orientation and motivation (Chapter 4).

The methodology is optimal in that it collects the maximum amount of information for a given area and in the minimum time.

The technique has been shown to be powerful enough to detect an 8.4% change in the presence of browsing damage (the number of damaged trees) and a 5.4% change in the DPS (damage product score combining both presence and severity) per year.

By following the flow diagram, incorporating optimisation in methodology design and determining a measure of the power of the technique, an ecological and cost effective monitoring system is achievable.

APPENDIX FOUR: Summary data for monitoring plots, 2006

Contents 2006

Table A

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*Totals*
No. Trees	53	76	87	48	95	40	89	107	45	68	87	58	73	54	70	***1050***
No.Trees D	21	38	40	29	37	17	40	43	22	30	24	15	39	43	31	***469***
Proportion D	0.40	0.50	0.46	0.60	0.39	0.43	0.45	0.40	0.49	0.44	0.28	0.26	0.53	0.80	0.44	***0.45***
% D	39.62	50.00	45.98	60.42	38.95	42.50	44.94	40.19	48.89	44.12	27.59	25.86	53.42	79.63	44.29	***44.67***
Total DPN	47	82	124	85	90	59	146	154	103	92	72	46	115	151	120	***1486***
Total DPS	0.8868	1.0789	1.4253	1.7708	0.9474	1.475	1.6404	1.4393	2.2889	1.3529	0.8276	0.7931	1.5753	2.7963	1.7143	***1.4152***
No.T D Ele	8	21	12	15	23	3	18	8	5	10	10	1	10	15	28	***187***
Propn of no.T	0.15	0.28	0.14	0.31	0.24	0.08	0.20	0.07	0.11	0.15	0.11	0.02	0.14	0.28	0.40	***0.18***
%T	15.09	27.63	13.79	31.25	24.21	7.50	20.22	7.48	11.11	14.71	11.49	1.72	13.70	27.78	40.00	***17.81***
Propn of D	0.38	0.55	0.30	0.52	0.62	0.18	0.45	0.19	0.23	0.33	0.42	0.07	0.26	0.35	0.90	***0.40***
%D	38.10	55.26	30.00	51.72	62.16	17.65	45.00	18.60	22.73	33.33	41.67	6.67	25.64	34.88	90.32	***39.87***
No.T D Rhi	18	22	29	7	17	8	21	26	12	8	7	11	21	21	5	***233***
Propn of no.T	0.34	0.29	0.33	0.15	0.18	0.20	0.24	0.24	0.27	0.12	0.08	0.19	0.29	0.39	0.07	***0.22***
%T	33.96	28.95	33.33	14.58	17.89	20.00	23.60	24.30	26.67	11.76	8.05	18.97	28.77	38.89	7.14	***22.19***
Propn of D	0.86	0.58	0.73	0.24	0.46	0.47	0.53	0.60	0.55	0.27	0.29	0.73	0.54	0.49	0.16	***0.50***
%D	85.71	57.89	72.50	24.14	45.95	47.06	52.50	60.47	54.55	26.67	29.17	73.33	53.85	48.84	16.13	***49.68***

Table A continued																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	***Totals***
No.T D Gir	1	0	4	6	0	6	6	13	8	18	11	2	15	19	3	***112***
Propn of no.T	0.02	0.00	0.05	0.13	0.00	0.15	0.07	0.12	0.18	0.26	0.13	0.03	0.21	0.35	0.04	***0.11***
%T	1.89	0.00	4.60	12.50	0.00	15.00	6.74	12.15	17.78	26.47	12.64	3.45	20.55	35.19	4.29	***10.67***
Propn of D	0.05	0.00	0.10	0.21	0.00	0.35	0.15	0.30	0.36	0.60	0.46	0.13	0.38	0.44	0.10	***0.24***
%D	4.76	0.00	10.00	20.69	0.00	35.29	15.00	30.23	36.36	60.00	45.83	13.33	38.46	44.19	9.68	***23.88***
No.T D Other	1	1	0	6	0	1	0	0	2	2	1	1	1	0	1	***17***
Propn of no.T	0.02	0.01	0.00	0.13	0.00	0.03	0.00	0.00	0.04	0.03	0.01	0.02	0.01	0.00	0.01	***0.02***
%T	1.89	1.32	0.00	12.50	0.00	2.50	0.00	0.00	4.44	2.94	1.15	1.72	1.37	0.00	1.43	***1.62***
Propn of D	0.05	0.03	0.00	0.21	0.00	0.06	0.00	0.00	0.09	0.07	0.04	0.07	0.03	0.00	0.03	***0.04***
%D	4.76	2.63	0.00	20.69	0.00	5.88	0.00	0.00	9.09	6.67	4.17	6.67	2.56	0.00	3.23	***3.62***
No.T MS D	6	14	22	16	22	8	28	19	18	11	10	6	13	18	22	***233***
Propn of no.T	0.11	0.18	0.25	0.33	0.23	0.20	0.31	0.18	0.40	0.16	0.11	0.10	0.18	0.33	0.31	***0.22***
%T	11.32	18.42	25.29	33.33	23.16	20.00	31.46	17.76	40.00	16.18	11.49	10.34	17.81	33.33	31.43	***22.19***
Propn of D	0.29	0.37	0.55	0.55	0.59	0.47	0.70	0.44	0.82	0.37	0.42	0.40	0.33	0.42	0.71	***0.50***
%D	28.57	36.84	55.00	55.17	59.46	47.06	70.00	44.19	81.82	36.67	41.67	40.00	33.33	41.86	70.97	***49.68***

Table A: Plot information 2006
Number of trees, number of trees damaged, proportion and percentage trees damaged for monitoring plots (1-15).
Calculated Damage Product Number (DPN) and Damage Product Score (DPS) (following figure 4.19, chapter 4) per plot and calculated as a total (>DPS = > damage presence & severity).
Damage breakdown for each browser species (and 'other' damage) including number of trees damaged (No T D), proportion of trees damaged from the total of trees recorded in the survey per plot (Propn of no.T), percentage of the total number of trees per plot damaged (%T), Proportion of the number of trees recorded as damaged per plot (Propn of D) and the percentage of damaged trees per plot (%D). All totals are in the last column.
All values calculated from raw plot data.

Table B1

	PLOT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*Total*
Height Class	**1**	42	49	68	28	65	27	77	88	40	46	77	57	64	37	49	***814***
	2	9	27	17	13	27	13	10	19	5	20	9	1	9	16	18	***213***
	3	2	0	2	7	3	0	2	0	0	2	1	0	0	1	3	***23***
		53	76	87	48	95	40	89	107	45	68	87	58	73	54	70	***1050***
D per HTcs	**1**	11	18	24	12	17	9	30	30	17	16	15	14	30	28	13	***284***
	2	8	20	14	10	18	8	8	13	5	13	8	1	9	14	16	***165***
	3	2	0	2	7	2	0	2	0	0	1	1	0	0	1	2	***20***
		21	38	40	29	37	17	40	43	22	30	24	15	39	43	31	***469***
Tree species	**AD**	9	1	26	21	1	35	15	32	40	54	36	58	58	49	21	***456***
	AS	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	***2***
	AX	0	2	3	0	1	0	0	0	0	0	1	0	0	0	0	***7***
	BG	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	***1***
	CE	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0	***4***
	ED	24	45	49	12	53	0	16	10	0	2	4	0	3	2	10	***230***
	GS	1	1	1	1	3	0	4	1	0	0	0	0	0	0	0	***12***
	MA	0	0	0	1	0	0	2	1	0	1	0	0	0	0	0	***5***
	MS	1	2	0	0	0	4	1	0	1	0	0	0	0	0	0	***9***
	PP	9	23	2	5	33	0	30	38	1	10	41	0	4	0	19	***215***
	RN	1	0	3	0	1	0	11	5	0	0	1	0	0	0	7	***29***
	RS	8	2	1	1	1	0	4	12	2	0	0	0	4	1	3	***39***
	SM	0	0	0	7	2	1	4	8	0	1	4	0	4	0	10	***41***
		53	***76***	***87***	***48***	***95***	***40***	***89***	***107***	***45***	***68***	***87***	***58***	***73***	***54***	***70***	***1050***

Table B1 Continued

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	*Total*
TS DMG	**AD**	2	1	5	13	1	14	8	15	18	26	17	15	31	38	14	*218*
	AS	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	*1*
	AX	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	*4*
	BG	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	*1*
	CE	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	*3*
	ED	10	27	26	10	28	0	9	2	0	1	1	0	1	2	4	*121*
	GS	0	0	1	1	1	0	1	0	0	0	0	0	0	0	0	*4*
	MA	0	0	0	1	0	0	2	1	0	1	0	0	0	0	0	*5*
	MS	1	2	0	0	0	2	0	0	1	0	0	0	0	0	0	*6*
	PP	1	7	1	1	5	0	5	2	0	1	1	0	0	0	1	*25*
	RN	1	0	3	0	1	0	6	4	0	0	1	0	0	0	5	*21*
	RS	6	0	0	0	0	0	4	11	2	0	0	0	4	1	1	*29*
	SM	0	0	0	3	1	1	4	8	0	1	4	0	3	0	6	*31*
		21	*38*	*40*	*29*	*37*	*17*	*40*	*43*	*22*	*30*	*24*	*15*	*39*	*43*	*31*	*469*

Table B1: Tree information

The number of trees in each height class (1: 0-1.9m, 2: 2-3.9m, 3: >4m), and the number of trees damaged (browsed) in each height class (D per HTcs) per plot (1-15).
The number of each tree species (no TS) snd the number of each tree species damaged (browsed) (TS DMG). All totals are in the last column and row following each set of data.
NOTE: one tree can suffer all damage types (elephant, rhino, giraffe, other)
Tree species key: AD: *A.drepanolobium*, AS: *A.africana*, AX: *A.xanthophloea*, BG: *B.glabra*, CE: *C.edulis*, ED: *E.divinorum*, GS: *G.similis*, MA: *M.triphylla*, MS: *M.senegalensis*, PP: *P.punctulata*, RN: *R.natalensis*, RS: *R.staddo*, SM: *S.myrtina*.

Tree	NO.T	NO.D	MS D	Edmg	EmsD	Rdmg	RmsD	Gdmg	GmsD	Odmg	OmsD	DPN	DPS
AD	456	218	104	65	31	96	67	78	4	11	2	799	***1.75***
AS	2	1	1	0	0	1	1	0	0	0	0	6	***3.00***
AX	7	4	4	0	0	4	4	0	0	0	0	27	***3.86***
BG	1	1	1	1	1	0	0	0	0	0	0	8	***8.00***
CE	4	3	3	0	0	3	3	0	0	0	0	17	***4.25***
ED	230	121	52	67	33	62	15	6	1	5	3	236	***1.03***
GS	12	4	4	0	0	3	3	0	0	1	1	13	***1.08***
MA	5	5	5	2	2	4	3	0	0	0	0	34	***6.80***
MS	9	6	4	1	0	5	4	0	0	0	0	31	***3.44***
PP	215	25	20	17	15	8	5	0	0	0	0	91	***0.42***
RN	29	21	18	8	7	16	11	0	0	0	0	78	***2.69***
RS	39	29	5	9	3	17	2	17	0	0	0	53	***1.36***
SM	41	31	12	17	12	14	0	11	0	0	0	93	***2.27***
	1050	***469***	***233***	***187***	***104***	***233***	***118***	***112***	***5***	***17***	***6***	***1486***	***1.42***

Table B2: Tree information - damage detail.

Tree species key: AD: *A.drepanolobium*, AS: *A.africana*, AX: A.*xanthophloea*, BG: *B.glabra*, CE: *C.edulis*, ED: E.*divinorum*, GS: *G.similis*, MA: *M.triphylla*, MS: *M.senegalensis*, PP: *P.punctulata*, RN: *R.natalensis*, RS: *R.staddo*, SM: *S.myrtina*.

Number of trees (NO.T), Number of trees damaged (browsed) (NO.D), number of trees with main stem damage (MS.D).
Number of trees damaged by each browser (elephant, rhino & giraffe) (e.g. Edmg = elephant damage), and 'other'.
Totals are shown in the last row.
Calculated Damage Product Number (DPN) and Damage Product Score (DPS) (following figure 4.19, chapter 4)
NOTE: DPN and DPS does not include other damage, it is browse specific (DPS = DPN/No.T)
(>DPS = > damage presence & severity).

Table C1

	Damage Class (DC)															
	Elephant				Rhino				Giraffe				Other			
PLOT	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	5	2	1	0	15	2	1	0	1	0	0	0	1	0	0	0
2	16	3	2	0	19	2	1	0	0	0	0	0	1	0	0	0
3	11	1	0	0	18	5	4	2	4	0	0	0	0	0	0	0
4	8	3	2	2	2	2	3	0	6	0	0	0	1	1	4	0
5	19	3	1	0	14	2	1	0	0	0	0	0	0	0	0	0
6	0	1	2	0	2	3	3	0	6	0	0	0	1	0	0	0
7	12	3	3	0	7	11	3	0	6	0	0	0	0	0	0	0
8	2	1	0	5	12	5	7	2	12	0	1	0	0	0	0	0
9	2	2	0	1	1	9	2	0	8	0	0	0	1	0	1	0
10	5	1	2	2	3	4	1	0	18	0	0	0	1	1	0	0
11	7	2	0	1	2	2	3	0	11	0	0	0	1	0	0	0
12	0	1	0	0	5	3	3	0	2	0	0	0	1	0	0	0
13	7	0	1	2	10	10	0	1	15	0	0	0	1	0	0	0
14	11	1	0	3	7	7	6	1	19	0	0	0	0	0	0	0
15	15	6	3	4	4	1	0	0	3	0	0	0	0	0	0	1
	120	***30***	***17***	***20***	***121***	***68***	***38***	***6***	***111***	***0***	***1***	***0***	***9***	***2***	***5***	***1***

Table C1 continued																
	Main Stem Class Score (CS)															
	Elephant				Rhino				Giraffe				Other			
PLOT	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0	1	2	0	1	0	1	0	0	0	0	0	1	0	0	0
2	6	1	1	1	1	2	0	2	0	0	0	0	0	0	0	0
3	4	2	1	0	3	1	1	10	0	0	0	0	0	0	0	0
4	4	0	1	4	0	0	3	1	0	0	0	0	0	0	0	3
5	11	4	0	1	1	0	3	2	0	0	0	0	0	0	0	0
6	0	0	0	2	0	1	2	3	0	0	0	0	0	0	0	0
7	3	2	3	3	2	1	13	1	0	0	0	0	0	0	0	0
8	1	0	0	5	2	0	2	8	0	0	1	0	0	0	0	0
9	1	0	0	2	0	2	1	7	0	0	0	4	0	0	0	1
10	1	0	0	5	0	1	0	4	0	0	0	0	0	0	0	0
11	2	0	0	3	0	0	3	2	0	0	0	0	0	0	0	0
12	0	0	1	0	0	0	1	4	0	0	0	0	0	0	0	0
13	0	0	1	2	0	0	3	7	0	0	0	0	0	0	0	0
14	0	0	1	3	0	1	5	8	0	0	0	0	0	0	0	0
15	5	3	2	9	0	1	0	1	0	0	0	0	0	0	0	1
	38	*13*	*13*	*40*	*10*	*10*	*38*	*60*	*0*	*0*	*1*	*4*	*1*	*0*	*0*	*5*

Table C1: Specific damage information

For each plot (1-15) the number of trees with Elephant, Rhino Giraffe and 'other' damage, separated into damage class (DC) (DC 1: 0-25% canopy damaged, 2: 25-50%, 3: 50-75%, 4: >75%) and main stem class score ((CS) = Proportion of total main stems of a tree damaged converted into a score 1-4) (CS 1: 0-0.24, 2: 0.25-0.49, 3: 0.50-0.74, 4 : >0.75)

Totals are shown in the last row of each section

			Elephant		Rhino		Giraffe	
PLOT	**No.T**	**No.TD**	DPN	DPS	DPN	DPS	DPN	DPS
1	53	21	20	0.38	26	0.49	1	0.02
2	76	38	43	0.57	39	0.51	0	0.00
3	87	40	24	0.28	96	1.10	4	0.05
4	48	29	51	1.06	28	0.58	6	0.13
5	95	37	51	0.54	39	0.41	0	0.00
6	40	17	16	0.40	37	0.93	6	0.15
7	89	40	55	0.62	85	0.96	6	0.07
8	107	43	45	0.42	91	0.85	18	0.17
9	45	22	19	0.42	60	1.33	24	0.53
10	68	30	42	0.62	32	0.47	18	0.26
11	87	24	29	0.33	32	0.37	11	0.13
12	58	15	5	0.09	39	0.67	2	0.03
13	73	39	29	0.40	71	0.97	15	0.21
14	54	43	40	0.74	92	1.70	19	0.35
15	70	31	105	1.50	12	0.17	3	0.04
	1050	***469***	***574***	***0.55***	***779***	***0.74***	***133***	***0.13***

Table C2: specific damage information (DPN &DPS)
For each plot: Damage product number (DPN and damage product score (DPS) following figure 4.19, chapter 4, calculated for each browser (elephant, rhino & giraffe) (DPS = DPN/ No T)
(No T = number of trees, No./TD = number of trees damaged)
Totals are calculated and shown in the final row.

APPENDIX FIVE: Summary data and key output charts for monitoring plots, 2007 (Training workshop)

Contents 2007

Table A 07

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
No. Trees	85	193	156	55	208	40	169	213	57	128	39	271	96	78	103	***1891***
No.Trees D	70	105	109	52	140	39	115	137	48	99	38	175	77	69	70	***1343***
Proportion D	0.82	0.54	0.70	0.95	0.67	0.98	0.68	0.64	0.84	0.77	0.97	0.65	0.80	0.88	0.68	***0.71***
% D	82.35	54.40	69.87	94.55	67.31	97.50	68.05	64.32	84.21	77.34	97.44	64.58	80.21	88.46	67.96	***71.02***
Total DPN	141	172	178	112	262	86	248	261	96	255	59	320	163	168	20	***2541***
Total DPS	1.6588	0.8912	1.141	2.0364	1.2596	2.15	1.4675	1.2254	1.6842	1.9922	1.5128	1.1808	1.6979	2.1538	0.1942	***1.3437***
No.T D Ele	7	20	21	18	44	8	48	40	7	25	7	50	13	19	49	***376***
Propn of no.T	0.08	0.10	0.13	0.33	0.21	0.20	0.28	0.19	0.12	0.20	0.18	0.18	0.14	0.24	0.48	***0.20***
%T	8.24	10.36	13.46	32.73	21.15	20.00	28.40	18.78	12.28	19.53	17.95	18.45	13.54	24.36	47.57	***19.88***
Propn of D	0.10	0.19	0.19	0.35	0.31	0.21	0.42	0.29	0.15	0.25	0.18	0.29	0.17	0.28	0.70	***0.28***
%D	10.00	19.05	19.27	34.62	31.43	20.51	41.74	29.20	14.58	25.25	18.42	28.57	16.88	27.54	70.00	***28.00***
No.T D Rhi	38	45	43	15	49	19	42	71	29	56	23	70	44	42	20	***606***
Propn of no.T	0.45	0.23	0.28	0.27	0.24	0.48	0.25	0.33	0.51	0.44	0.59	0.26	0.46	0.54	0.19	***0.32***
%T	44.71	23.32	27.56	27.27	23.56	47.50	24.85	33.33	50.88	43.75	58.97	25.83	45.83	53.85	19.42	***32.05***
Propn of D	0.54	0.43	0.39	0.29	0.35	0.49	0.37	0.52	0.60	0.57	0.61	0.40	0.57	0.61	0.29	***0.45***
%D	54.29	42.86	39.45	28.85	35.00	48.72	36.52	51.82	60.42	56.57	60.53	40.00	57.14	60.87	28.57	***45.12***

Table A 07 continued															
No.T D Gir	3	0	0	9	0	9	3	24	8	21	7	9	23	27	13	***156***
Propn of no.T	0.04	0.00	0.00	0.16	0.00	0.23	0.02	0.11	0.14	0.16	0.18	0.03	0.24	0.35	0.13	***0.08***
%T	3.53	0.00	0.00	16.36	0.00	22.50	1.78	11.27	14.04	16.41	17.95	3.32	23.96	34.62	12.62	***8.25***
Propn of D	0.04	0.00	0.00	0.17	0.00	0.23	0.03	0.18	0.17	0.21	0.18	0.05	0.30	0.39	0.19	***0.12***
%D	4.29	0.00	0.00	17.31	0.00	23.08	2.61	17.52	16.67	21.21	18.42	5.14	29.87	39.13	18.57	***11.62***
No.T D Other	29	45	51	23	57	4	30	34	9	17	11	47	12	7	7	***383***
Propn of no.T	0.34	0.23	0.33	0.42	0.27	0.10	0.18	0.16	0.16	0.13	0.28	0.17	0.13	0.09	0.07	***0.20***
%T	34.12	23.32	32.69	41.82	27.40	10.00	17.75	15.96	15.79	13.28	28.21	17.34	12.50	8.97	6.80	***20.25***
Propn of D	0.41	0.43	0.47	0.44	0.41	0.10	0.26	0.25	0.19	0.17	0.29	0.27	0.16	0.10	0.10	***0.29***
%D	41.43	42.86	46.79	44.23	40.71	10.26	26.09	24.82	18.75	17.17	28.95	26.86	15.58	10.14	10.00	***28.52***
No.T MS D	40	42	37	23	56	9	47	23	11	34	10	39	16	17	30	***434***
Propn of no.T	0.47	0.22	0.24	0.42	0.27	0.23	0.28	0.11	0.19	0.27	0.26	0.14	0.17	0.22	0.29	***0.23***
%T	47.06	21.76	23.72	41.82	26.92	22.50	27.81	10.80	19.30	26.56	25.64	14.39	16.67	21.79	29.13	***22.95***
Propn of D	0.57	0.40	0.34	0.44	0.40	0.23	0.41	0.17	0.23	0.34	0.26	0.22	0.21	0.25	0.43	***0.32***
%D	57.14	40.00	33.94	44.23	40.00	23.08	40.87	16.79	22.92	34.34	26.32	22.29	20.78	24.64	42.86	***32.32***

Table A 07: Plot information 2007

Number of trees, number of trees damaged, proportion and percentage trees damaged for monitoring plots (1-15).
Calculated Damage Product Number (DPN) and Damage Product Score (DPS) (following figure 4.19, chapter 4) per plot and calculated as a total (>DPS = > damage presence & severity).
Damage breakdown for each browser species (and 'other' damage) including number of trees damaged (No T D), proportion of trees damaged from the total of trees recorded in the survey per plot (Propn of no.T), percentage of the total number of trees per plot damaged (%T), Proportion of the number of trees recorded as damaged per plot (Propn of D) and the percentage of damaged trees per plot (%D). All totals are in the last column.
All values calculated from raw plot data.

Table B1 07

	PLOT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Height Class	**1**	74	149	122	27	159	31	145	178	53	109	37	233	82	58	68	***1525***
	2	9	44	29	16	45	9	16	33	4	18	2	34	14	16	26	***315***
	3	2	0	5	12	4	0	8	2	0	1	0	4	0	4	9	***51***
		85	***193***	***156***	***55***	***208***	***40***	***169***	***213***	***57***	***128***	***39***	***271***	***96***	***78***	***103***	***1891***
D per HTcs	**1**	61	71	83	24	97	30	95	108	44	80	36	149	63	49	42	***1032***
	2	7	34	21	16	39	9	13	27	4	18	2	25	14	16	23	***268***
	3	2	0	5	12	4	0	7	2	0	1	0	1	0	4	5	***43***
		70	***105***	***109***	***52***	***140***	***39***	***115***	***137***	***48***	***99***	***38***	***175***	***77***	***69***	***70***	***1343***
Tree species	AD	8	5	33	15	12	38	18	82	50	110	32	111	76	76	28	***694***
	AX	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	***3***
	BG	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	***3***
	CA	0	0	2	0	0	0	3	0	0	0	0	0	0	0	0	***5***
	CE	0	2	2	0	0	0	3	0	0	0	0	3	0	0	0	***10***
	ED	26	80	81	20	86	0	36	16	1	1	2	31	4	1	25	***410***
	EC	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	***2***
	G	2	2	0	1	3	0	0	1	0	0	0	1	0	0	0	***10***
	GS	11	11	14	1	5	0	18	13	0	2	0	3	0	0	3	***81***
	LS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	***1***
	MS	10	10	7	1	7	0	7	2	0	0	0	4	0	0	0	***48***
	MT	2	2	3	2	6	0	2	0	0	1	0	1	0	0	0	***19***
	Mut	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	***1***
	OA	0	0	0	0	0	0	1	0	0	0	0	0	3	0	0	***4***
	PP	5	67	2	2	79	0	43	60	1	11	0	56	6	0	15	***347***
	RN	4	3	5	3	9	0	15	4	0	0	0	18	2	0	15	***78***
	RS	10	4	4	0	1	0	12	22	3	0	1	19	5	0	4	***85***
	SM	4	3	1	9	0	1	8	13	0	1	4	21	3	1	13	***82***
	SpXX	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	***2***
	SpX	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	***2***
	SpY	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	***1***
	SpYY	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	***1***
	Teclea	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	***2***
		85	***193***	***156***	***55***	***208***	***40***	***169***	***213***	***57***	***128***	***39***	***268***	***99***	***78***	***103***	***1891***

Table B1 07 continued																	
	PLOT	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	Tree																
TS DMG	AD	7	4	24	14	9	37	14	62	43	87	31	85	66	68	26	*577*
	AX	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	*3*
	BG	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	*3*
	CA	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	*3*
	CE	0	2	2	0	0	0	3	0	0	0	0	3	0	0	0	*10*
	ED	18	55	55	20	73	0	22	9	0	1	2	19	1	0	10	*285*
	EC	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	*2*
	G	2	2	0	1	3	0	0	0	0	0	0	0	0	0	0	*8*
	GS	10	9	10	1	5	0	16	11	0	1	0	0	0	0	3	*66*
	LS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	*1*
	MS	9	9	5	1	7	0	5	2	0	0	0	2	0	0	0	*40*
	MT	0	1	1	2	3	0	1	0	0	1	0	1	0	0	0	*10*
	Mut	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
	OA	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	*2*
	PP	3	15	0	1	31	0	16	16	0	6	0	19	0	0	6	*113*
	RN	4	2	5	3	8	0	13	3	0	0	0	16	2	0	10	*66*
	RS	10	1	3	0	1	0	11	21	3	0	1	10	5	0	4	*70*
	SM	4	1	1	8	0	1	8	13	0	1	4	19	3	1	11	*75*
	SpXX	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	*2*
	SpX	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	*2*
	SpY	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	*1*
	SpYY	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	*1*
	Teclea	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	*2*
		1891	*105*	*109*	*52*	*140*	*39*	*115*	*137*	*48*	*99*	*38*	*175*	*77*	*69*	*70*	*1343*

Table B1 07: Tree information 2007

The number of trees in each height class (1: 0-1.9m, 2: 2-3.9m, 3: >4m), and the number of trees damaged (browsed) in each height class (D per HTcs) per plot (1-15).

The number of each tree species (no TS) snd the number of each tree species damaged (browsed) (TS DMG). All totals are in the last column and row following each set of data.

NOTE: one tree can suffer all damage types (elephant, rhino, giraffe, other)

Tree species key: AD: *A.drepanolobium*, AX: *A.xanthophloea*, BG: *B.glabra*, CA: (unidentified – most likely to be CE) CE: *C.edulis*, ED: E.*divinorum*, EC: (unidentified, most likely to be ED) G: (unidentified – most likely to be GS) GS: *G.similis*, LS: *Lantana spp*, MT: *M.triphylla*, Mut (unidentified species in field), OA: *O.africana*, PP: *P.punctulata*, RN: *R.natalensis*, RS: *R.staddo*, SM: *S.myrtina*, (SpXX, spX, spY, spy: unknown trees species in the field), Teclea: *Teclea spp.*

Tree	NO.T	NO.D	MS D	Edmg	EmsD	Rdmg	RmsD	Gdmg	GmsD	Odmg	OmsD	DPN	DPS
AD	694	577	159	117	70	308	90	112	0	118	18	1215	*1.75*
AX	3	3	2	0	0	3	2	0	0	0	0	13	*4.33*
BG	3	3	2	1	1	0	0	0	0	2	1	8	*2.67*
CA	5	3	2	1	1	2	1	0	0	2	1	11	*2.20*
CE	10	10	6	3	3	4	2	0	0	4	1	29	*2.90*
ED	410	285	96	103	52	103	17	3	0	107	24	371	*0.90*
EC	2	2	0	0	0	0	0	0	0	2	0	0	*0.00*
G	10	8	5	0	0	2	2	0	0	5	2	5	*0.50*
GS	81	66	25	3	2	39	20	1	0	29	5	115	*1.42*
LS	1	1	1	0	0	1	1	0	0	1	0	3	*3.00*
MS	48	40	29	8	7	24	17	0	0	11	7	138	*2.88*
MT	19	10	4	2	2	4	2	0	0	4	0	30	*1.58*
Mut	1	1	1	0	0	0	0	0	0	1	1	0	*0.00*
OA	4	2	1	2	1	0	0	0	0	0	0	6	*1.50*
PP	347	113	35	52	26	9	3	1	0	46	9	189	*0.54*
RN	78	66	35	33	25	20	11	2	0	12	4	159	*2.04*
RS	85	70	11	16	3	35	5	23	0	21	5	101	*1.19*
SM	82	75	15	34	8	41	5	14	0	17	2	123	*1.50*
SpXX	2	2	1	0	0	1	1	0	0	1	0	7	*3.50*
SpX	2	2	1	0	0	1	1	0	0	1	0	6	*3.00*
SpY	1	1	1	0	0	1	1	0	0	0	0	5	*5.00*
SpYY	1	1	0	0	0	0	0	0	0	0	0	0	*0.00*
Teclea	2	2	2	1	1	0	0	0	0	1	0	7	*3.50*
	1891	*1343*	*434*	*376*	*202*	*598*	*181*	*156*	*0*	*385*	*80*	*2541*	*1.34*

Table B2: Tree information - damage detail.

Tree species key: AD: *A.drepanolobium*, AX: *A.xanthophloea*, BG: *B.glabra*, CA: (unidentified – most likely to be CE) CE: *C.edulis*, ED: *E.divinorum*, EC: (unidentified, most likely to be ED) G: (unidentified – most likely to be GS) GS: *G.similis*, LS: *Lantana spp*, MT: *M.triphylla*, Mut (unidentified species in field), OA: *O.africana*, PP: *P.punctulata*, RN: *R.natalensis*, RS: *R.staddo*, SM: *S.myrtina*, (SpXX, spX, spY, spy: unknown trees species in the field), Teclea: *Teclea spp.*

Number of trees (NO.T), Number of trees damaged (browsed) (NO.D), number of trees with main stem damage (MS.D). Number of trees damaged by each browser (elephant, rhino & giraffe) (e.g. Edmg = elephant damage), and 'other'. Totals are shown in the last row.

Calculated Damage Product Number (DPN) and Damage Product Score (DPS) (following figure 4.19, chapter 4) NOTE: DPN and DPS does not include other damage, it is browse specific (DPS = DPN/No.T) (>DPS = > damage presence & severity).

Table C1 07

	Damage Class (DC)															
	Elephant				Rhino				Giraffe				Other			
PLOT	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	3	2	2	0	25	10	3	0	3	0	0	0	23	2	2	2
2	16	3	1	0	30	12	2	1	0	0	0	0	35	7	2	1
3	17	2	2	0	27	14	1	1	0	0	0	0	38	4	6	3
4	12	2	1	3	10	4	1	0	9	0	0	0	16	1	2	4
5	27	11	4	2	39	7	3	0	0	0	0	0	48	6	3	0
6	2	0	1	5	18	1	0	0	9	0	0	0	4	0	0	0
7	24	15	6	3	38	2	1	1	3	0	0	0	25	4	0	1
8	21	14	1	4	60	8	2	1	23	1	0	0	33	1	0	0
9	5	1	0	1	20	7	2	0	8	0	0	0	8	2	1	0
10	9	8	3	5	40	11	5	0	21	0	0	0	15	1	1	0
11	5	2	0	0	16	1	0	0	7	0	0	0	8	3	0	0
12	24	16	6	4	52	17	0	1	8	1	0	0	36	6	2	3
13	7	3	2	1	35	8	1	0	23	0	0	0	11	1	0	0
14	8	7	0	4	38	3	1	0	26	1	0	0	5	1	1	0
15	18	15	8	8	20	0	0	0	13	0	0	0	6	1	0	0
	198	*101*	*37*	*40*	*468*	*105*	*22*	*5*	*153*	*3*	*0*	*0*	*311*	*40*	*20*	*14*

Table C1 07 continued																
	Main Stem Class Score (CS)															
	Elephant				Rhino				Giraffe				Other			
PLOT	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	0	0	1	1	2	4	10	6	0	0	0	0	1	7	1	6
2	7	3	1	0	3	3	6	10	0	0	0	0	3	1	3	4
3	3	2	1	4	0	4	1	13	0	0	0	0	2	4	2	3
4	1	3	1	5	0	2	3	2	0	0	0	0	1	1	1	6
5	10	10	2	12	1	7	4	5	0	0	0	0	0	0	3	2
6	0	0	0	6	0	0	0	2	0	0	0	0	0	1	0	0
7	3	3	10	13	1	2	4	1	0	0	0	0	0	2	3	5
8	0	3	3	8	1	0	2	7	0	0	0	0	0	0	0	0
9	0	0	0	3	0	0	3	4	0	0	0	0	0	0	0	1
10	0	3	3	6	1	1	7	10	0	0	0	0	0	0	2	1
11	0	1	0	1	0	0	1	4	0	0	0	0	0	0	1	0
12	0	3	7	12	0	4	8	8	0	0	0	0	1	2	3	5
13	0	1	1	5	0	0	2	8	0	0	0	0	0	0	0	0
14	0	1	2	7	0	1	3	2	0	0	0	0	0	0	0	1
15	0	3	6	18	1	2	0	0	0	0	0	0	0	0	1	0
	24	*36*	*38*	*101*	*10*	*30*	*54*	*82*	*0*	*0*	*0*	*0*	*8*	*18*	*20*	*34*

Table C1 07: Specific damage information 2007

For each plot (1-15) the number of trees with Elephant, Rhino Giraffe and 'other' damage, separated into damage class (DC) (DC 1: 0-25% canopy damaged, 2: 25-50%, 3: 50-75%, 4: >75%) and main stem class score ((CS) = Proportion of total main stems of a tree damaged converted into a score 1-4) (CS 1: 0-0.24, 2: 0.25-0.49, 3: 0.50-0.74, 4 : >0.75) Totals are shown in the last row of each section

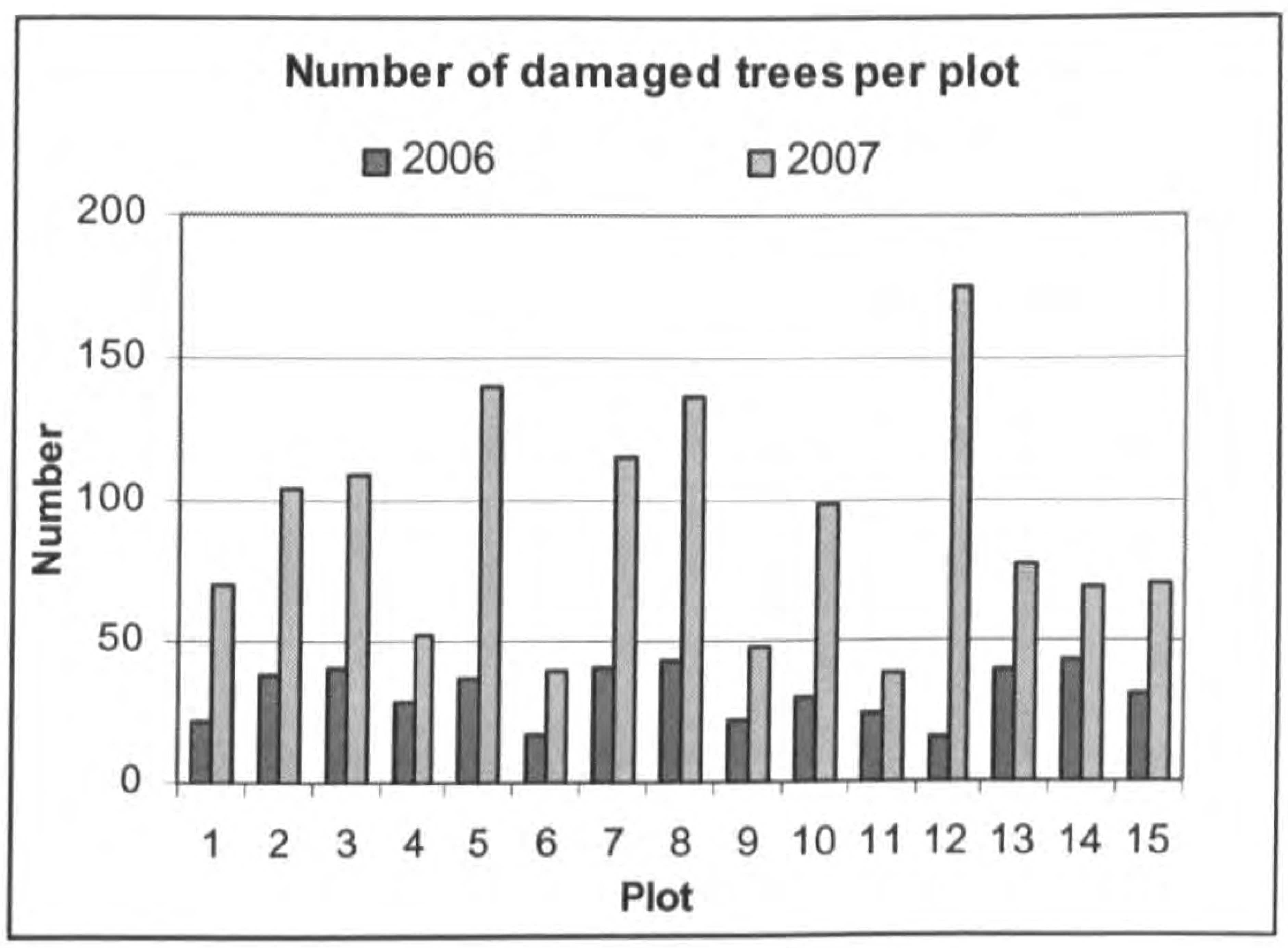
			Elephant		Rhino		Giraffe	
PLOT	**No.T**	**No.TD**	DPN	DPS	DPN	DPS	DPN	DPS
1	85	70	20	0.24	118	1.39	3	0.04
2	193	105	41	0.21	131	0.68	0	0.00
3	156	109	53	0.34	125	0.80	0	0.00
4	55	52	61	1.11	42	0.76	9	0.16
5	203	140	153	0.75	109	0.54	0	0.00
6	40	39	49	1.23	28	0.70	9	0.23
7	169	115	175	1.04	70	0.41	3	0.02
8	213	137	115	0.54	121	0.57	25	0.12
9	57	48	23	0.40	65	1.14	8	0.14
10	128	99	93	0.73	141	1.10	21	0.16
11	39	38	15	0.38	37	0.95	7	0.18
12	271	175	165	0.61	154	0.57	1	0.00
13	96	77	48	0.50	92	0.96	23	0.24
14	78	69	74	0.95	66	0.85	28	0.36
15	103	70	6	0.06	1	0.01	13	0.13
	1886	***1343***	***1091***	***0.58***	***1300***	***0.69***	***150***	***0.08***

Table C2 07: specific damage information (DPN &DPS)
For each plot: Damage product number (DPN and damage product score (DPS) following figure 4.19, chapter 4, calculated for each browser (elephant, rhino & giraffe) (DPS = DPN/ No T)
(No T = number of trees, No./TD = number of trees damaged)
Totals are calculated and shown in the final row.

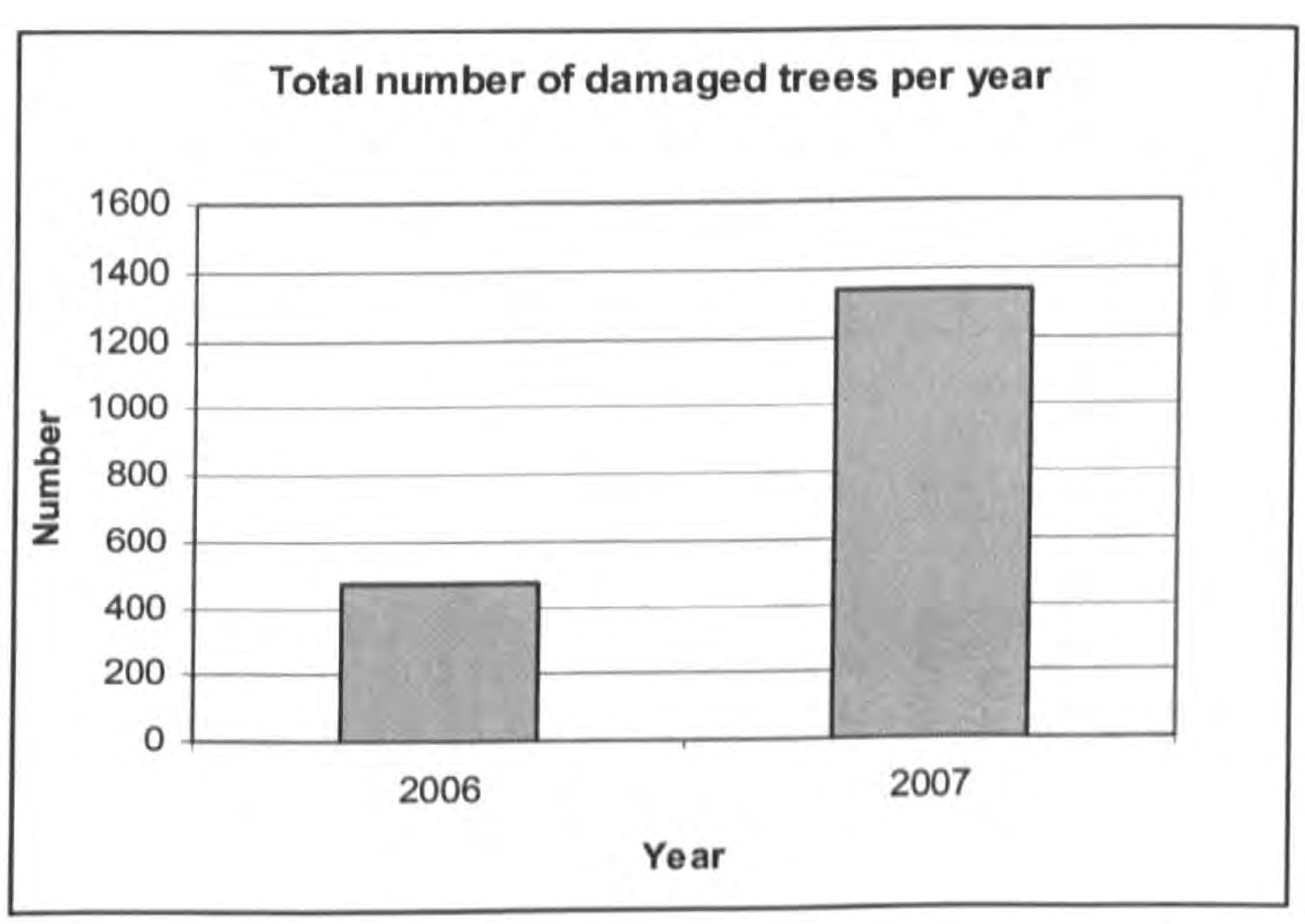
Key output charts (suggested section 4.6, chapter 4 - Design Test: Summary and Recommendations)

K1: Total number of damaged trees per plot
K2 :Total number of damaged trees per year (all plots combined)
K3: Proportion of damaged trees per plot
K4: Mean proportion of damaged trees per year
K5: DPS per plot
K6: Total DPS per year
K7: Running mean for the number of damaged trees
K8a-c: DPS per browser species per plot
K9 DPS per browser species per year

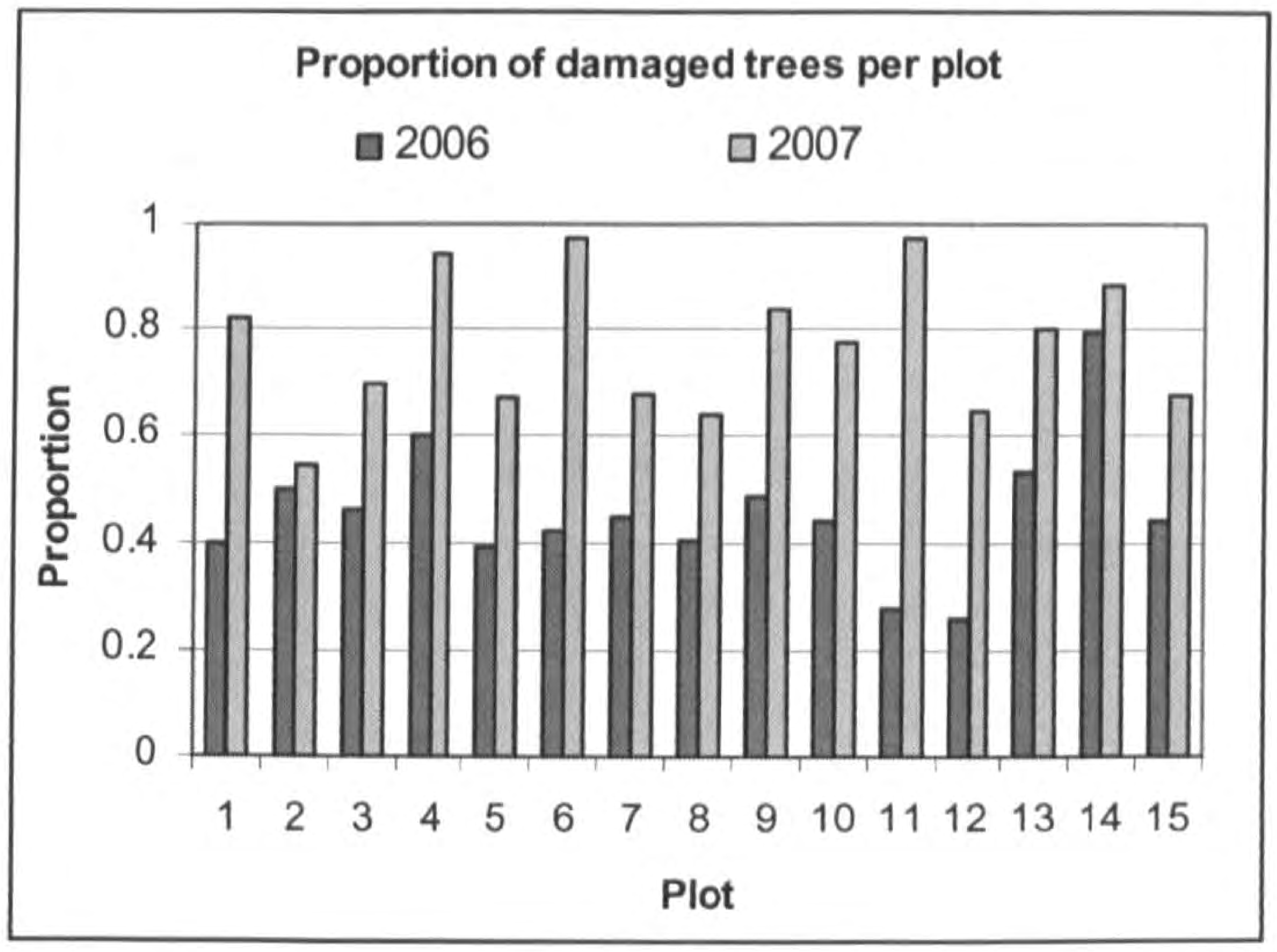
K1



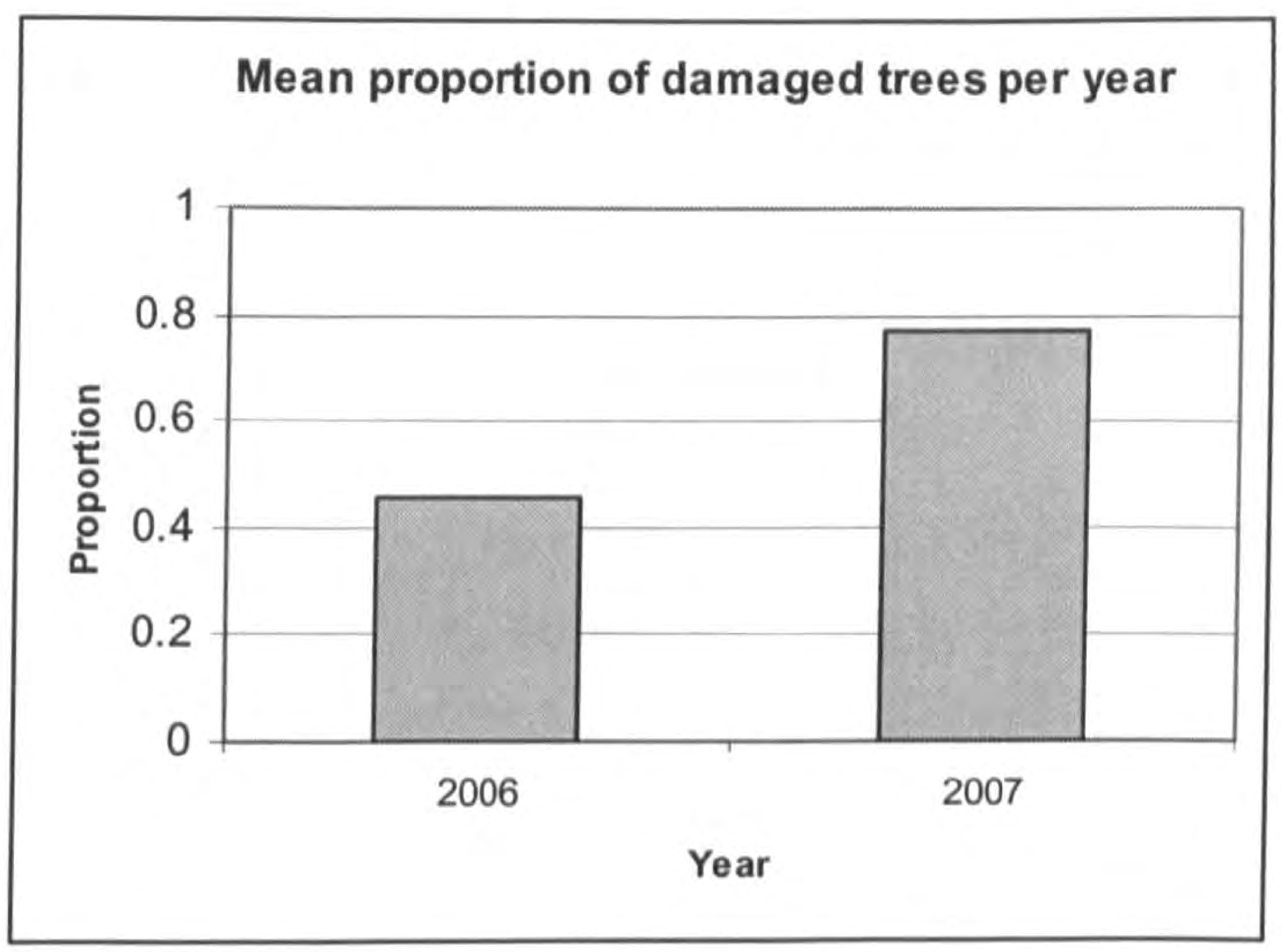
K2



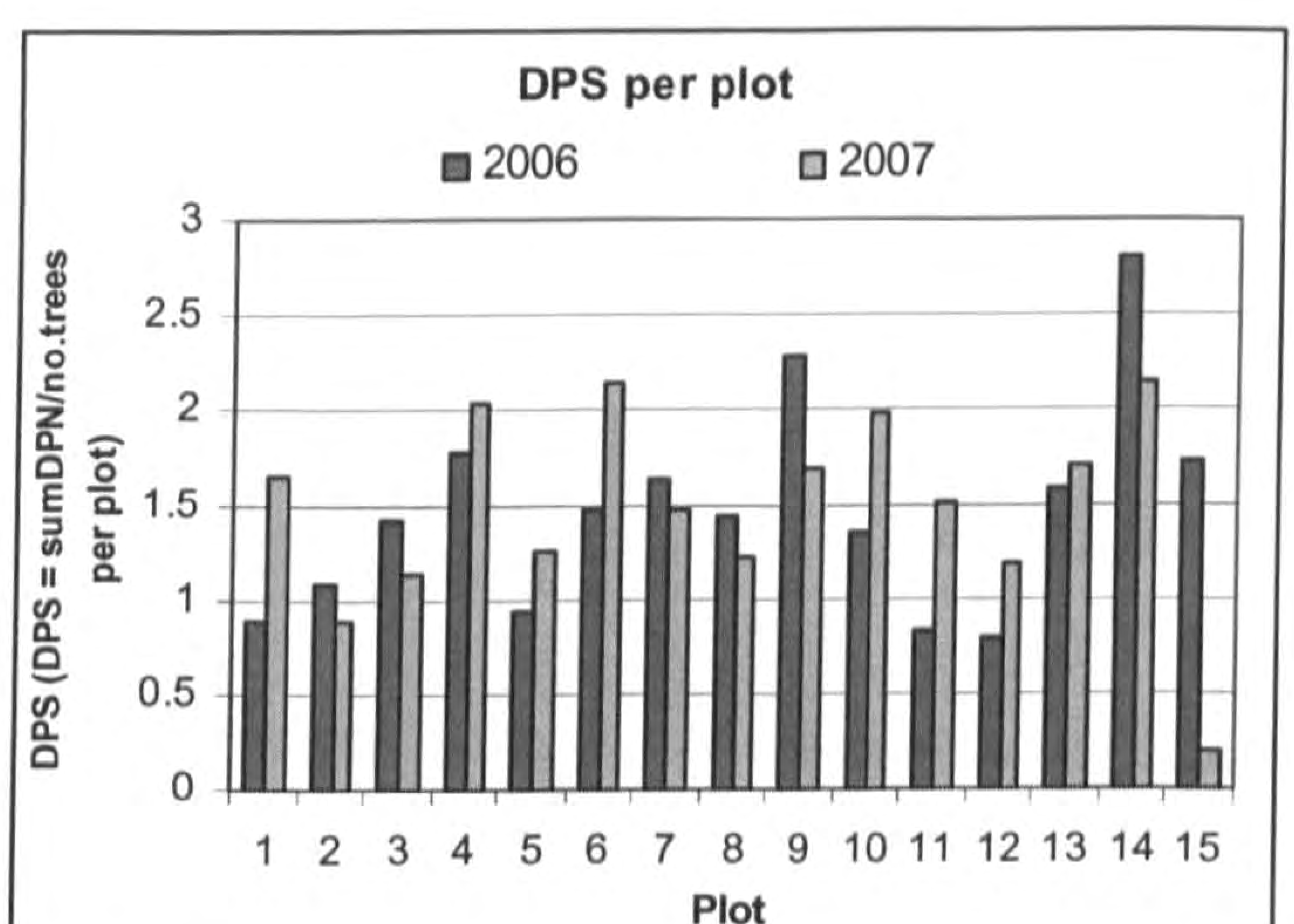
K3


Proportion of damaged trees per plot
2006
2007
1
0.8
0.6
0.4
0.2
0
Proportion
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Plot

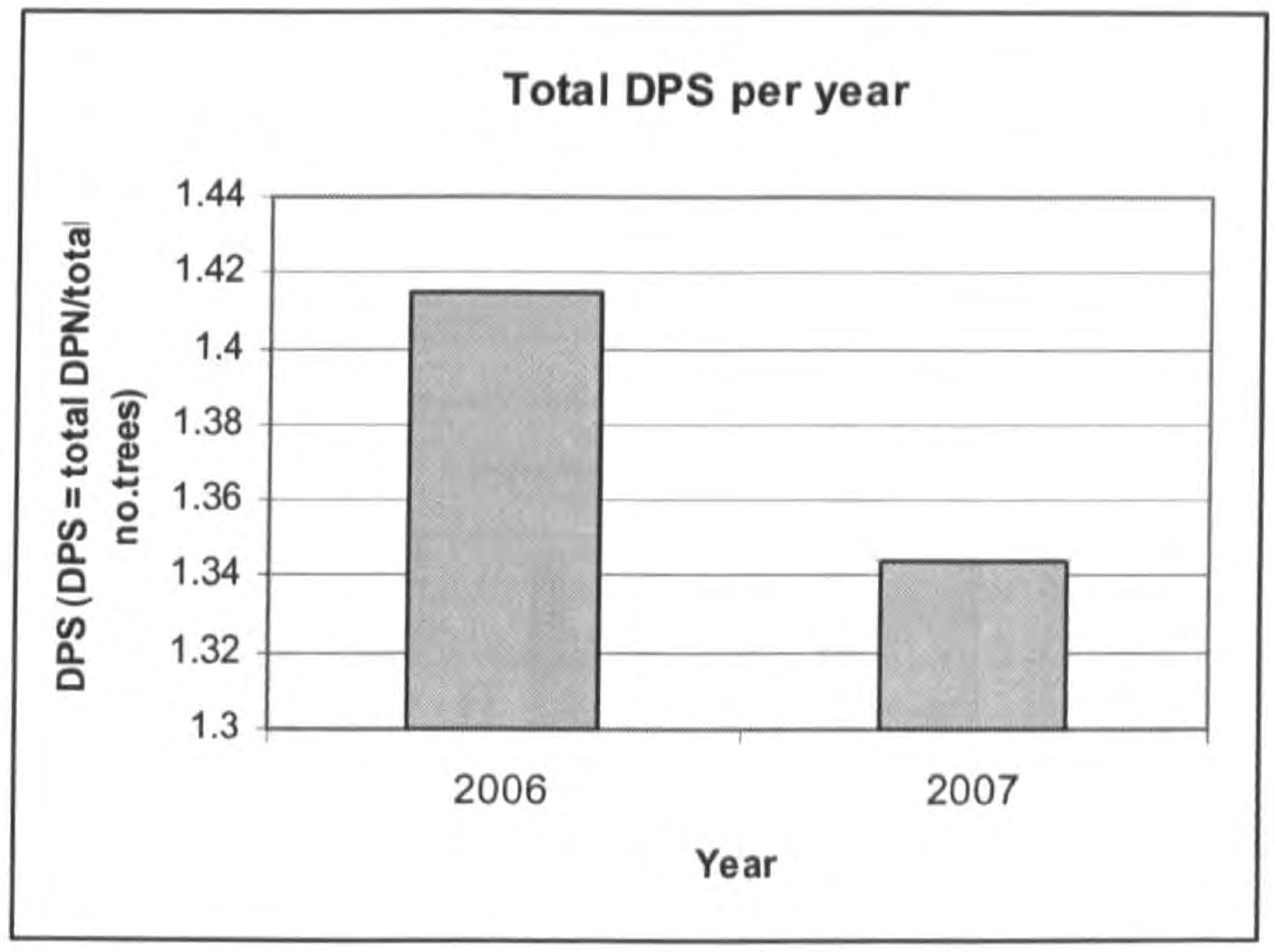
K4


Mean proportion of damaged trees per year
1
0.8
0.6
0.4
0.2
0
Proportion
2006
2007
Year

K5

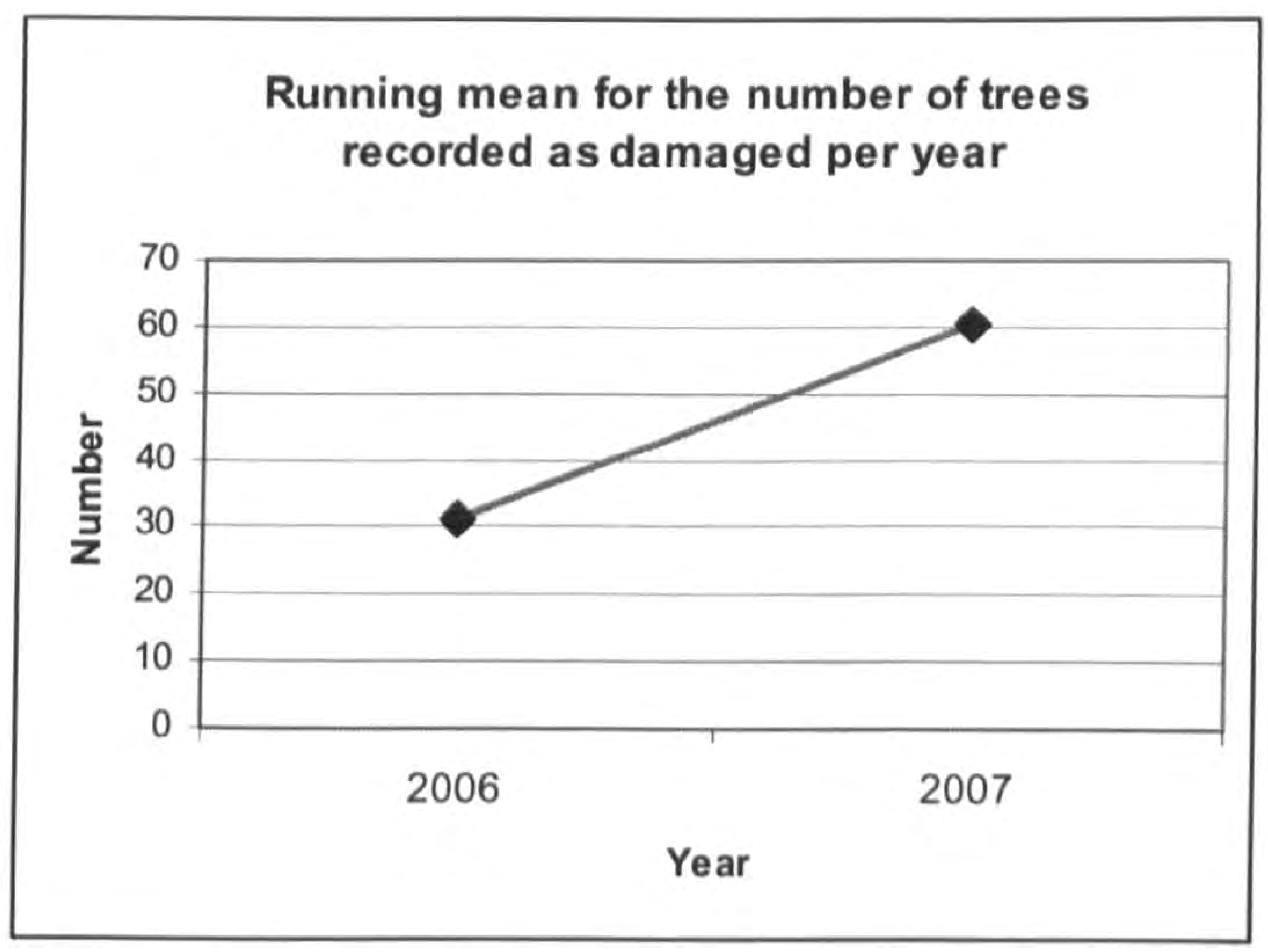

DPS per plot
2006
2007
3
2.5
2
1.5
1
0.5
0
DPS (DPS = sumDPN/no.trees per plot)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Plot

K6



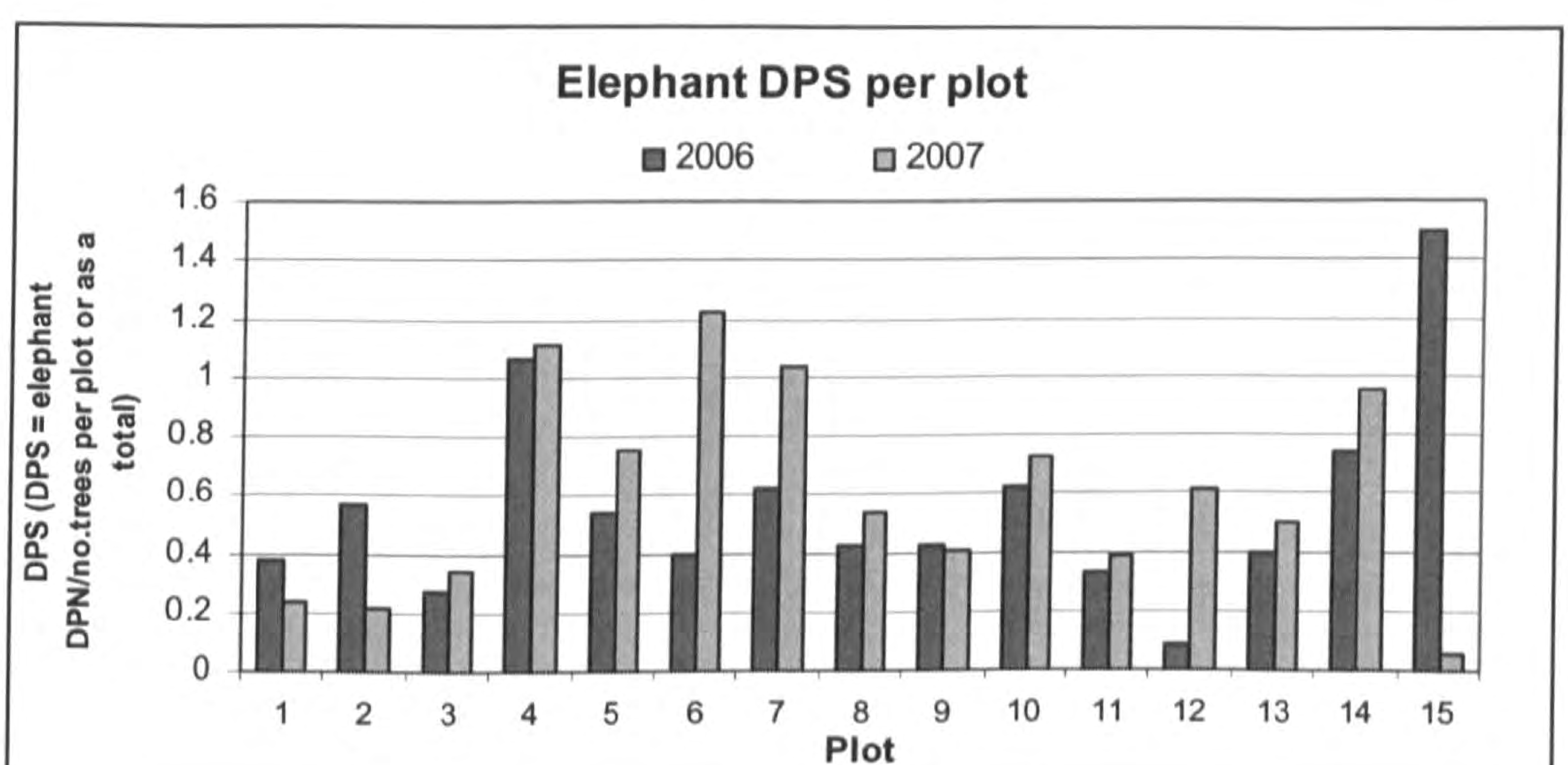
Total DPS per year
DPS (DPS = total DPN/total no.trees)
1.44
1.42
1.4
1.38
1.36
1.34
1.32
1.3
2006
2007
Year

K7



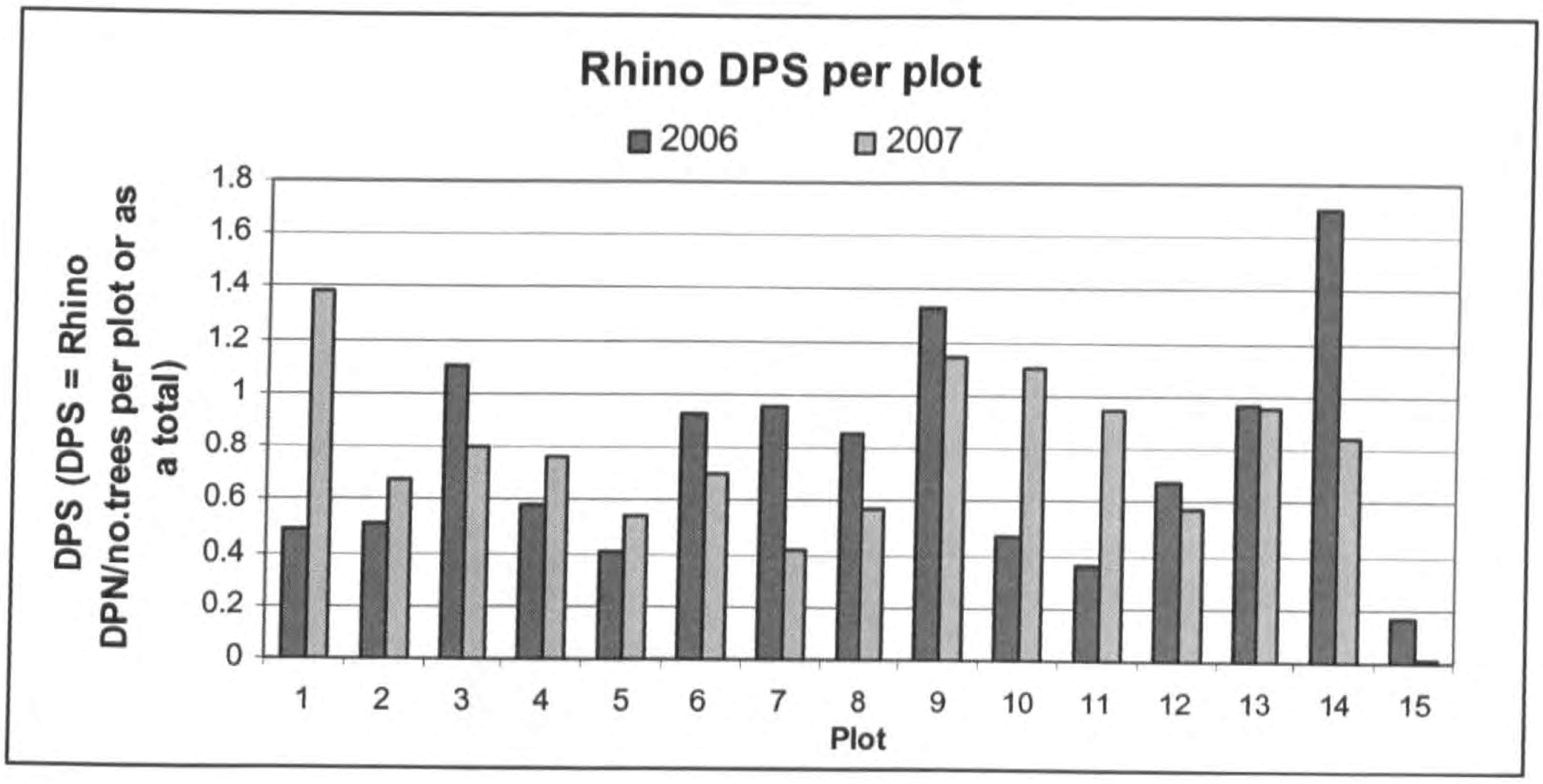
Running mean for the number of trees recorded as damaged per year
Number
70
60
50
40
30
20
10
0
2006
2007
Year

K8a

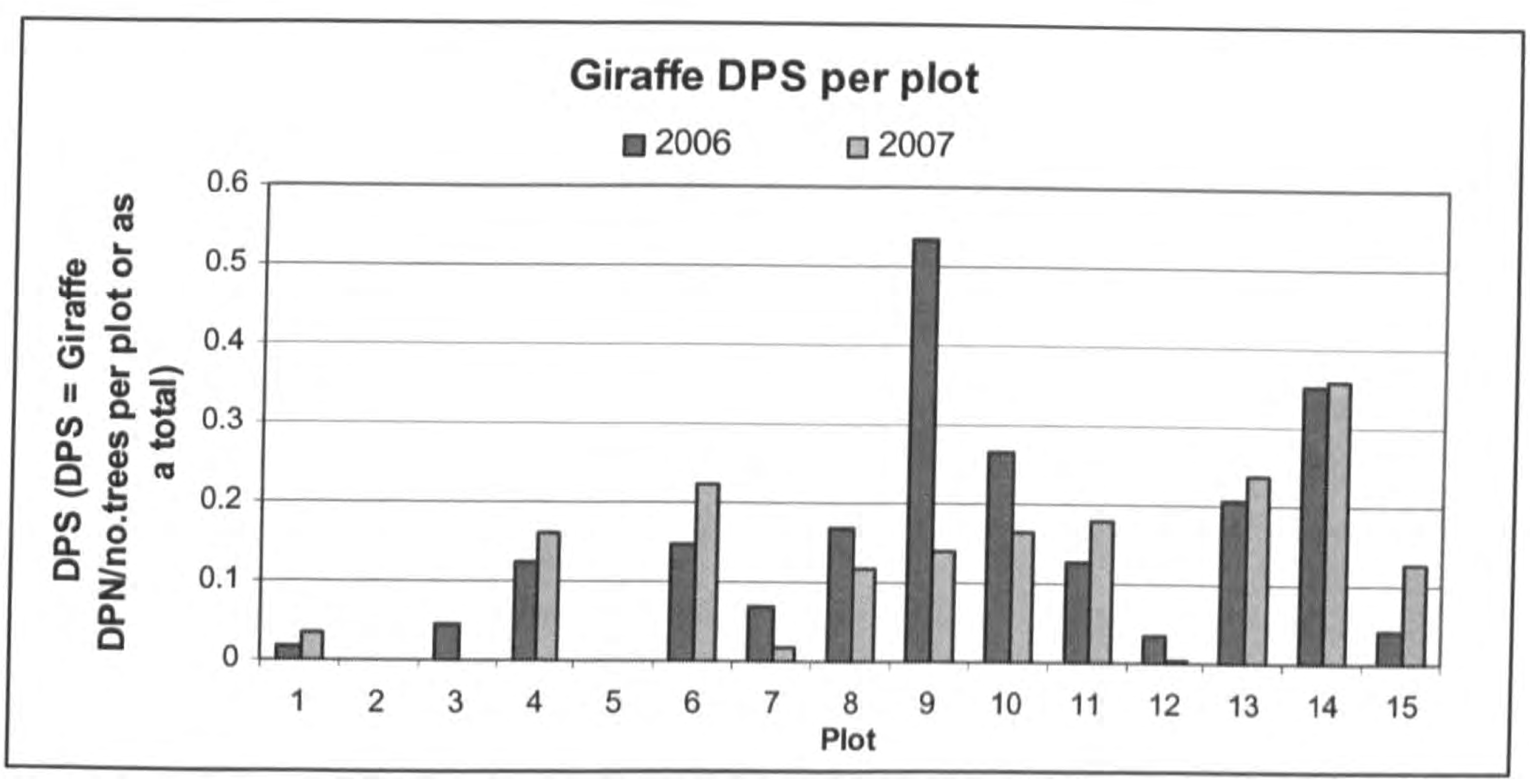


Elephant DPS per plot
2006
2007
DPS (DPS = elephant DPN/no.trees per plot or as a total)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Plot

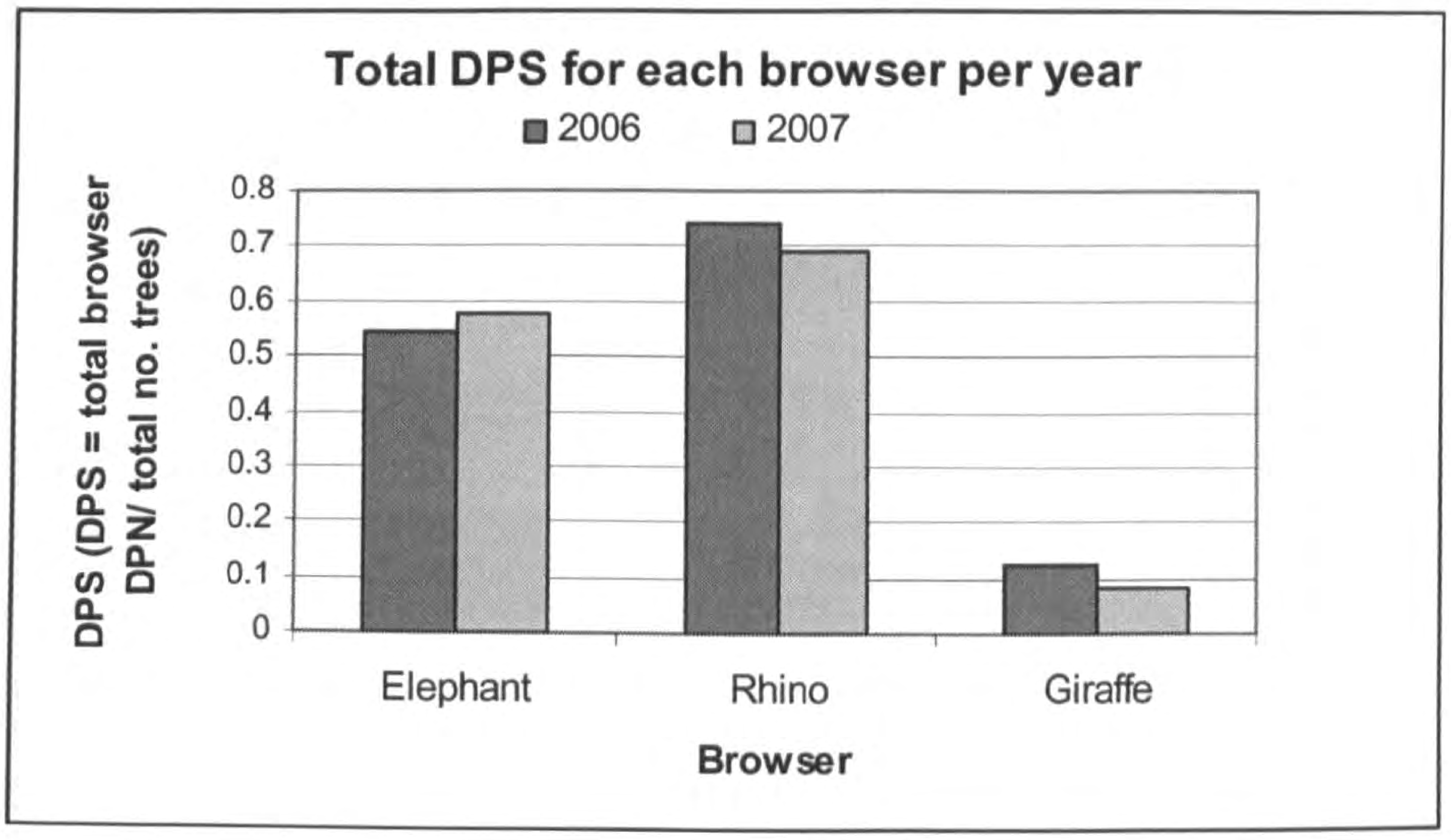
K8b


Rhino DPS per plot
2006
2007
DPS (DPS = Rhino DPN/no.trees per plot or as a total)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Plot

K8c


Giraffe DPS per plot
2006
2007
DPS (DPS = Giraffe DPN/no.trees per plot or as a total)
0.6
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Plot

K9



Total DPS for each browser per year
2006
2007
DPS (DPS = total browser DPN/ total no. trees)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Elephant
Rhino
Giraffe
Browser

APPENDIX EIGHT: thesis chronology

September 2003:	Enrolment on PhD programme
September – December 2003:	Planning around 'effectiveness of ambassador species' and possible areas of study. Funding restrictions to field work required. Change of focus from ambassador species, to general effectiveness of management and monitoring of endangered species.
January – September 2004:	Literature review Data collection and collation (e.g. IUCN, WCMC, CITES) incorporating new Redlist changes and updates 2004.
September 2004:	Continued data collection and field season planning.
November 2004:	Field team meetings begin for following year, planning logistics and project design. Students chose from a list of methodologies I provided.
January - April 2005:	Field team confirmed, field season dates finalised. Students collecting vegetation data are: Frances Atterton, Ruth Porter, Chris Aitchison, Nicola Gibson, Sonya Gadhia, Vicky Booth. Continued logistical meetings with the team. Basic vegetation collection technique designed. Continual planning, background literature and data collection. Critically endangered and endangered species data refined to spreadsheet. Species management grade (SMG) and Research and Monitoring grade (RMG) designed and applied to data set. Monitored species and potential case study species identified.
February 2005:	Iberian Lynx field visit: Seville, Donana National Park and El Acebuche captive breeding centre, Spain. (3 days) Rough report written.
May – August 2005:	Field season 1. Base monitoring plots set up using vegetation, rhino density and GPS maps on site. Students organised into pairs for field days and a rota system for the plots, guards and vehicle organised. All logistics with reserve staff also managed (e.g. food and supplies). Training into vegetation data collection technique provided by myself, prior to actual field work. Control repeat plot and transect set up and organised. Other field work organised and carried out (e.g. whole park census, driven and walked animal counts) and observed (e.g. rhino ear notching).
September – December 2005:	Data input, collation and preparation, standardised spreadsheet designed. Collection of literature on 20 monitored species to identify key issues, conservation action and monitoring techniques.

	Top ten considerations for a good monitoring system question sheet emailed and received from Kenyan managers and scientists, and lynx contact. Questionnaire sent with fellow researcher (David Lee) to China regarding the Giant Panda – rough report written.
January – June 2006:	Data analysis: identification of optimal field design and power analysis (pers.comm Dr. Alan Fielding). DPS formula invented by myself. Continued research into 20 monitored species.
June – September 2006:	Field season 2: testing the technique. I surveyed the 15 monitoring plots set up the previous year. In addition I surveyed 10 comparison plots (1km away from the originals). A block of control plots were also set up and surveyed by 2 students who were using the technique in their field work. Questionnaire completed regarding the Black Rhino as a case study species, monitoring techniques were observed and recorded (e.g. experience on rhino patrol).
October – December 2006:	Data input and analysis. Compilation of monitored species reports (appendix 2)
January – June 2007:	Continued data analysis and design of practical workshop for Kenyan research department. Also design of a presentation workshop for tourism staff based at the tented camp in Kenya (part funded by Chester Zoo). Contact made with Friends of the Island Fox and the National Park Service (USA) regarding the Channel Island Fox. Rough report written following receipt of questionnaire, and top ten responses added to collection. Planning for field visit to Kenya and California.
June – July 2007:	Workshop for research department at Ol Pejeta Conservancy. This involved training into theoretical background of the monitoring system, field techniques, data collection followed by data collation and analysis. A presentation about previous student projects was also written and given to management, as well as the training programme for the tourism staff.
August – September 2007:	Data input and analysis. Field visit planning.
October 2007:	Field visit to California. Meeting with Tim Coonan in Ventura, California, regarding the Channel Island Fox. Meeting with Pat Meyer from friends of the island fox. Meeting with Mike Dee regarding rhino conservation (LA Zoo), meeting with Angie Fiore regarding Giant Panda husbandry and research (San Diego Zoo). Site Visit to Santa Cruz island (fox habitat).
November – December 2007:	Collation and editing of case study information (appendix 3). Planning and writing of main chapter content (literature review, global analysis results, monitored species and case study reports, field work methodologies and results)

	Content to supervisory team.
January to March 2008:	Editing of chapters. Global analysis spreadsheet converted for Random Forest Analysis (pers.comm Dr Martin Jones). Summarising of monitored species and case study information to tables and re-writing chapter. Refining introduction.
March – July 2008:	Part time job at Chester Zoo (until July) alongside continued editing of chapters. Collation of bibliography by hand. Investigation of updated red list 2008.
July - December 2008:	Refinement of chapters and re-writing. Monitoring system flow chart finalised. Introductions and discussions for each chapter written
January 2009:	Rough draft minus final discussion submitted to supervisors
February – May 2009:	editing and re-writing of sections Abstract written and re-written
June 2009:	Main discussion written and final editing to chapters made Contents and list of table and figures. Printing and binding
July 3rd 2009:	Submission of thesis
February 2nd 2010:	VIVA and award.

APPENDIX NINE: glossary of terms

Ambassador Species	A species used in some way to support the conservation of their own kind or other species (e.g. as a flagship species)
Black spots	Habitats and species which are not receiving much needed conservation resources due to the prioritisation of other areas or species (e.g. hotspots)
Case studies	Information generated from direct contact with managers working in the conservation of a critically endangered or endangered terrestrial mammal (Iberian lynx, black rhino, giant panda, Californian channel island fox)
Charismatic species	A species which is deemed to be more attractive. In this study the term was used in a public perception survey and it was made aware that 'charisma' is subjective
Comparison plots	10 vegetation sampling plots surveyed 1km away from 10 of the set monitoring plots. This was designed to assess for patchiness and how representative the monitoring plots were
Control plots	A set of 8 plots arranged in a grid and used to assess the affects of different surveyors and plot subdivision.
Critically endangered	When a taxon is facing an extremely high risk of extinction in the wild (IUCN 2001).
Data deficient	When there is inadequate information to make a direct or indirect assessment of a species' risk of extinction based on its distribution and/or population status.
Damage Class (DC)	A visual assessment of a tree canopy for browsing damage. Each tree is assigned a score based on the proportion of the canopy broken (DC1 = <0.25, DC2 = 0.25-0.50, DC3 = 0.50 – 0.75, DC4 = >0.75).
Damage Product Number (DPN)	Browser specific value (elephant, rhino, giraffe), which is the sum of the damage class (DC) and the main stem class score (CS).
Damage Product Score (DPS)	Browser specific index e.g. the DPN / the number of trees. This measure can be flexible – it can use a variety of denominators.
Endangered	When a taxon is facing a very high risk of extinction in the wild (IUCN, 2001)
Extinct	When there is no doubt that the last individual of a species has died (IUCN, 2001).
Extinct in the wild	When a taxon is known only to survive in cultivation (IUCN, 2001)
Flagship species	Flagship species are charismatic species that serve as a symbol and rallying point to stimulate conservation awareness and action (Caro et al 2004)
Flow diagram for monitoring design	A flow chart to guide the design of a monitoring system based on information from conservation scientists and managers. (it guides through initiation, mobilization and implementation stage to the monitoring cycle)
Gold standard	A level of monitoring for a species, which has qualified for criteria and precedents identified from evidence from the 20 monitored species and 4 case studies.
Hot spots	Geographical areas which are described as having exceptional concentrations of endemic species and threats (mostly based on vascular plants and additional data on mammals, birds, reptiles and amphibians). Areas for which there is little documentation, and / or which have not lost >75% of habitat, are not included.
Indicator species	Species whose presence can be used to measure the presence of other species or ecosystem quality (Andleman and Fagan 2000, Caro et al 2004)
Least concern	A taxon which does not qualify for critically endangered, endangered, vulnerable or near threatened status, and which can be widespread and abundant (IUCN, 2001)
List of best practice	A top ten list of considerations for monitoring a threatened species, based on inputs from conservation scientists and managers

Main stem class score (CS)	A score generated form the proportion of main stems recorded as damaged per tree (CS = number of stem damaged / total number of stems)
Monitored species	A species identified as having a monitoring programme in place (following collation of information from the IUCN red list 2004 and WCMC, 2004)
Monitoring plots	15 set vegetation plots designed to incorporate a range of habitat types, rhino densities and which are identifiable from a central GPS co-ordinate
Near threatened	A taxon which is close to qualifying for a critically endangered, endangered, or vulnerable status, or which is likely to qualify for a threatened category in the near future (IUCN, 2001)
Not evaluated	A taxon which has not yet been evaluated against the IUCN red list criteria (IUCN, 2001)
Random forest analysis (RFA)	A multivariate classification analysis which can analyse extrinsic and intrinsic variables, in a large data set and which can detect associations and differences between variables by generating scores of 'importance' (p48-49, p68-69)
Repeat plot / transect	A set 10 x 10 metre square plot and 30 metre transect used to test the effect of different surveyors
Research	The research areas focused on in the global analysis are 'population & range', 'biology & ecology', 'trend' and 'threats'
Research and monitoring grade (RMG)	RMG (0-5): where 0 = no evidence of research and monitoring and where RMG 5 = evidence of all / most areas of research, and an established monitoring programme
Species management	Species management in the global analysis refers to ex-situ, captive breeding and re-introduction programmes
Species management grade (SMG)	SMG (0-3); where 0 = no evidence of any of the three focus management programmes, and where SMG 3 = evidence of and ex situ population, captive breeding programme and re-introduction.
Status	This study focuses on critically endangered and endangered status
Terrestrial mammals	Species which rely on land and its resources for some or all of its life
Trend	Whether a population is increasing, decreasing, stable or unknown.
Umbrella species	Species which require a large range, which if protected, will also bring many other species under protection (Caro 2003, Caro et al 2004)
Vulnerable	A taxon which is facing a high risk of extinction in the wild (IUCN, 2001)

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