Recommendations for Elephant Management at Pongola Private Game Reserve, South Africa

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Executive Summary

Pongola Game Reserve in KwaZulu-Natal, South Africa is a small (12,959 ha private land and 1,943 ha state land) fenced reserve with a large elephant population (79 individuals). Landowners are increasingly concerned about elephant impact on vegetation in the reserve and thus steps must be made to ensure the sustainable management of this elephant population. In 2008 Disney Corporation funded vasectomies of the adult bulls as a means of preventing further population growth. The dominant male in the population was too large to undergo surgery and is receiving GnRH hormone suppressant to prevent breeding. Despite contraception, the elephant density at Pongola is still a cause for concern. In addition, little is know about the long-term effects of vasectomies on elephant behaviour and herd dynamics. Consequently, the ranging, habitat use, association patterns and social behaviour of the elephants at Pongola have been studied in detail during 2011 by a joint team from Disney's Elephant Population Management Programme, Operation Wallacea, Wildlife & Ecological Investments, and Space For Elephants. The purpose of this report is to relay the findings of this study and use the empirical data in conjunction with information from other reserves to make a series of management recommendations for the elephants at Pongola Game Reserve.

In Section A, elephant ranging behaviour and habitat preferences during 2011 were compared with published data of the same population from 2001 when there were only 39 elephants in the reserve. Results indicated that as with other reserves, elephant ranging at Pongola was heavily constrained by access to water. Elephant ranging in 2001 showed the normal pattern of small home ranges in the dry season that incorporate a water source and large home ranges in the wet season across a range of habitat types. Data from 2011 found no difference in home range size between dry and wet season suggesting that the elephants are already using the desirable habitat available to them during the dry season and are unable to expand their range during wet season due to the confines of the reserve. To address this issue, we recommend that the reserve is expanded, ideally by dropping fences around the perimeter of the Jozini Lake to allow access to KZN wildlife state land to the north east and south east of the Pongolapoort Dam. We also strongly recommend a standardized monitoring programme of elephant impact to vegetation throughout the reserve to better inform management decisions.

In Section B, elephant association patterns and social behaviour were investigated in light of contraception methods. Results indicated that vasectomies had no effect on social and sexual behaviour of the bull elephants and that, as expected, dominance hierarchy of the bulls was mediated by age. Collectively these findings strongly support the use of vasectomies to modify population growth as they prevent conception, but still enable males to maintain herd dynamics. Further attention needs to be paid to the dominant male receiving GnRH suppressants as this male came into full musth and was observed to copulate during the study due to a longer than anticipated gap in GnRH doses. As the dominant male is the only fully mature bull in the reserve, the GnRH

dosage for this male should be monitored closely to ensure that mating is prevented, but at least some symptoms of musth remain as a means of regulating younger bull behaviour and preventing early onset of musth in the vasectomised bulls. A change in the association patterns of three adolescent bulls indicating the progression from adolescence to adulthood also suggested that subsequent vasectomies should be scheduled for the near future.

Section C focussed on the various methods of population reduction and used elephant association patterns to make recommendations for cohesive units suitable for removal. Due to the high probability of increased aggression and delinquent behaviour as a result of breaking up family units, we strongly recommend that family units are removed in their entirety. Translocation is preferable to culling due to the ethical implications and increased risk of behavioural problems associated with the latter. The orphan herd, containing 14 individuals, and the one male that preferentially associates with them could be moved as an entire unit, possibly with the addition of another male that splits his time evenly between the two different female herds. However, as the orphan herd has already experienced one traumatic translocation event following culling of their herd, any attempts to move these elephants for a second time should be considered carefully. Due to their large size, the A&B family herd is unlikely to be suitable for translocation because breaking up the herd is ill advised. Moreover, translocating elephants for a second time is not recommended (the older individuals in the herd originated from Kruger and elephants can only be translocated once). In recent months, 6 individuals from A&B family herd and one bull have been seen ranging separately from the herd. If these individuals were all born in the reserve, they may be suitable for translocation as a cohesive unit in the future if they continue to range independently from the herd. Any decisions regarding the removal of elephants should be made following assessment of elephant impact on vegetation as a means of determining exactly how many elephants need to be removed. Nevertheless, we emphasize that range expansion is preferable to population reduction by translocation or culling.

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Section A: Elephant habitat use and recommendations for land management

A1: Factors affecting elephant ranging and habitat use

The majority of South African wildlife is confined within physical barriers, usually in the form of electrified fences. These fenced enclosures are characteristic of conservation areas, tourism oriented game reserves, private and state owned properties. Successful management of fenced reserves requires a balance between maintaining high densities of large animals that are popular with tourists and the protection of vegetation and habitat heterogeneity. Landscape heterogeneity is extremely important for maintaining biodiversity as it provides variation in shelter and food resources. The African elephant (*Loxodonta africana)* is the largest herbivore species in the savannah ecosystem and, therefore, has a significant impact on vegetation (Guldemond & van Aarde, 2008). Elephant impact on vegetation has been cited as the cause of the conversion of woodland to grassland (Cumming et al 1997; O'Connor et al., 2007; Ribeiro et al 2008), increasing the intensity and frequency of fires (Ribeiro et al 2008; Moncrieff et al., 2008), loss of large trees from the landscape (Kalwij et al., 2010), homogenization of the habitat and loss of diversity in plant and animal species (Cumming et al 1997; Lombard et al 2001; Birkett, 2002). African elephants preferentially browse on woody vegetation such as baobabs (*Adansonia digitata*) and acacia trees (*Acacia spp*) by stripping the bark, removing foliage, uprooting the tree and breaking branches. This foraging behaviour has been linked to the decline of woody vegetation in African game reserves (Edkins et al., 2007; O'Connor et al., 2007; Moncrieff et al., 2008) and local extinction of certain species particularly baobabs (Edkins et al., 2007) and acacia (Gandiwa et al., 2011).

In contrast, recent evidence from game reserves where the elephant population is within the recommended carrying capacity has shown that elephant impact on vegetation is distributed evenly across the landscape and thus the impact to any given vegetation type is not sufficient to cause permanent damage to the plants (Boundja & Midgley, 2010; White et al., 2010). In some cases, elephant impact on vegetation was found to increase browse heterogeneity by facilitating the availability and redistribution of browse and encouraging new growth which is particularly important for small browsing herbivores (Kohi et al., 2011). These findings suggest that the key to successful elephant management is to ensure that population density remains at a level where elephant impact on vegetation remains a natural part of the ecosystem rather than causing widespread vegetation extinction.

However, elephant density is only one part of the problem. To ensure evenly distributed elephant impact on vegetation, fenced reserves must encourage elephants to utilize all the space available to them. Many studies have indicated that elephant habitat use is heavily constrained by access to water (Redfren et al., 2003; de Beer & van Aarde, 2008; Gaugris & van Rooyen, 2010; de Knegt et al., 2010). If access to water in fenced reserves is limited, during dry season, elephants will preferentially browse on vegetation close to these few water sources rather than utilizing all available browse within the reserve (Harris et al., 2008; Chamaille-Jammes et al., 2009; Loarie et al., 2009; Roux & Bernard, 2009). Consequently, vegetation in the near vicinity of water becomes heavily impacted by the elephants to the extent of plant extinction (Chamaille-Jammes et al., 2009; Smit et al., 2010). One possible solution to this problem is the addition of artificial water sources to fenced reserves as a means of modifying elephant ranging and habitat use.

Artificial water sources allow elephants to use vegetation in dry season that they could not normally use. Data from GPS collars on 73 elephants in reserve across southern Africa indicated that during dry season elephant ranging patterns average no more than 4km from water during the day and significantly closer to water at night (Loarie et al., 2009). Consequently, elephant movements are

severely restricted in reserves with limited access to water. In Kaudom Game Reserve in Namibia, a series of small artificial water sources were introduced during dry season and as a result, the elephants ranged throughout the reserve, which in turn lead to more evenly distributed impact on vegetation (Loarie et al., 2009). The placement of artificial water sources can also be used to redirect elephant movement patterns (Shannon et al., 2009). In Tembe Elephant Park in KwaZulu-Natal, South Africa, artificial water sources were introduced throughout the reserve to encourage elephants to utilize the full extent of space available to them, but this led to elephant paths between water sources in sand forest. The removal of key artificial water sources was then used to redirect elephant paths away from the delicate sand forest as a means of protecting this habitat (Shannon et al., 2009).

At Kruger National Park, artificial waterholes were introduced to maintain large herbivore stocks and to encourage animals to use all areas of the reserve (Smit et al., 2007a). Further investigation of the effect of artificial waterholes on elephant ranging, suggested that mixed herds avoid artificial water sources, and so closing or opening them would have little influence on the distribution of the mixed herds (Smit et al., 2007b). In contrast, male elephants used both natural and artificial water sources (Smit et al., 2007b). Further investigation of elephant use of artificial water sources indicated that the size of the water source was directly related to the number of elephants that associated with it (Smit et al., 2010). Thus, individual males will associate with small artificial water sources, but mixed herds or large cow herds will not travel far from a large water source in favour of a smaller one. Herds will however spread across a larger area if there are a series of small artificial water sources close to a large water source (Smit et al., 2010).

The alternative strategy for controlling elephant impact on vegetation is to expand reserves by dropping perimeter fences. Following the recent expansion of Phinda Private Game Reserve in KwaZulu-Natal, South Africa, elephants were observed to use new areas following the removal of a fence line, even though the increase in range was not immediate and not all herds and bulls utilized the space (Druce et al 2008). However, if area expansion is used in an attempt to reduce elephant impact on vegetation in another area of the reserve (e.g. close to a water source), then it is important to ensure that the new area contain sufficient resources (e.g. food and water) to modify existing elephant ranging patterns. Thus, it is necessary to investigate the activity, diet and habitat preferences of the elephant population in question prior to range expansion of a given reserve.

Perimeter fences to keep people out and wildlife in are only one possible use for fencing. Fencing can also be used to create sub-regions within a reserve by restricting animal access to certain areas or to restrict browser access to certain plants. These “exclosure” fences have successfully been used to protect plants in Addo Elephant Park, South Africa (Grant et al., 2007; Lombard et al., 2001) and Kruger National Park, South Africa (Levick & Rogers, 2008). Exclosure areas are also crucial for studying the effects of grazers and browsers on vegetation (c.f. Levick & Rogers, 2008).

A2: Objectives for monitoring elephant movement patterns in Pongola Game Reserve

The Pongola Game Reserve in KwaZulu-Natal, South Africa is a small fenced reserve with a very high density of elephants. Landowners in the reserve are concerned about the impact of the elephants on the vegetation in the reserve as some areas (close to the only water source in the reserve) are showing significant signs of damage to the habitat. Previous studies of the elephant population at Pongola have indicated that the elephants do not utilize all the space available to them, and in the dry season, their ranges are restricted to within a short distance from the one water source in the reserve (Shannon et al., 2006a). In addition, males and females differ in body size and therefore in their energetic requirements. As such, the elephant population is generally sex segregated with

males ranging separately from cohesive female herds due to their different foraging needs and thus different activity budgets (Shannon et al., 2006b; 2008).

The elephant population has more than doubled since the time of these studies so it is necessary to re-evaluate elephant ranging, activity and habitat use in the reserve before decisions can be made regarding land management in the reserve. A recent study of elephant movement patterns at Pongola indicated that the elephants do not move in a random pattern and are instead using an energy conserving strategy of direct paths between the water source and areas of preferred food sources (Duffy et al., 2010). These data suggest that despite the increase in population size, the elephants are still ranging in the same areas of the reserve rather than using all the space available to them. This current study therefore aims to investigate the ranging patterns of the bulls and two female herds to determine whether these have changed as the population has increased. The study also aims to investigate habitat preferences and activity budgets of the elephants. Collectively, these data will be used to make recommendations regarding land management at Pongola Game Reserve.

A3: Methods for monitoring elephant ranging, activity and habitat use

A3.1: Subjects and study site

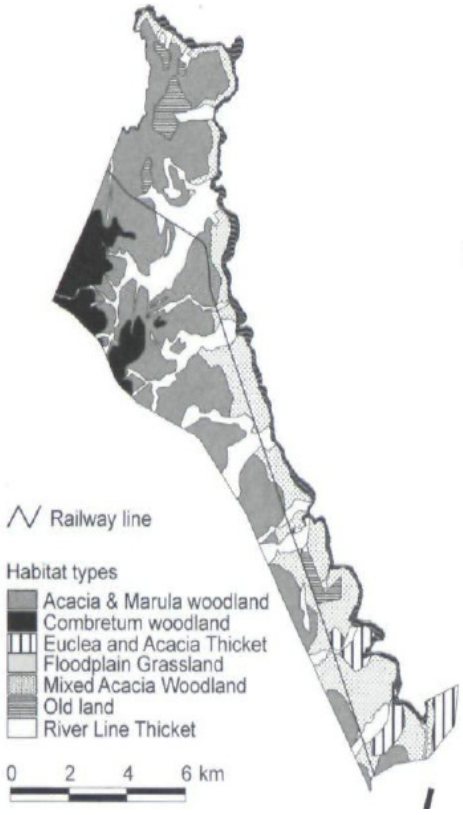

Figure 1: Distribution of habitat types in Pongola Game Reserve taken from Shannon et al., 2006a

Pongola Game Reserve was established in 1993 and covers an area of approximately 12, 959ha on the western shore of the Pongolapoort Dam. The dam occurs along the entire eastern and northern boundary (Figure 1), and this is the only water source in the reserve. The climate is hot and arid with an average 400-600mm of rainfall per year. The major habitat types in the reserve depicted in Figure 1.

Seventeen elephants in two family groups were translocated from Kruger National Park to Pongola Game Reserve throughout June 1997. Four bulls were introduced, three within the course of 1998 (one of which died and one was shot); and three in 2002 (one of which died and one was shot). Five orphan elephants (all approximately ten years old) broke into the Pongola Game Reserve from a nearby reserve in July of 2000 and remained together as a separate group of four females and one male. The current population consists of 8 adult bulls, the A&B family herd containing 57 individuals and the orphan herd which now contains 14 individuals

A3.2: Data collection

Data were collected each day by Disneys' Elephant Population Management Program and Space for Elephants funded researcher Heike Zitzer (year round) and university students working in conjunction with Operation Wallacea and Wildlife & Ecological Investments (June, July and August) from February to the end of November 2011. The oldest bull receiving GnRH suppressants, six of the seven vasectomised bulls, and the matriarchs of each of the two herds (A & B families, and the orphans) have been fitted with a radio collar. The approximate location of the bulls and herds were

identified each morning between 5.30am and 6.00am. From this information, a decision was made regarding which individual or herd to track that day, while ensuring equal numbers of observation days of each bull and herd. Data collection commenced upon location of the individual/herd, using standardized data collection sheets. General ranging patterns, habitat use and herd behaviour were collected using instantaneous scan samples (Altman, 1974) at 30-minute intervals. For each scan, the date, time, herd being observed (A & B family or orphans), bulls present, GPS location of the group (longitude, latitude, bearing and distance from observer to the elephants), the vegetation type, predominate vegetation species, general herd behaviour based on predefined behavioural categories (Table 1), and type of food consumed when feeding (grass, browse, roots, fruit, bark and pith) were recorded.

Table 1: Ethogram of behaviours used for activity budget data collection

Behaviour	Code	Description
Feeding	FE	Placing food items in the mouth and masticating. Elephant may be stationary or moving. Actively searching for or extracting food items such as bark stripping, drinking or sucking up water to drink.
Moving	MO	All forms of locomotion
Resting	RE	Elephant is not moving and not engaged in any other activity, may be asleep.
Social	SO	All forms of social interaction including friendly behaviour, sexual behaviour and aggression
Other	OT	All forms of behaviour that don't fit within the other behavioural categories, including social interaction, mud or sand bathing etc.
Alert	AL	Head high, ears lifted and looking specifically in one direction.
Out of View	OV	Elephant is completely out of view, or partially in view and it is not possible to determine what they are doing

A3.3: Data Analyses

Following Shannon et al., (2006a), kernel analysis was used to calculate elephant home ranges using ArcView 9.2. 50% kernels and 95% kernels calculated using distance units of 500 m. Separate analyses were run for each of the three groups of elephants (bulls, A&B family herd, and the orphan herd) in the dry and wet season during 2011. The percentage of scans spent feeding, moving, resting, being alert or engaging in other behaviour was calculated for each month and presented graphically. The same procedure was used to investigate the percentage of scans spent in different habitat types. In addition, the percentage of scans allocated to different types of thickets was calculated across all months.

A4: Results

A4.1: Ranging patterns

Table 2 shows the home range sizes of the bulls, A&B family herd and orphan herd during the dry and wet seasons in 2001 (Shannon et al., 2006a) and in 2011. In 2001 the bulls and both the herds showed the usual pattern of a larger home range during the wet season in comparison to the dry

season. In contrast, the 2011 data indicates that the bulls and both herds show little difference in the size of their home ranges between the dry and wet seasons. In 2001, when the density of elephants was significantly lower (39 individuals: Shannon et al., 2006a) the elephants showed the expected ranging patterns of closely associating with water during the dry season and ranging across a greater proportion of the reserve during the wet season (Figure 2).

Table 2: Home ranges (95% density kernels) and core home ranges (50% density kernels) for the bulls, A&B family herd and the orphan herd during wet and dry season in 2001 (taken from Shannon et al., 2006a) and 2011. Ranges are presented in km^2.

		2001		2011	
	Season	**95%**	**50%**	**95%**	**50%**
Bulls	Dry	33.6	19.4	58.1	17.6
	Wet	61.2	18.7	61.1	17.7
A&B Herd	Dry	17.5	4.3	48.0	12.8
	Wet	36.7	18.9	41.3	13.6
Orphan Herd	Dry	26.8	8.1	30.0	8.7
	Wet	60.5	11.3	35.6	9.4

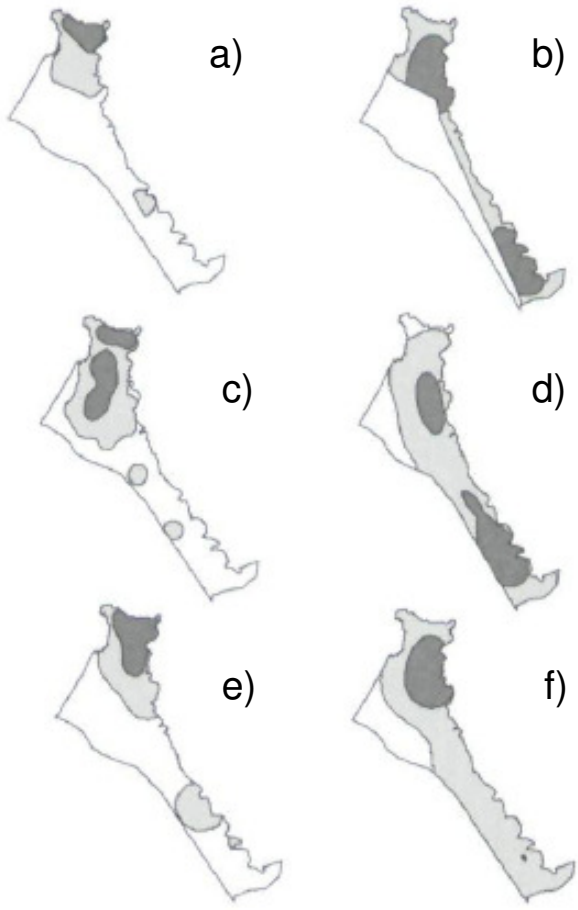

Figure 2: Home range density kernels for elephants at Pongola in 2001 taken from Shannon et al., 2006a (a = A&B family herd dry season, b = A&B family herd wet season, c = bulls dry season, d = bulls wet season, e = orphan herd dry season, f = orphan herd wet season).

In 2011 the differences between dry season and wet season ranging patterns were less pronounced than in 2001 (Figure 3). The bulls utilize significantly more of the space available to them than the two herds. There is little difference in range patterns of the bulls between the seasons, but interestingly, the bull ranging patterns essentially overlap with those of the two female herds, suggesting that bull are associating with the herds the majority of the time.

As with the 2001 ranging, in 2011 the A&B family herd range remains closely associated with the Pongolapoort Dam throughout both the dry and wet seasons and does not utilize the middle section of the reserve at all.

In 2011, the orphan herd has maintained the same core home range as in 2001 (in the northern section of the reserve) and did not range outside this area during the dry season. This core area was maintained during wet season, but an additional core area appears during wet season that overlaps with one of the A&B family core areas in the floodplain grasses that border the Pongolapoort Dam.

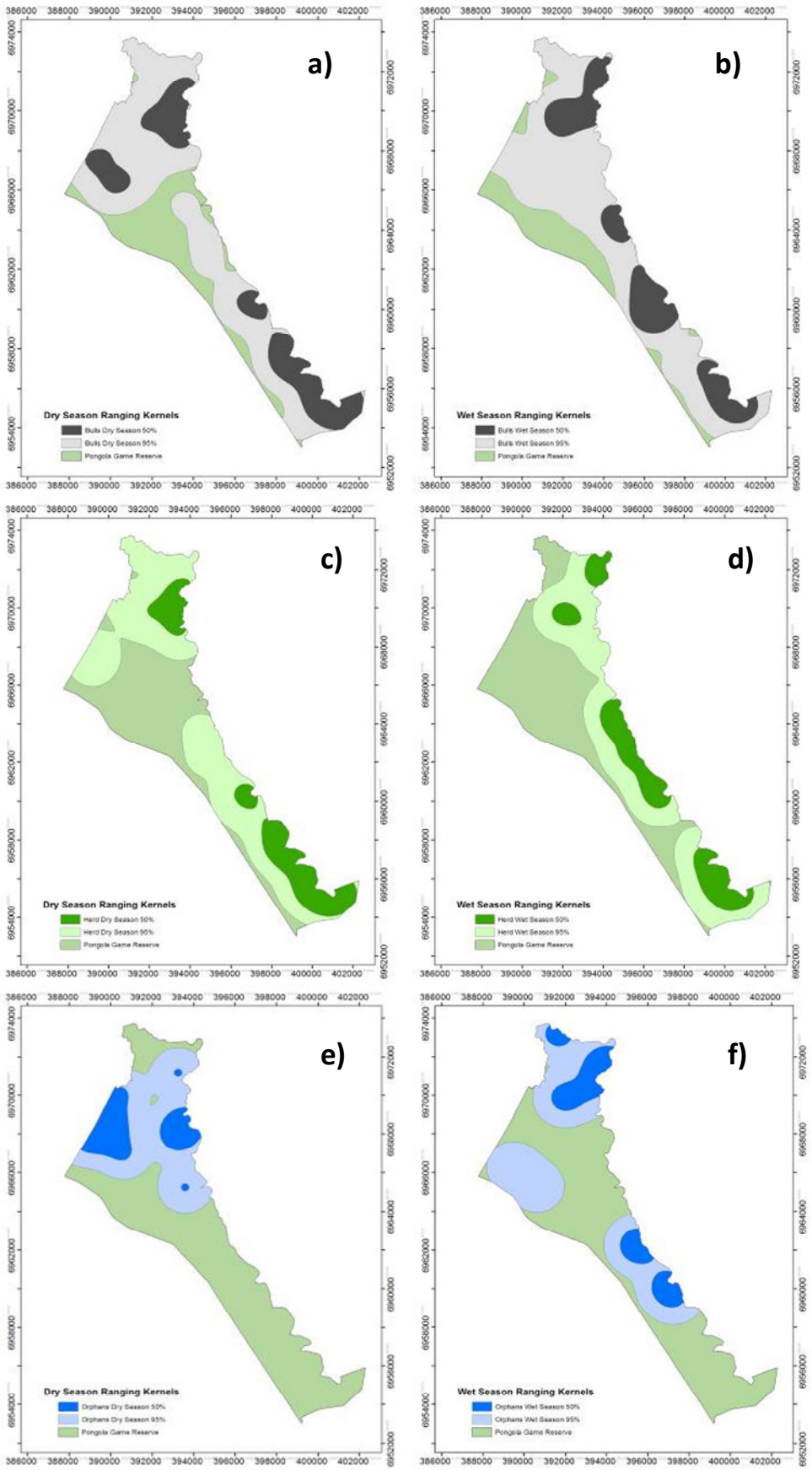

Figure 3: Home range density kernels (50% and 95%) for elephants at Pongola (1a: bulls dry season, 1b: bulls wet season, 1c: A&B family herd dry season, 1d: A&B family herd wet season, 1e: Orphan herd dry season, 1f: Orphan herd wet season).

A4.2: Activity budgets

Variation in herd activity from month to month can be seen in Figure 4. Alertness remains relatively constant across months as does the percentage of scans spent engaging in other behaviour (i.e. not feeding, resting, moving or alert). The overall percentage of scans spent resting is very low, but this is most likely because the elephants often rest in the heart of the thickets where they cannot be observed (and thus their behaviour is recorded as "out of view" and is subsequently removed from the dataset). Although we cannot say for certain what the elephants do while out of view in the thickets, their often stationary position acquired from radio telemetry emitted from radio collars is indicative of resting.

Feeding and moving accounted for the majority of the activity budget for all months, but there were notable changes in the percentage of scans dedicated to these behaviours in certain months. The month of April showed a notable increase in feeding and decrease in moving, suggesting that the elephants were feeding on a favoured food source that had a clumped distribution in a certain part of the reserve. Conversely, moving increased in June and feeding decreased, suggesting that food availability was low causing the elephants to travel further and for longer in search of food. In the months of October and November there is a progressive decrease in moving and increase in feeding, which is to be expected due to the patterns of rainfall and food availability in the reserve. Fluctuations in the percentage of scans spent feeding and moving throughout the year suggest that food supply at Pongola is not constant and the elephants must adjust their behaviour accordingly.

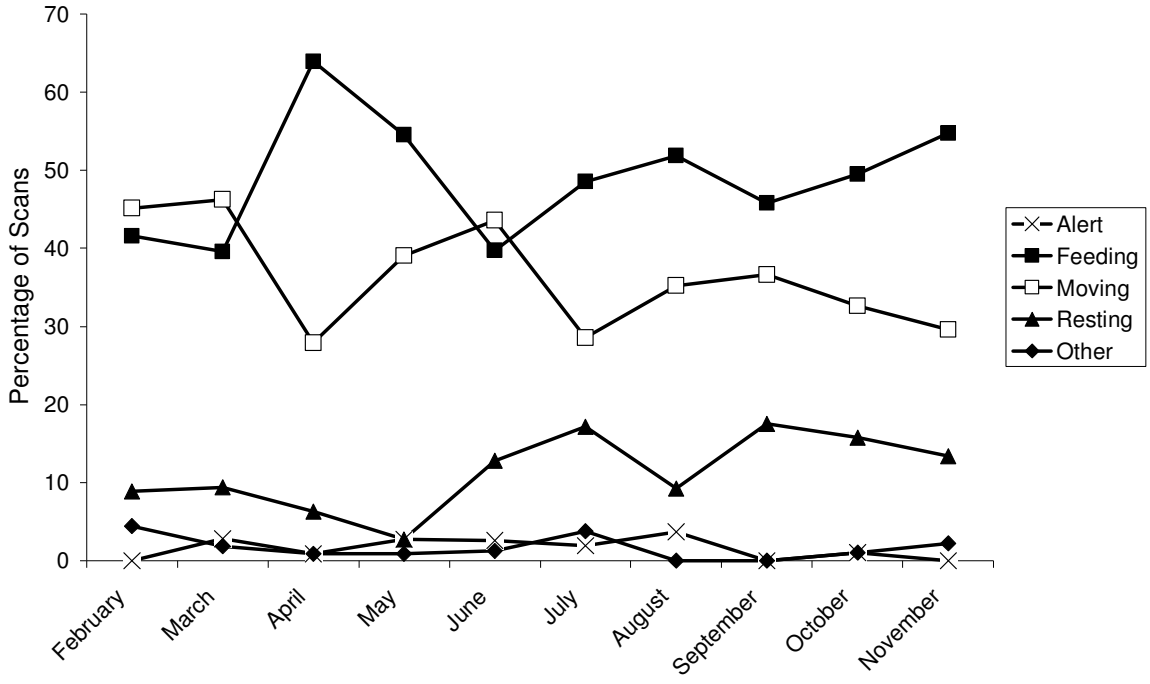

Figure 4: Activity budgets by month since data collection began, Feb – Nov 2011

A3.3: Habitat associations

Figure 5 shows the percentage of scans that the elephants were found in each habitat type from February through November. The two major habitat types utilized by the elephants were the floodplain grasslands close to Lake Jozini and thickets. Savannah habitat was rarely used by the elephants across all months. The winter pattern observed from June to August, where the majority of time was spent in thickets, will most likely recur as a seasonal pattern of habitat use, because the shelter provided is necessary during the cold dry season and the majority of food is browse from thickets. September sees the occurrence of 'spring', an increase in temperature and rainfall which leads to an increase in young grasses in the floodplain grasslands. Having taken advantage of the new grasses during the month of October, the elephants appear to be returning to the thickets in November.

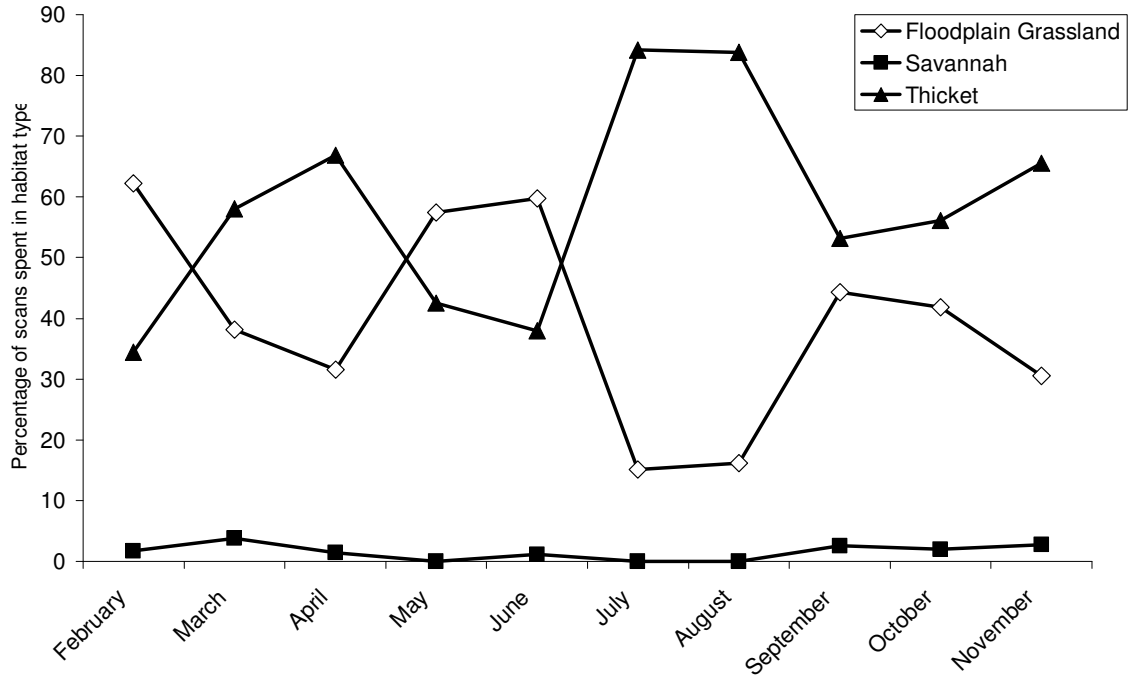

Figure 5: Percentage of scans spent in each habitat type from February through November 2011

Due to the difficulty of identifying grass species throughout the year (identification is generally only possible in spring when the grasses are flowering), the predominant vegetation in the floodplains can only be listed as "grasses". In the thickets it was possible to identify the predominant vegetation species during behavioural scans of the elephants. Figure 6 shows the percentage of scans in which each shrub species was the dominant species in the thicket occupied by the elephants. *Acacia nigrescens* appears to be the favoured vegetation type of elephants while in thickets accounting for almost half of the scans spent in thickets. However, it is not clear if the elephants actually favour this species, or if *Acacia nigrescens* is simply the most prevalent species in the reserve. It would therefore be interesting to conduct some basic habitat plots within the reserve to assess the abundance and distribution of *Acacia nigrescens* in relation to the movement patterns of the elephants.

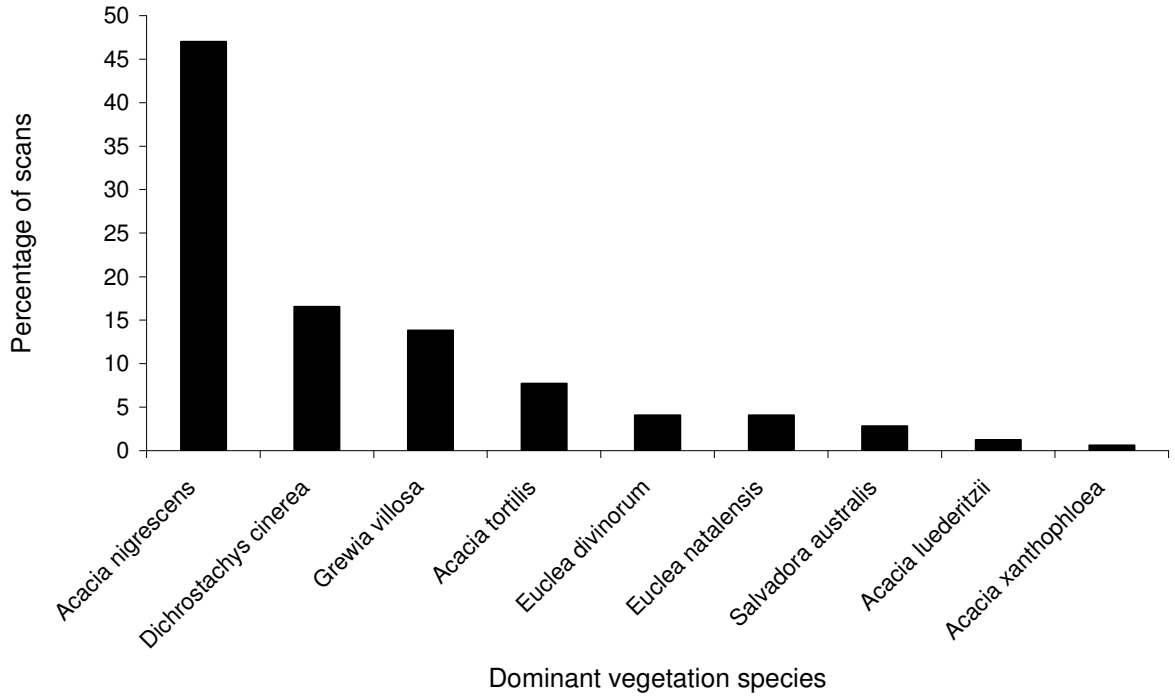

Figure 6: Dominant vegetation species used by the elephants while in thickets represented as the percentage of scans in thickets where a given species was the predominant vegetation type.

A4: Discussion

Home range size and ranging patterns of the bulls, A&B family herd and orphan herd for 2011 were compared with home ranges of the same elephant population in 2001 (taken from Shannon et al., 2006a). In 2001 the elephant population contained 39 individuals and in 2011 the population contained 79 individuals. Home range size is known to positively correlate with group size across a wide range of mammals including elephants (c.f. Chapman & Chapman 2001). It is therefore expected that the home range size of the elephants at Pongola would be significantly larger in 2011 compared to 2001 due to the increase in population size. As expected, the dry season home ranges of the bulls and both herds were notably larger in 2011 than 2001. However, wet season home range sizes in 2011 were very similar to those of 2001 and in 2011, there was little difference between the dry season and wet season home ranges. Previous studies of elephants across a wide range of reserves, including Pongola, have indicated that wet season home ranges are significantly larger than dry season home ranges (c.f. Shannon et al., 2006a; Harris et al., 2008; Chamaille-Jammes et al., 2009). The wet and dry season home ranges in Pongola are now virtually identical suggesting that the elephants are unable to increase their range during wet season as there is simply no more space available within the confines of the reserve. This finding, in conjunction with anecdotal evidence of severely impacted vegetation can be taken as a clear indication of an elephant population at Pongola well above the carrying capacity of the reserve.

Based on the percentage increase in home range size from the dry season to wet season from 2001 (Shannon et al., 2006a), the home range (95% kernel) increase in the wet season is 20.5% for the bulls, 6.4% for the A&B family herd and 16.21% for the orphan herd. Thus, to maintain the elephant population at Pongola at its current size would require a significant increase in the size of the reserve. If fences are to be dropped to increase the available land for the elephants then it is

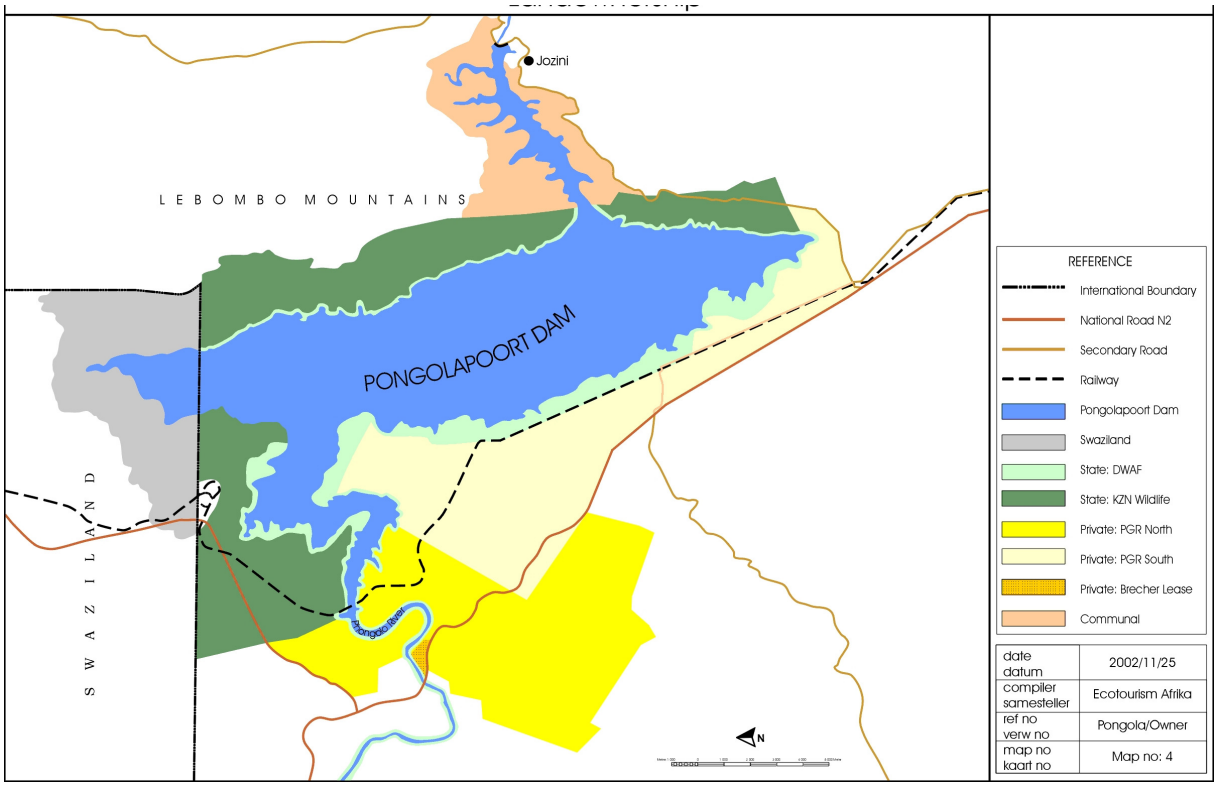

Figure 7: Map of landownership in Pongola. Map provided courtesy of Pongola Game Reserve management team.

important to ensure that the new areas of the reserve contain the necessary resources for the elephants, namely: water and the preferred habitat types of floodplain grasslands and *Acacia* and *Dichrostachys* thickets. Elephant ranging is heavily constrained by access to water (Redfren et al., 2003; de Beer & van Aarde, 2008; Gaugris & van Rooyen, 2010; de Knegt et al., 2010). With this in mind, the section of Pongola Game Reserve most suitable for expansion the land adjacent to the Pongolapoort Dam.

The entire eastern side of the reserve is the Pongolapoort Dam and thus expansion in this direction is not possible. Expansion is, however, possible in the north/northeast and of the reserve where fences could be dropped to enable the elephants to travel through Pongola North into the KZN Wildlife state land located around the northern perimeter of the Pongolapoort Dam (green shaded area in Figure 7). If additional fences were dropped, the elephants could range around the entire perimeter of the Pongolapoort Dam by incorporating a section of land in Swaziland (purple shaded area in Figure 7). As the habitat in the proposed expansion area is close to water, elephants are expected to fully utilize the new space available to them both in the wet and dry seasons, which will achieve a more even distribution of elephant impact on vegetation. However, there would be a considerable expense associated with expanding the reserve if the fencing surrounding the KZN Wildlife state land is not sufficient for containing elephants. In addition, the reserve could be extended in the southeast to provide access to the KZN Wildlife state land commonly known at Pongolapoort Nature reserve (green shaded area south east of Pongolapoort Dam, between the dam and the secondary road: Figure 7). Indeed, when the water level in the Pongolapoort Dam is low enough, some of the bulls have travelled around the southern tip of the dam to browse in Pongolapoort Nature Reserve. Expansion into Pongolapoort Nature Reserve is very likely because the World Wildlife Fund (WWF) who lead the Black Rhino Range Expansion Project (BRREP), are funding the completion of fencing in the Pongolapoort Nature Reserve.

The alternative to range expansion is to reduce the elephant population. Attempts have been made to cap the elephant population at it current size by vasectomies of the adult bulls (see Section B of this report), but an immediate reduction in the population via translocation or culling (see Section C of this report) is necessary for the sustainable management of the land and elephants at Pongola. If the elephant population is reduced, then additional steps can be taken to modify the ranging patterns of the remaining elephants (these steps should not be attempted with the existing population size at Pongola as reducing access to the already limited resources could lead to an elephant population crash or increased aggression in the elephants caused by frustration). Exclosure fences could be used to limit elephant access to certain sections of the reserve or certain plant species that are being over exploited to allow vegetation sufficient time to recover from elephant impact (Lombard et al., 2001; Grant et al., 2007; Levick and Rogers, 2008). However, as elephant impact on vegetation is a natural and important part of the African savannah ecosystem (Kohi et al., 2011), a widespread monitoring programme of elephant impact on vegetation in Pongola should be conducted to confirm that impact is sufficiently severe to cause plant extinction, before decisions regarding intervention are made. Operation Wallacea and Wildlife & Ecological Investments currently conduct this form of habitat monitoring in a number of reserves in South Africa and can easily apply the same methods to monitoring elephant impact on vegetation at Pongola as part of the student research programme.

Once elephant density at Pongola has been reduced by increasing the space available to them, elephant ranging patterns may be further modified by the addition of artificial water sources. At present, the elephants do not utilize the majority of land in the western part of the reserve. There is an artificial water source in the western section of the reserve that is used by the bulls and orphan herd, but the A&B family herd to not use it. As elephant density at water sources is positively correlated with the size of the water source (Smit et al., 2010) any attempt to redirect the large A&B family herd away from the Pongolapoort Dam, must involve a sufficiently large water source to provide water for an entire herd. Alternatively, a series of small water holes in close proximity to one another would achieve the same goal. However, any changes to the landscape in this area must be planned and monitored very carefully because changes to water supply will have a knock on affect on surrounding vegetation and will encourage elephants and other herbivores to browse in areas they would not normally use, which may lead to extinction in plant species that are not accustomed to year-round browsing. In addition, any changes to the landscape in Pongola will likely have an impact on biodiversity in general and thus monitoring should extend to other taxa such as birds (Valentine et al., 2007), herpetofauna (Nasseri et al., 2011) and invertebrates (Haddad et al., 2010) that are excellent indicators of faunal responses to changes in vegetation.

A5: Land management recommendations for Pongola Game Reserve

Landowners at Pongola have expressed concern with the level of elephant impact on vegetation in the reserve. Based on the data presented in this report and published literature from other elephant populations we make the following recommendations for addressing this issue:

1. A long-term monitoring programme of elephant impact on vegetation should be established using a series of standardized habitat plots throughout the reserve to better inform land management decisions
2. If the elephant population remains the same size then the space available to the elephants must be increased by dropping fences to expand the reserve. The most suitable areas for expansion are in the north/northeast of the reserve to enable the elephants to travel along the perimeter of the Pongolapoort Dam to gain access to the KZN Wildlife state land beyond,

and in the southeast of the reserve to allow access to the KZN Wildlife state land commonly known as Pongolapoort Nature Reserve. The landscape in the proposed expansion zone is close to water and contains the preferred habitat of the elephants, suggesting that there is a very high probability that the elephants will utilize the new space available to them.

3. If range expansion is not possible due to the cost of replacing the fencing in the KZN Wildlife state land then the elephant population in Pongola Game Reserve must be reduced (see Section C of this report)
4. Once elephant density is reduced (either by range expansion or population reduction), then elephant access to areas of the reserve that are heavily impacted by browsing could be temporarily restricted to give plants time to recover
5. Clusters of additional artificial water sources in the western part of the reserve could encourage elephants to utilize this section of the reserve.

Section B: Contraception, behavioural monitoring, and long-term population control

B1: Contraception and the social behaviour of elephants

As high densities of elephants in fenced reserves can lead to permanent, negative impact on vegetation (Guldemond & van Aarde, 2008), elephant population control is a necessary part of game reserve management. Contraception has been argued to be the most effective control method for discrete elephant populations (Delsink et al., 2006; Bertschinger et al., 2008). Ideally, contraception should be applied to some, but not all, females as a means of reducing breeding, while still maintaining a full age distribution within the herd (Bertschinger et al., 2008). In addition, the females receiving contraception should be changed over time as a means of maintaining genetic diversity in the herd (Bertschinger et al., 2008). The porcine zona pellucida (pZP) contraceptive vaccine is the preferred method of female contraception because the vaccine does not have any physiological side effects in the recipient, the procedure can be reversed, and the vaccine has over an 90% success rate and preventing conception (provided that sufficient booster applications are used – see Delsink et al., 2006; Bertschinger et al., 2008). However, the vaccines must be applied regularly, and should be applied by darting from helicopters because darting from game vehicles leads to elephant avoidance of game vehicles (Delsink et al., 2007). Hiring helicopters on a regular basis means contraception via pZP may be cost prohibitive to reserve managers.

Due to their smaller numbers in comparison to females, contraception of bull elephants is the most cost effective method of contraception. There are two general methods for bull elephant contraception: gonadotropin-releasing hormone (GnRH) suppressant and vasectomies. GnRH is a non-steroid based hormone that regulates reproduction in both male and female elephants and is used to stimulate Gonadtropin, Luteinising (LH) and Follicle-Stimulating (FSH) hormones, and testosterone (Becker & Katz, 1997). Suppression of GnRH prevents conception, but also has significant affects on elephant hormones and behaviour (Bertschinger et al., 2008). Despite the invasiveness of the surgical procedure, laparoscopic vasectomy is the preferred method of male contraception because they prevent conception, but do not affect male hormones (Stetter et al., 2006) and are therefore significantly less likely to affect elephant behaviour and herd dynamics.

Sexual activity in mature male African elephants is predominantly associated with the occurrence of musth (Poole 1989). Musth is a condition which refers to a set of physiological and behavioral characteristics including heightened aggression (Poole, 1987) and an elevation in testosterone secretions (Poole et al., 1984; Rasmussen et al., 2010). Although bulls show signs of sexually activity from around 12-15 years old, bull elephants are not fully mature until they reach 40 years of age (Slotow & van Dyke, 2001; Evans & Harris, 2008). In natural populations, musth first occurs between 25 and 30 years of age and its duration increases with age (Poole, 1987; Slotow et al., 2000). In young bulls it can last a few days, while in fully adult bulls, musth can last up to four months (Poole, 1987; Slotow et al., 2000; Druce et al., 2006b).

When bulls become sexually mature they separate from their natal herds and form fluid subgroups of one or more individuals that may exists in same-sex subgroups or mixed sex subgroups when associating with female herds (Wittemyer et al., 2005; Archie et al., 2006b; Aureli et al., 2010). During musth periods, bulls alter their spatial use to coincide with females (Slotow & van Dyke 2004). The duration and intensity of musth experienced by bull elephants are moderated by hormone suppression from other bulls within the same population (Slotow et al., 2000; Ganswindt et al., 2010). Young bulls in a natural population lose the physical signs of musth shortly after an aggressive

interaction with a higher-ranking musth male (Poole, 1987; Slotow et al., 2000). As a result, larger males may delay the onset of musth in young males (Poole, 1987; Slotow et al., 2000). Social experience and a gradual acquisition of musth is necessary for behavioural control under musth, by acclimatizing males physiologically and psychologically to the extremely high levels of circulating testosterone (Slotow et al, 2000; Ganswindt et al., 2010). In the absence of older bulls, younger bulls can display heightened rates of aggression and abnormal behaviour (Slotow & van Dyke, 2001). For example, the elephant population at Pilansberg National Park, KwaZulu-Natal, South Africa consisted of only younger bulls due to the culling of older individuals. These younger bulls showed high rates of 'delinquent' behaviour which including killing rhino and attacking game vehicles. When fully adult bulls were introduced to this reserve, the delinquent behaviour of the younger bulls ceased (Dickerson, 2004). Thus, elephant populations should always contain older adult bulls as a means of regulating younger bull behaviour.

Dominance among bull elephants is generally associated with age and body size (Archie et al., 2006a; Wittemyer & Getz, 2007) and dominant individuals have preferential access to fertile females (Poole, 1989). Female-male sexual interactions usually include bulls within older age classes (Moss, 1983) and females actively stay within close proximity with these bulls (Poole, 1989). However, elephants have complex and dynamic social organisations (Wittemyer et al., 2005) and although females usually mate with dominant bulls in mid-oestrus they may also mate with younger subordinate bulls during early or late oestrus (Moss & Poole 1983). With this in mind, it is important that male vasectomies are managed correctly. Vasectomising only dominant bulls in a population can have adverse affects on natural genetic selection because an increased frequency of females in heat could lead to young males becoming potential breeders (Bokhout *et al.* 2006; Bertschinger *et al.* 2008). Therefore, all adult bulls in a population need to be vasectomised to ensure females do not conceive and to reduce affects on natural genetics.

B2: Objectives for behavioural monitoring of male elephants in Pongola

Although vasectomies are a successful tool for elephant population control and the physiological effects of vasectomy are well understood, little is known about the influence of vasectomies on behaviour and the overall dynamics of a herd. In theory, male behaviour should be unaffected by vasectomies and hormonal levels remain unchanged. However, it is possible that rates of male sexual behaviour or female interest in vasectomised males will change after sustained periods of unsuccessful mating, which may have a knock on effect on male dominance interactions. Behaviour and relationships amongst elephants are primarily influenced by a hierarchy of spatial and social interactions (Moss & Poole 1983). Elephants display multileveled transitive dominance relationships (Archie *et al*. 2006a; Wittemyer & Getz, 2007) and it is suggested that a herd's social stability can be affected by a female's reproductive state (Wittemyer *et al*. 2004).

This current study aimed to investigate association patterns, dominance and sexual behaviour of elephants at Pongola Game Reserve following the vasectomies of seven of the eight adult bulls and GnRH hormone suppressants of the remaining bull. Unfortunately, vasectomies had long since occurred before the start of this study and thus it will not be possible to compare pre and post vasectomy behaviour. Nevertheless, data collected during this study may be used to ascertain whether the behaviour exhibited by elephants at Pongola is within the normal range for the species, based on published literature from other elephant populations. In addition, the association patterns and social behaviour of adolescent bulls at Pongola were monitored as a means of assessing the urgency of subsequent vasectomies in the population.

B3: Methods for behavioural monitoring of male elephants

B3.1: Subjects and study site

A description of the study site can be found in section A2.1 of this report. The elephant population at Pongola Game Reserve consists of 8 adult bulls, the A&B family herd containing 57 individuals and the orphan herd containing 14 individuals. Only one bull (Ingani, born 1969) can be described as fully adult (i.e. over 40 years old). The rest of the bulls are similar in age and are best described as young adults (Shayisa, born 1991; Kohlewe, born 1995/1996, Lucky born 1996; Asiphephe, born 1997; Khumbula, born 1997; Nitini, born 1997; Mgangane, born 1999).

In 2008, the Disney Corporation provided funding for vasectomies of the bull elephants in an attempt to cap the population. Only seven bulls were actually vasectomised because the alpha male Impi and beta male Ingani were so large that the risks associated with surgery for these individual was too high. Impi was removed from the reserve in May 2010 and Ingani was darted with GnRH suppressant. In addition to the eight adult males that are the focus of this study, three sub-adult males (referred to as SAM1, SAM2 and SAM3) have been included in the study as a means of monitoring their sexual development. Although the focus of the study is on the male elephants, data has also been collected on 11 females: the sex longest resident females in the A&B family herd, the 4 longest resident females in the orphan herd and an additional younger female in the orphan herd that conceived at an unusually early age and thus warranted close monitoring.

B3.2: Data collection

A general description of the method for locating the elephants and recording data is provided in section A2.2 of this report. The general health of the elephants was monitored on a daily basis noting any changes in weight, injuries and the condition of the vasectomy wound (where applicable). Signs of stress such as temporal gland secretions were recorded for all individuals, and the physical characteristics of musth were noted for males where applicable. Births and deaths in the population were also recorded.

Elephant individual, social and sexual behaviour were recorded using 15-minute focal animal samples with continuous recording (Altman, 1974), based on predefined behavioural categories (Table 3). Two focal samples were collected per hour, with each sample to be taken between the 30 minute instantaneous scan samples (i.e. one focal sample per 30 minute interval between scans). No repeat samples of the same individual collected within a one-hour period and efforts were made to collect an equal number of focal samples on each of the focal animals. If the focal animal was out of view for longer than 4 minutes during a focal sample then the sample was terminated. Where social interactions are recorded, the actor and recipient of the behaviour were also recorded. In cases where the interaction partner could not be reliably identified, they were recorded according to age-sex class (adult male, adult female or juvenile). In the case of aggression and dominance interactions the winner and loser of the contest were identified. Where aggression and dominance interactions have no clear winner, the outcome of the interaction was recorded as unclear.

Table 3: Ethogram of behaviour for social and sexual behavioural data collection

Behaviour	Code	Description
Friendly Behaviour		
Body contact	BC	Any type of body contact is considered friendly including touching, rubbing and smelling.
Greeting	GR	Elephant approaches another while rapidly flapping ears. One elephant may place the trunk in the mouth of another.
Play	PL	Running, chasing, tumbling and pushing accompanied with rapid ear flapping
Aggressive Behaviour		
Threat	TH	Elephant looks directly at another elephant with head held high and ears lifted. Elephant may also shake the head abruptly causing ears to flap sharply or shake the trunk in the direction of the other elephant. The elephant may also swing their head or body round abruptly to face another individual. Rapid steps or running at another individual whilst vocalizing, lifting or flapping ears is classed as a 'mock charge', which also counts as a threat.
Charge	CH	Elephant rushes towards an adversary – generally silent with head down and ears flat against the body, stopping just short of the target, forward trunk swing may follow and kicking dust.
Contact Charge	CC	Elephant rushing towards an adversary with ears spread, head raised or lowered and the charge continues until contact with the adversary is made The trunk may be curled in so that the tusks make first contact. Usually silent.
Dominance Behaviour		
Non-physical Displacement	DI	Elephant displaces another just by approaching (without contact).
Physical Displacement	PD	Elephant pushes or shoves another out of their position, and then moves in to replace them.
Trunk over body	TB	Elephant places the trunk along the back of a partner, or their head. This is typical courtship behaviour from male-female but is also a dominance display between males.
Trunks interlocking	TI	Two elephants face each other and interlock trunks or tusks. Can escalate into pushing against each other. The interaction ends when one individual submits (in which case there is a clear winner and loser) or both individuals simultaneously break contact (in which case there is no winner or loser of the interaction)
Submissive Display	SD	Elephant actively shows submission by presenting their rear end to the partner and/or walking backward towards another elephant.
Sexual Behaviour		
Oestrus walk	OW	Female walks with head high and maybe angled to the side to watch for following male. Tail may be raised. She usually has a greater stride and moves away from the herd slightly.

Genital Inspection	GI	This involves the male touching or smelling the female's vulva and/or urine.
Copulation	CO	The male places his trunk on her spine and rests his head on her rump. He then rears up on his hind legs and penetrates her.
Musth Walk	MU	Male only behaviour. Purposeful walk with his head held high, ears slightly out and stiff. Can include a figure of eight pattern with their head while walking, or 'indecisive' movements, when the elephant is hesitant or uncertain of where to move to. Can include individual ear waving. Sometimes the top half of the ear moves forward while the back half moves back and visa versa. May be accompanied by a constant dribbling of urine which marks the path where the animal is walking or the rubbing of the temporal gland on a tree or other substrate

B3.3: Data analyses

The mean percentage of time spent alone, in same-sex associations and in mixed-sex associations was calculated for each of the adult bulls and also for the three adolescent males at Pongola. Mean rates of sexual behaviour were calculated for each male based on the frequency of this behaviour and the time each male spent in mixed-sex associations (where interactions between the sexes could occur). The effect of the presence of females on bull dominance interactions was investigated by comparing mean rates of male-male dominance interactions when in same-sex association versus mixed-sex association using a paired t-test. The male dominance hierarchy was calculated using a matrix of winners and losers of dominance interactions. The linearity of the hierarchy was tested using Landau's index of linearity:

$$h = \frac{12}{n^3 - n} \cdot \sum_{a=1}^{n} \left(v_a - \frac{1}{2(n-1)} \right)^2$$

Where n is the number of individuals and v_a is the number of individuals that individual a dominates. h = 1 indicates a completely linear hierarchy, h = 0 indicates no hierarchy.

B4: Results

Eight hundred and forty nine focal animal samples of the eight adult males and three adolescent males were collected between February 5th 2011 and November 28th 2011 giving rise to 160 hours and 37 minutes of observations. All male elephants are in good health and have shown no signs of complications following the vasectomies. In the last 12 months, Ingani has experienced a period of musth due to insufficient dosage of GNRH. Although confirmation of full musth has not been observed in any of the remaining bulls, signs associated with musth have occurred among younger individuals in the population. Urine dribbling and swollen temporal glands (STG) have been observed in four individuals besides the dominant bull since July 2010 (individuals Ntini, Lucky, Shayisa, and Asiphephe). A white discolouration of the penis sheath has also been observed in Lucky and Shayisa. In addition to the physical signs of musth, behavioural signs associated with musth have also been observed in individuals other than the sole fully mature adult bull. These signs include the 'musth walk' (observed in Lucky and Kohlewe), indecisive movement (observed in Ntini and Shayisa) and 'ear waving' (observed in Lucky and Shayisa). In addition to these signs that are associated with musth, temporal gland secretion (TGS) is frequently observed in all individuals. Although a physiological sign of stress rather than being solely associated with musth, TGS along with other musth signs can be an indicator of the heightened hormonal state. Indications from the monitoring of musth signs are that incipient musth periods are occurring in the younger adult bulls.

B4.1: Association patterns of adult and adolescent males

The cohesion of female herds appeared to be unaffected by male vasectomies as both the A&B family herd and the orphan herd remained intact with no changes to the matriarchs. The percentage of observation time each bull spent alone, in same-sex groups (i.e. with other males but neither of the female herds) and in mixed-sex groups (with one or more of the female herds) was calculated for the eight adult males and three adolescent males (Figure 7). In August it was noted that ADM2 had begun to disassociate from his natal herd (A&B family herd) to spend time alone or with other males in same-sex groups. In September this change in association patterns was seen in all three of the adolescent males at Pongola and has continued throughout October and November. ADM2 was also found to associate with the orphan herd (see Section C of this report).

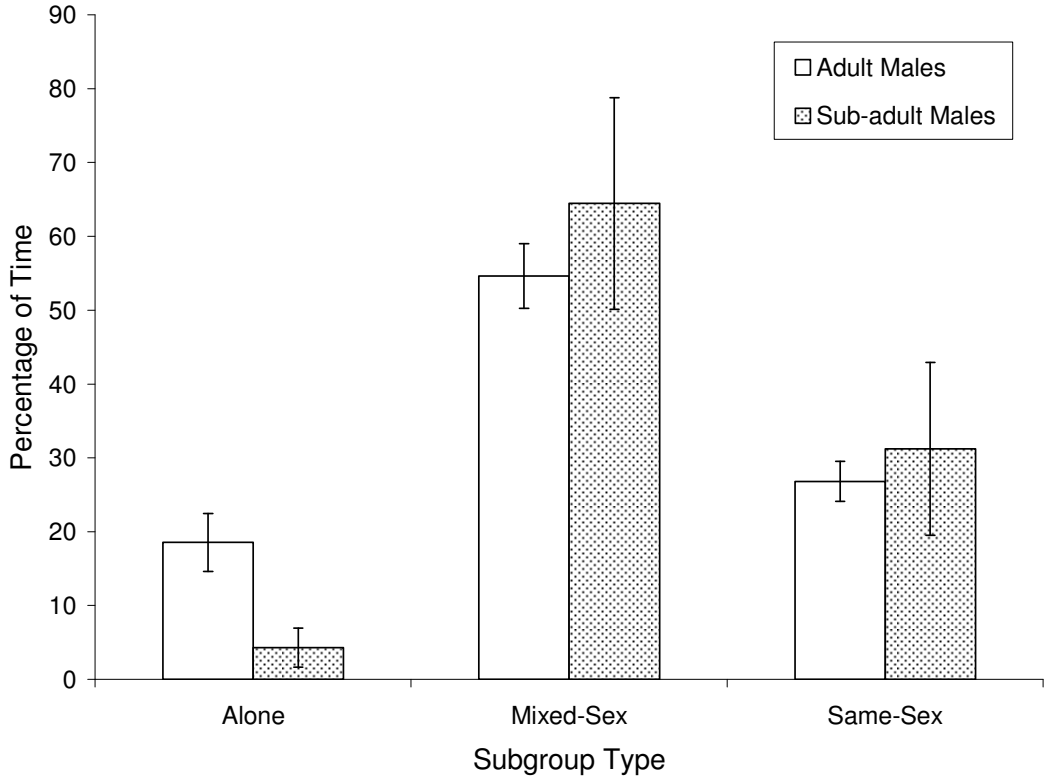

Figure 8: Mean (±SEM) percentage of time adult male elephants (n=8) and adolescent males (n=3) spent in each sub-group type (sub-adult and adult bulls only)

B4.2: Social interactions

No cases of abnormal or 'delinquent' behaviour have been observed at Pongola. The mean rate of bull-bull aggression was very low (0.04±0.12 aggressive interactions per hour) and all observed cases were limited to threats rather than actual contact aggression. No cases of bull-female or female-female aggression were observed during the course of the study. No cases of copulation involving the vasectomised bulls were observed during the study. However, all the vasectomised bulls showed signs of sexual interest in adult females except from the youngest adult (Ntini). Ingani also directed sexual behaviour towards females and was observed to copulate suggesting that he is not receiving a sufficient dose of GNRH hormone suppressants. None of the adolescent bulls were observed to show sexual interest in adult females.

Table 4: Rates of sexual behaviour directed from the adult and adolescent bulls towards adult females

Individual	Count	Rate
Asiphephe	3	0.47
Ingani	3	0.29
Khumbula	4	0.34
Kohlewe	5	0.42
Lucky	1	0.26
Mgangane	1	0.08
Ntini	0	0.00
Shayisa	4	0.41
ADM1	0	0.00
ADM2	0	0.00
ADM3	0	0.00

Dominance interactions (N=188) of bull elephants were arranged in a dominance matrix of winners and losers to determine the dominance hierarchy (Table 5). Ingani is clearly dominant to all other bulls having won all of 16 of the dominance interactions he was involved in. Shayisa is also clearly dominant to all other bulls apart from Ingani. Kohlewe and Khumbula interacted most frequently with one another, although Kohlewe is clearly the dominant of the two. The dominance relationship between Asiphephe and Lucky is unknown as no dominance interactions were observed between these bulls. Lucky appears to be dominant to Khumbula, but as he has only one four of the seven dominance interactions observed between this dyad, the ranks are most likely tied. The two remaining bulls (Mgangane and Ntini) have lost all their dominance interactions with the six older bulls. Ntini is the dominant of these two, having won 16 of the 22 contests between them. Landau's index of linearity produced a value of 0.66 for the Pongola bulls, which describes a roughly linear hierarchy, with no rank reversals. There was a significant difference in mean rates of bull-bull dominance interactions when in same-sex associations versus mixed-sex associations [Figure 6: $t_{(8)} = 9.37$, $p=0.05$].

Table 5: Matrix of dominance interactions between adults bulls depicting winners and losers.

		WINNERS							
		IN	**SH**	**KO**	**AS**	**LU**	**KH**	**NT**	**MG**
LOSERS	**IN**	X	0	0	0	0	0	0	0
	SH	12	X	0	0	0	0	0	0
	KO	2	8	X	6	1	13	0	0
	AS	0	0	10	X	0	0	0	0
	LU	1	3	1	0	X	3	0	0
	KH	0	5	41	9	4	X	0	0
	NT	2	1	4	1	11	12	X	6
	MG	0	1	1	8	4	4	16	X

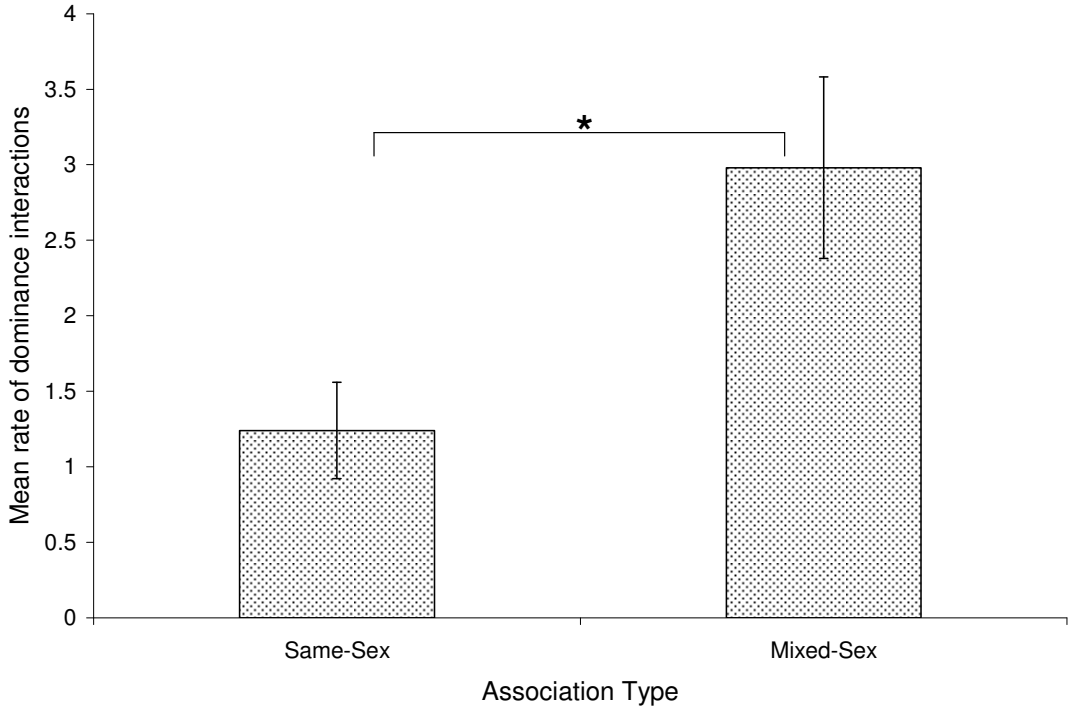

Figure 9: Mean rates of bull-bull dominance interactions in same-sex and mixed-sex associations. * refers to a significance in means at the 0.05 level.

B5: Discussion

Physical and behavioural observations of the adult bulls, adolescent bulls and key adult females of the two female herds in the Pongola Game Reserve were made to determine whether recent vasectomies and hormone suppressants of the bulls had affected their health, behaviour and general herd dynamics. All male elephants were found to be in good health and showed no signs of complications following the vasectomies. Full musth has not been observed in any of the vasectomised bulls, but that is to be expected because musth is not normally observed in bull elephants until they are 25-30 years old (Poole, 1987; Slotow et al., 2000). The oldest of the vasectomised bulls is only 20 years of age and the others age between 12-15 years. Some of the vasectomised bulls did however show behaviours that are associated with musth. As musth increases in duration and intensity with age (Poole, 1987; Slotow et al., 2000), musth associated behaviour in the younger bulls at Pongola is within the normal range. As expected, the adolescent bulls showed no signs of musth.

Ingani has experienced a period of musth that lead to copulation due to insufficient dosage of GnRH. Seven births in the A&B family herd occurred during 2011 (1 birth in March, 1 birth in June, 1 birth in July, 1 birth in September, 2 births in October and 1 birth in November). As elephant gestation is approximately 22 months (Poole, 1989), all calves were conceived in 2009. Consequently, the most likely sire of these calves is Impi as he was the dominant bull in the population prior to his removal in May 2010. Impi was supposedly receiving GnRH suppressants since 2009 so it is clear that the dosage or time between applications was not calculated correctly. Ingani has received GnRH suppressant since 2008. As Ingani has experienced musth and is still mating with females the dosage of GnRH he is receiving has also been calculated incorrectly, or not applied with sufficient frequency. Additional GnRH suppressants should be administered to Ingani as soon as possible to prevent breeding in the population.

Application and dosage of GnRH to Ingani should, however, be calculated extremely carefully. Musth in fully adult bulls is known to delay the onset of musth in younger bulls within the same population (Poole, 1987; Slotow et al., 2000) and modify younger male behaviour (Slotow & van Dyke, 2001). Ingani is the only fully adult bull at Pongola so if he is prevented from achieving musth by high doses of GnRH then it is possible that this will lead to an early onset of musth in other bulls. Although musth and mating activity in these younger vasectomised bulls could not lead to conception, early onset of musth in young and therefore inexperienced bulls could lead to heightened aggression and 'delinquent' behaviour (Slotow & van Dyke, 2001). If the dosage of GnRH for GnRH cannot be correctly calculated, the reserve managers should consider pZP contraception vaccines for female elephants at Pongola.

Association patterns of the adult elephant population at Pongola corresponded with published literature of association patterns in other elephant populations; namely that females reside in cohesive herds whereas bulls form fluid subgroups of one or more individual either as same-sex or mixed-sex associations (Wittemyer et al., 2005; Archie et al., 2006b; Aureli et al., 2010). Adult bulls do appear to associate more frequently with female herds and spend less time alone than has been reported in other elephant populations. This may be due to male attraction towards the constant presence of cycling females, but it could also be an artefact of the high population density. The ranging patterns of bull elephants can be likened to fission-fusion dynamics of gas molecules moving in a confined space (Aureli et al., 2010). When the density of molecules (or in this case, elephants) is higher, the probability of encountering other molecules (elephants) is significantly higher than at lower densities. It will not be possible to determine which of these factors is driving male associations with females unless changes are made to elephant density by range expansion or population reduction.

In the last few months of the study, the three adolescent bulls started to disassociate from their natal herds and showed similar association patterns to those of the adult bulls. Although no cases of sexual behaviour were observed between adolescent males and adult females, the change in association patterns of these three adolescent males indicates the first key step in reaching sexual maturity. Consequently, the behaviour of these three adolescents, particularly SAM2, should be monitored very closely to inform management interventions such as further vasectomies and the potential removal of groups from the reserve. Initial plans have been made to schedule vasectomies for April/May 2012 (H. Zitzer, personal communication).

No cases of abnormal or delinquent behaviour were observed in the elephant population at Pongola and aggression occurred at a very low rate and intensity. As predicted, dominance among bull elephants was closely related to the age of the individual (Archie et al., 2006a; Wittemyer et al., 2007; McComb et al., 2010). The linearity of the dominance hierarchy was not particularly high, but this is to be expected due to closely matched ages of 6 of the 8 bulls. With such little difference in age between these younger bulls, dominance rank is most likely correlated with body condition and personality rather than being strictly tied to the age of the individual. Dominance interactions occurred at significantly higher rates when bulls were associating with females compared to when bulls where only in the presence of other bulls. An increase in male-male aggression and dominance interactions when in the presence of females have been reported for other "fission-fusion" societies (spider monkeys: Slater et al., 2009; chimpanzees: Muller, 2002; bonobos: Hohmann & Fruth, 2003) and thus is to be expected in elephants although it has not yet been investigated. The significant increase in bull elephant dominance interactions when in mixed-sex associations suggests that bulls still consider females to be a contested resource. Although copulation was only observed once, all males with the exception of Ntini showed sexual interest in adult females. Collectively, these data

indicate that vasectomies and GnRH suppressants have had no negative impacts on the social behaviour of elephants at Pongola.

B6: Recommendations for contraception and behavioural monitoring at Pongola

Our data indicates that vasectomies are an excellent method for elephant population control at Pongola game reserve. Based on the data presented in this report and published literature from other elephant populations we make the following recommendations for subsequent contraception and behavioural monitoring:

1. Close monitoring of musth behaviour in Ingani and the vasectomised bulls should be used to determine the optimal dosage of GnRH suppressants for Ingani. The aim is to reduce hormonal levels in Ingani to prevent conception, but still allow some of the physiological and behavioural associates of musth to occur as a means of preventing early onset of musth in the vasectomised younger bulls.
2. If GnRH cannot be correctly applied to Ingani, then pZP contraception vaccines for female elephants should be considered.
3. Continued monitoring of the social behaviour of adult bulls and females using the current methods to confirm that behaviour and herd dynamics are within the normal range. Behavioural data collection may also be used to monitor elephant responses to changes to their environment or populations as a result of management decisions at the reserve
4. Continued monitoring of the social behaviour of adolescent bulls using the current methods to ascertain when the next round of vasectomies should take place
5. If changes are made to elephant population density, continued monitoring of elephant association patterns using the current methods, will determine whether the high levels of male association with female herds are a consequence the contraception interventions or simply a by-product of high elephant density.

Section C: Translocation, culling and short-term population reduction

C1: Cost-benefit assessment of hunting, culling and translocation

The popularity of wildlife viewing as a form of tourism has lead to a rapid increase in the number of small (<1000 km²) game reserves in South Africa. Elephants are one of the most sought after animals for tourist to view, but due their large size, maintaining elephant populations in small fenced reserves is extremely difficult. If kept at high densities, elephant browsing can lead to irrevocable changes to the landscape (c.f. Mapaure & Moe, 2009). Contraception can be used to cap population sizes (Bertschinger et al., 2008), but when elephant populations have already grown too large before management interventions are implemented, immediate action must be taken to reduce the population size. Options to achieve an immediate reduction in population size by removing individuals or groups currently consist of culling, translocation or hunting. Things to consider when determining the most applicable method in a given reserve are:

- Variation in the impact of each method in terms of the number of individuals that will be affected
- Stress and disturbance caused from the event
- The necessity of repeated interventions to achieve the original aim

Incorrect management interventions can lead to incidences of dysfunctional behaviour, which can be severe (Slotow & van Dyke 2001; van Aarde et al., 2008). Dysfunctional behaviour as a result of management interventions is generally associated with the breaking up of family units, such as the now abandoned practice of culling adults and sub-adults in the presence of their offspring, and translocation the orphans (Slotow et al., 2008). Family units must be maintained to safeguard infant development and social learning processes (Cumming & Jones, 2005). However, it is not only the lack of key social roles or disruption of attachment and social bonds that causes long term problems, the traumatic event itself can lead to abnormal behaviour. The symptoms following trauma such as that experienced by orphaned offspring during culling events, have been described as analogous to post-traumatic stress disorder (PTSD) in humans (Bradshaw et al., 2005). Trauma interferes with social learning, and the lack of key phases of social learning has been linked to interference with the development of normal brain patterns and brain re-organisation in mammals (Bradshaw & Schore, 2007). Instances of infant rejection, depression, immunosuppression, elevated cortisol, and heightened aggression have been associated trauma and disruption of the social system (Bradshaw et al., 2005; Bradshaw & Schore, 2007).

An example of the potential effects of badly managed culling and translocation is the orphaned males introduced into Pilanesberg National Park (Slotow & van Dyke, 2001; Slotow et al., 2008). These elephants were translocated to the reserve following the culling of all adult individuals in their original herds at Kruger. The orphaned elephants showed unpredictable behaviour, heightened aggression and systematically killed 40 white rhino over a five-year period (Slotow & van Dyke, 2001). As previously mentioned in Section B of this report, the duration and intensity of musth experienced by bull elephants are moderated by hormone suppression from other bulls within the same population (Slotow et al., 2000; Ganswindt et al., 2010). Having matured in the absence of older bulls, the orphaned bulls at Pilanesberg showed 'delinquent' behaviour are were observed to come into musth and mate much earlier in life than in natural populations (at 18 years as opposed to mid-thirties). Moreover, the duration of musth periods were much longer than they would be for

individuals of a similar age in natural populations (several months as opposed to days or weeks: Slotow et al, 2000). These aberrant musth features and behavioural problems were significantly reduced with the introduction of fully adult older bulls (Dickerson, 2004), whose musth periods effectively limited frequency and duration of the musth periods of the younger bulls (Slotow et al, 2000).

Translocation of elephants has gained favour among the general public for the relative gentility of the approach when viewed against the fatal alternative (Grobler et al., 2008). Evidence from recent translocation events that did not involve culling or the breaking up of family units suggest that the stress and experienced by the elephants is minimal (Grobler et al., 2008; Pinter-Woollman et al., 2009). Physiological and behavioural assessment of translocated elephants indicated that stress hormone levels in translocated elephants did not differ from the long-term resident elephants in their new reserve, and over time, the translocated elephant activity budgets corresponded with that of the resident elephants (Pinter-Woollman et al., 2009). However, elephant death rates were higher, and body condition was poorer in translocated elephants in comparison to resident elephants, and translocated elephants preferentially ranged in sections of the reserve with similar habitat to their previous reserve (Pinter-Woollman, 2009, Pinter-Woollman et al., 2009). These data indicate that decisions regarding the suitability of elephants for translocation and release locations should be thought through carefully.

However, translocation of elephants is extremely costly and as many reserves are already saturated with elephants, it is not always easy to find a reserve willing to accept new elephants, at least not in large numbers. In addition, according to the National Environment Management Biodiversity Act of 2004: National norms and standards for the management of elephants in South Africa, elephants should not be translocated more than once. Although culling should be used with caution, it is unlikely to result in the same disastrous consequences of widespread culling in Kruger in the late 1990s if entire family units are removed leaving non relatives of the culled elephants behind (Slotow et al., 2008). In addition, culling can generate significant income for reserves via the sale of meat and hides (Slotow et al., 2008), such that reserves can actually make a substantial profit from culling. Nevertheless, the ethical issues surrounding elephant culling are such that culling should only be used if all other management interventions are not possible or have failed (Lotter et al., 2008).

Hunting of specific individuals rather than mass culling can also be used to manage elephant populations. However, as removing individuals from cohesive female herds is ill advised, hunting in generally restricted to individual bull elephants. A recent study investigated the physiological and behavioural responses of elephants following a successful hunt of one of members of their herd (Burke et al., 2008). Stress hormone assays from faecal samples showed a significant increase in cortisol following the hunt, which in many individuals persisted for over a month after the hunt (Burke et al., 2008). Moreover, individuals that did not even witness the hunt, showed the same pattern of increased cortisol suggesting that these elephants were reacting to the trauma experienced by their conspecifics (Burke et al., 2008). However, the increase in stress hormones was neither severe nor permanent suggesting that hunting of elephants is ethically acceptable, provided that remaining individuals have time to recover in between hunts.

Anecdotal evidence of elephant response to hunting occurred at Pongola during 2010 when the dominant bull Impi was hunted. Two days after the hunt, the herd visited the abattoir where the bull's remains were processed in an area of the reserve that they do not normally utilize (H. Zitzer, personal communication); indicating the herd connection to the dead individual and their knowledge that something had happened to him. However, within a few weeks, the herd had returned to their normal home range and showed no long-term signs of distress (H. Zitzer, personal communication).

C2: Methods for monitoring association patterns of elephants at Pongola

Bull elephant behaviour (adults and adolescents) was recorded using 15-minute focal animal samples with continuous recording (Altman, 1974), based on predefined behavioural categories (Table 3). During these focal samples, the presence of other bulls, the A&B family herd and the orphan herd were recorded noting the time with which the association started and ended. From these data is was possible to calculate total amount of time that each bull was in view and the percentage of time in view that was spent alone, in same-sex subgroup and in mixed-sex subgroups (see Section B4.1 of this report). Using only those instances where the bulls where in mixed-sex subgroups, it was then possible to calculate the percentage of time spent associating with each of the female herds. Full details of the focal sampling protocol are provided in Section B3.2 of this report. A full description of the subjects and study site can be found in sections A3.1 and B3.1 of this report.

C3: Association patterns of Pongola elephants

Data from 2011 indicate that Asiphephe splits his mixed-sex association time equally between the two herds (although it should be noted that this individual spends a larger proportion of time alone than other individuals). Ingani, Khumbula, Kohlewe, Mgangane, Ntini and Shayisa associate preferentially with the A&B family herd, and Lucky spends more time with the orphan herd. At certain times of the year, the A&B family herd temporarily split into two separate foraging groups. These subgroups contain different individuals each time they occur and the subgroups rejoin the remainder of the herd at the end of each day (H. Zitzer, personal communication). Although all three adolescent bulls were observed to disassociate from their natal A&B family herd in order to for same-sex associations with adult bulls, only SAM2 was observed to leave his family herd in order to associate with the other female herd at Pongola (i.e. the orphan herd).

Table 2: Percentage of time spent with each herd (in part or in full) for each male when in mixed-sex groups.

	A&B Family	A&B Family / Orphans	Orphans
Asiphephe	56.09	21.75	22.16
Ingani	95.60	4.40	0.00
Khumbula	85.89	14.11	0.00
Kohlewe	89.72	10.28	0.00
Lucky	28.64	7.31	64.05
Mgangane	93.51	4.33	2.16
Ntini	87.83	6.24	5.94
Shayisa	87.40	9.17	3.43
SAM1	97.27	2.73	0.00
SAM2	68.68	11.95	19.37
SAM3	100.00	0.00	0.00

C4: Recommendations for culling and translocation of Pongola elephants

Data presented in this report indicates that the current elephant population at Pongola Game Reserve exceeds the carrying capacity of the reserve. This problem can be overcome by expanding the reserve, but if this is not possible then a reduction in elephant population size is required. All plans for elephant removal via culling or translocation should be based on existing recommendations for elephant population control and empirical data on the elephant ranging, habitat use and behaviour of the elephants at Pongola. Recommended protocols are:

1. Wherever possible, alternatives to removing individuals should be considered. Increasing the area available to the elephants is a non-invasive method of reducing elephant population density (see section A of this report).
2. If it is necessary to reduce population size by culling or translocation, then family units must be maintained to safeguard infant development and social learning processes. Consequently, either the A&B family herd or the orphan herd would have to be moved in their entirety. Failure to do so could lead to increased aggression and unpredictable behaviour in the elephants.
3. Translocation is preferable to culling because, provided that elephants are translocated in family units, the process is unlikely to cause trauma to the elephants.
4. As herds must be translocated in their entirely, the most likely candidate for translocation is the orphan herd because it seems unlikely that a any reserve would be willing to receive 57 new elephants at the same time.
5. However, the national norms and standards for the management of elephants in South Africa recommend that elephants should only be translocated once. This would prevent translocation of both the orphan herd and the A&B herd because as the majority of individuals in these herds were translocated from Kruger (A&B family herd were translocated from Kruger to Pongola and the orphan herd were translocated from Kruger to a reserve south west of Pongola and then later broke into Pongola). A full assessment of the welfare implications of translocating elephants for a second time must be undertaken before any decision regarding the removal of elephants from Pongola is made.
6. Bull elephants can be removed from Pongola either as individuals or as part of a group. However, fully adult, sexually mature bulls must remain at Pongola to regulate young bull musth periods and provide the socialization phase for newly independent bulls. Consequently, Ingani should not be removed from Pongola under any circumstances. Failure to do so could lead to increased aggression and delinquent behaviour in the remaining bull elephants
7. If bull elephants are to be removed along with one of the female herds then the decision regarding which bulls to remove should be based on their association patterns. If The A&B family herd are removed then Shayisa, Kohlewe, Khumbula, Mgangane and Ntini could accompany them. If the orphan herd is removed then Lucky should accompany them. Asiphephe could accompany either of the two herds.

Based on the evidence presented in this report, our recommended strategy for the immediate management of the elephant population at Pongola is as follows:

1. Implement a long-term habitat monitoring programme throughout the reserve to quantify elephant impact on vegetation. These data may then be used to inform decisions regarding

exclosure fences, the addition of artificial water sources, potential for range expansion and the need for elephant population reduction

2. Increase the area of land available to the elephants by dropping fences around the perimeter of the Pongolapoort Dam to enable elephants to connect Pongola Game Reserve to the KZN Wildlife state land to the north east and south east of the existing reserve.
3. Range expansion should take preference over all other management interventions such as translocation or culling
4. As the family unit of the A&B family herd cannot not be disbanded, and the likelihood of finding another reserve willing to receive 57 elephants in slim, the A&B family herd is not a suitable candidate for translocation
5. The orphan herd and Lucky could be translocated to a neighbouring reserve reducing the elephant population by 15. This would be sufficient to alleviate elephant impact on vegetation if in conjunction with range expansion (i.e. dropping fences to connect PGR with PNR). Moreover, the orphan herd seems to maintain their territory in the north of the reserve so their removal could encourage the A&B family herd to use this space, thus alleviating elephant impact in the southern section of the reserve close to the Jozini Lake. However, as the orphan herd has already been translocated once, a full welfare assessment must be undertaken before any decision for elephant removal from Pongola is made.
6. The alternative to translocation is culling. Culling is more cost effective than translocation, but can lead to severe behavioural problems with the remaining elephants. Before any decisions to cull are made, assessment of elephant impact on vegetation in Pongola should be used to determine exactly how many elephants should be removed. This figure will in turn determine whether the orphan herd or A&B family herd remains.
7. Continue with the behavioural monitoring of the elephants using the methods presented in the report as a means of informing and monitoring the effects of management interventions

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