THE INTERACTION BETWEEN THE PROVISION OF ARTIFICAL WATER, ELEPHANT AND BIODIVERSITY

WATER-PROVISION IN THE KNP

DANIE PIENAAR

From the KNP management plan 1998

History

When the Sabie Game Reserve was proclaimed in 1898 and the Shingwedzi Game Reserve in 1903, there were no artificial water impoundments in what is now the Kruger National Park. Game numbers were low as a result of persistent hunting and the great rinderpest epidemic of 1896. The vegetation structure was also different from the present with for instance open grassy plains in the Pretoriuskop area and extensive stands of tall mlala palm trees (*Hyphene natalensis*) on the northern basalt plains, certain differences which we interpret as being the result of human influence at that time.

As early as 1927 the possibility of boreholes to provide water for game during droughts was mentioned at a Board Meeting. Reasons given for the stabilization of the water supply included making the more arid areas more accessible to game in order to spread the animals more evenly over the whole of the Kruger Park, and to prevent emigration of animals out of the KNP which was still unfenced.

Brynard (1969) as quoted by Pienaar (1985) identified five phases in the history of what became the artificial water-for-game programme in the KNP.

The first phase (1929 - 1946) of the water provision programme started in 1929 with the Board’s decision to provide artificial water in the KNP.

In 1976 the eastern boundary of the KNP was fenced off with elephant-proof fencing as a result of deteriorating international relations and political turmoil in Mozambique. The KNP was now almost fenced in completely. The game within the park was now completely dependant for survival on local natural resources including those which are man made. Mass migration to escape natural catastrophes such as droughts and extensive veld fires was now impossible (Pienaar 1985).

The total number of boreholes providing water to game reached a peak in the late 80’s. Thirty-five dams also provided water in selected catchments. Pienaar (1985) foresaw a sixth phase which would entail consolidation and elimination of the mistakes made in the past. Greater knowledge about the long-term and short-term rainfall cycles and its effect on the animal populations, the removal of the western boundary fence and recent experience of herbivore population dynamics and interactions will guide this phase. It will probably imply that certain boreholes (for example those in the traditional summer grazing areas) will be removed, and that some dams which were built in the past will serve no further purpose and will be drained or even removed, if necessary (Pienaar, 1985).

We saw the beginning of this phase in 1994 when 12 boreholes were closed and one earth dam (Stangene Dam) was drained on the basalt plains north of Shingwedzi. This was motivated by a drastic decline of low density herbivores (roan antelope, sable antelope and tsessebe) in this area. In contrast, a rapid increase in zebra and lion numbers were experienced in the same area and an increase in competition and predation coupled with a deteriorating veld condition were thought to be the main causes of the roan decline. The artificial waterpoints were closed in an effort to push zebra and lion off the plains and to provide more tall grass refuges for the roan. This seems to have had the desired effect as zebra numbers on the plains declined and the roan numbers stabilized.

Fig. 1. The number of active boreholes providing water for game in the KNP, illustrating the increase in boreholes from 1929 to 1985, and the decrease after closure of boreholes since 1994.

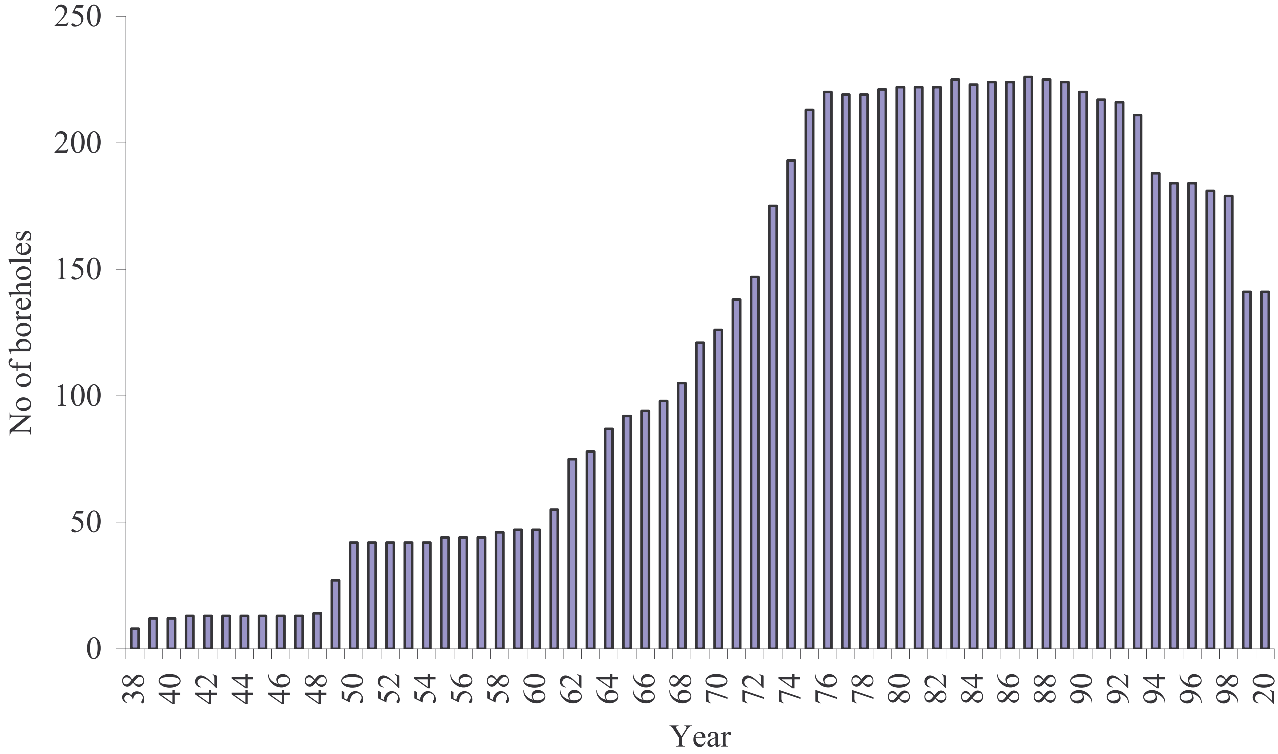
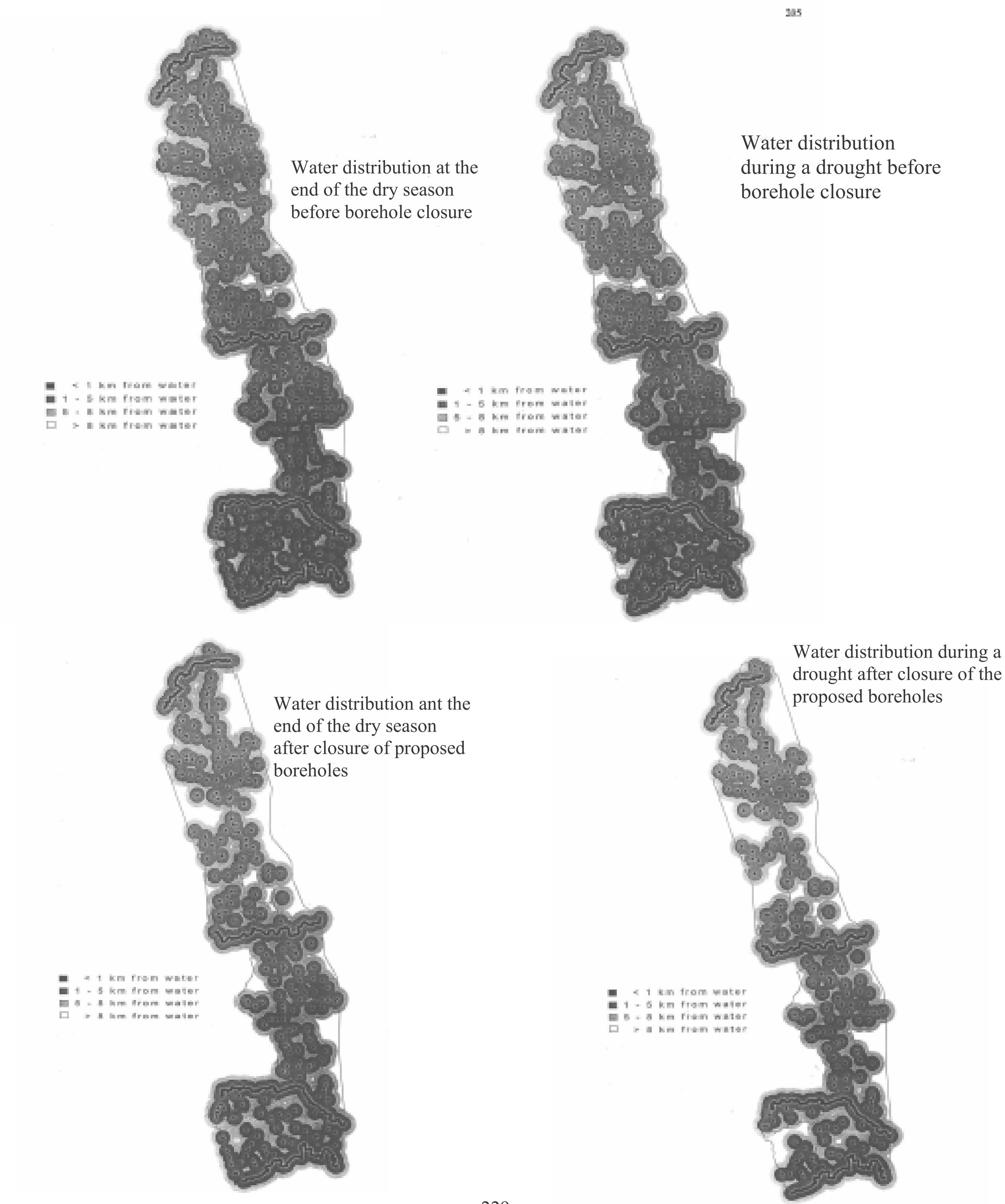


Fig 2. Temporal and spatial heterogeneity in the total water source assemblage, when all boreholes and no boreholes are included, are depicted for the dry season of dry years. A GIS was used to determine the number of dry years (out of a total of six) each 1 km x 1 km grid cell was more than 5 km from a water source. Maps produced for wet years have fewer areas that are consistently more than 5 km from a water source. The locations of these areas, however, may differ between wet and dry years because of the variability in the location of dry season, ephemeral water sources.(From Redfern et al submitted)

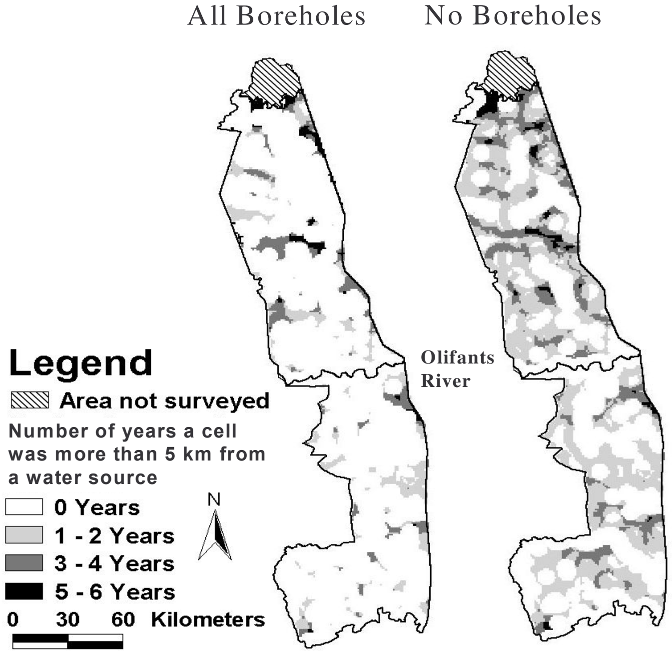


Factors determining water availability in the KNP

Oscillations in rainfall

Medium term climatic fluctuations, with approximately 8 - 10 years of generally above-average rainfall and similar spells of generally below average rainfall, were acknowledged by Stevenson-Hamilton (1938) and confirmed with more substantial data by Tyson and Dyer (1975) and Gertenbach (1980). Long term oscillations, in the order of 80 - 100 years, have also recently been suggested by Pienaar (1985).

It is important to note, however, that prior to the fencing of the KNP the animal populations had the advantage to migrate/disperse to water resources beyond the limits of the KNP - a situation that no longer exists, but whose previous scale and extent is not well understood exept for the wildebeest movements over the western boundary of the KNP before it was fenced off (Whyte, 1985).



The fencing of the KNP

With the fencing of especially the western boundary of the KNP in the early 1960's, access to large tracts of the favoured summer and winter habitats of migratory animal populations, especially wildebeest and zebra, was cut off for animals in the KNP. The winter ranges included perennial water resources such as the Sand River. The exclusion of such water resources prompted the move to provide alternative water resources along the western boundary area - in fact, such a contingency was foreseen even before the fence was erected. The provision of water alone, without the substitution of the habitats that were excluded, was not successful in saving the western boundary migratory wildebeest and zebra populations (Whyte, 1985).

The eastern boundary fence was finally completed during the high rainfall phase of the climatic cycle during the 1970's. This fence effectively cut off the migration/dispersion routes of species such as eland, elephant and others to and from Mozambique, and its effect could not be ignored in the formulation of management strategies, such as the provision of artificial water supplies.

Abuse of perennial rivers

Since the early 1920's the perennial rivers have sporadically been subjected to a series of incidents of pollution and, particularly from the mid-1940's, to increased silting and deteriorating water quality. These phenomena were intimately related to industrial and agricultural expansion, as well as to the fast growing rural populations in the Lowveld and adjoining areas. While the quality of the water in the rivers was the first to be affected, heavy silting and extraction also soon led to a progressive decrease in the quantity of water.

This led to a cessation of water flow in rivers such as the Letaba and Luvuvhu, recorded for the first time during the late 1940's. In addition to these rivers, the water flow in the Crocodile and Sand rivers also stopped during the protracted drought of the 1960's. The drought of 1992 accentuated the seriousness of the situation when both the Luvuvhu and Letaba rivers stopped flowing for longer than 10 months. The base flow of the Sabie, Olifants and Crocodile rivers were only maintained through negotiations with neighbours in catchment areas, resulting in restrictions on abstraction (often voluntary) on releases from dams.

Other considerations for the provision of additional water resources

Other than water availability from currently recognized water sources, a number of motivations through the years have prompted the provision of additional water supplies. Importantly, these reflected the desire to obtain a more even utilization of the available grazing. Concomitantly, this was also intended to increase the numbers of animals. An additional motivation was to provide water as an attraction to animals for the benefit of tourists. An increase in the numbers of highly gregarious large mammals, specifically buffalo and elephant, provided the incentive for the construction of large earthen and concrete dams. Dams of this nature were seen to fulfil a triple purpose: to relieve the perennial rivers of excessive grazing pressure during the dry (winter) season, to avert competition between species by providing sufficient opportunity for spatial separation on long water frontages, and to provide additional refuges for endangered forms of aquatic life away from the rapidly drying perennial rivers.

Since none of these latter considerations are ecologically sound and therefore not in line with present KNP philosophies which strive to simulate natural fluxes, they no longer represent adequate motivation for the provision of artificial water (except for the possible justification as a refuge away from the rapidly drying perennial rivers).

Proposed new water policy

Principles involved in the water distribution programme

Only in the case where the water provision programme was instituted as a contingency measure to counter the disruptions caused by the erection of the boundary fences, or in the case of weirs in the perennial rivers where the quality and quantity of the water had deteriorated through unnatural interferences, such action may be based on the principle of the preservation of diversity. In these cases certain reservations may, however, be raised. Where water provision was intended to counter the effects of the fencing of the boundaries and the exclusion of traditional water resources, the principle would hold good for the more sedentary species which occupied habitats within the KNP and were excluded from the water resources. However, in the case of species which were dependent on habitats beyond the KNP boundaries, in addition to the water resources, the provision of only one of a number of habitat features could hardly be expected to provide a suitable solution. This has been sufficiently illustrated with the dramatic decline in the migratory wildebeest and zebra populations along the western boundary of the Central District. It is reasonable to accept that, to a large extent, the declines were in relation to the loss of habitat beyond the KNP boundaries (Whyte, 1985).

However, the situation should also be seen in its broader perspectives. It has been recorded (Stevenson-Hamilton, 1913) that during times of severe drought all the known water resources along the western boundary between the Olifants and Sabie rivers dried up. Under these circumstances the animal populations either had to disperse to areas where water was still available within the KNP or to the more perennial resources in the foothills of the Drakensberg.

In the past the construction of weirs in the perennial rivers was merely considered a "holding action" to provide refuges for the aquatic life and hippo populations as relief from the depletion of the natural flow of water in the rivers. There is, however, evidence from other similar projects that such artificial structures could have a detrimental effect on various aspects of the aquatic ecosystems.

The principles related to the provision of artificial water can be summarized as follows:

i) It is accepted that the availability of surface water resources other than perennial rivers in the KNP are primarily dependent on the annual, medium and long term rainfall cycles.

ii) Due to the fluctuating nature and intensity of rainfall, both in terms of medium and longer term cycles, it is also accepted that the surface water resources will fluctuate accordingly and that such fluctuations have played a decisive role in moulding the intricacies of the Lowveld ecosystems.

iii) It is also accepted that the KNP has been restricted in its entirely natural development by spatial and other unnatural limitations (boundary fences etc.) although the extent of this has not been accurately assessed.

iv) As far as flow and quality of water in the perennial rivers flowing through the KNP are concerned, it is accepted that the KNP rivers are largely dependant on what happens in the catchments outside the KNP and that very few managerial measures inside the KNP can be taken to effectively conserve these systems. Constant and active contact with water users and managers outside the KNP should therefore be sought by the KNP to negotiate the maintenance of flow and quality, until appropriate legislative measures have been implemented.

Effect of the closure of the identified artificial waterpoints

In order to gauge the influence of water distribution in the KNP it was decided to draw buffer areas of 1 km, 5 km and 8 km around each waterpoint and calculate the percentage area of the KNP that is within 1 km of water, within 1 - 5 km of water, within 5 - 8 km and further than 8 km from water. This was calculated for before and after waterpoint closure and during normal and drought years.

The dams in the KNP were classified as being permanent (lasting through droughts), almost permanent (drying up in drought years) and seasonal (drying up annually at end of winter). During drought years the only water in the KNP was taken to exists as the boreholes, perennial rivers and permanent dams. For the normal years with avarage rainfall, the almost permanent dams were added. No waterholes in seasonal rivers were used in this exercise except for the ones in the Nsikazi and Phabeni Rivers on the south-western boundary. Thus Table 1 show the absolute **minimum** water that there could possibly occur under the four scenarios as there usually are some waterholes in seasonal rivers during normal years and even during droughts, a few waterholes will remain.

The relatively small difference in water availability during normal and drought years (Table 1), is because pools in seasonal rivers were not taken in consideration. This would increase the water distribution especially during normal years.

Before the borehole closure 82,5% of the area in the KNP is within 5 km from water and this changes to 80,6% during droughts (Table 1). During drought years only 4% of the area of the KNP is further than 8 km from water.

After the identified boreholes have been closed the area closer than 5 km from water changes to 67,6% during normal years and 62,9% during droughts (Table 1). During drought years the areas further than 8 km from water increase to 14%.

Daily journeys of up to 5 km to water seem typical for medium-sized ungulates such as wildebeest and zebra, although elephant and buffalo are capable of travelling somewhat further (Young 1970). For this reason areas closer than 5 km from permanent water are seen as dry season concentration zones, while areas further than 5 km from permanent water are seen as wet season dispersal areas. Owen-Smith (1996) suggests a 2:1 ratio of wet season/dry season range for extensive conservation areas.

As can be seen from Table 2 even in drought conditions after the suggested boreholes have been closed, the wet season range (further than 5km from water) is still smaller than the dry season range (37,2% : 62,8%). The elongated shape of the KNP and the large number of major perennial and seasonal rivers that dissect it, precludes the reaching of a 2:1 ratio of wet season/dry season range as proposed by Owen-Smith (1992). It is suggested that for the KNP one should strive for a 1:1 wet season/dry season range during drought conditions. This should ensure an adequate food reserve during drought times.

During droughts in areas with a dense, evenly spaced waterpoint distribution all grass reserves become depleted and population crashes of high density species such as buffalo can occur.

Between 1994 and 1998 200 of the 300 boreholes for animal use, have been closed according to this policy. A research programme is in place to study the effects of the closure of the boreholes and results of this study will be reported on in the scientific literature and at congresses. The distribution of open and closed boreholes can be seen in the following figure.

Open and closed boreholes in the KNP

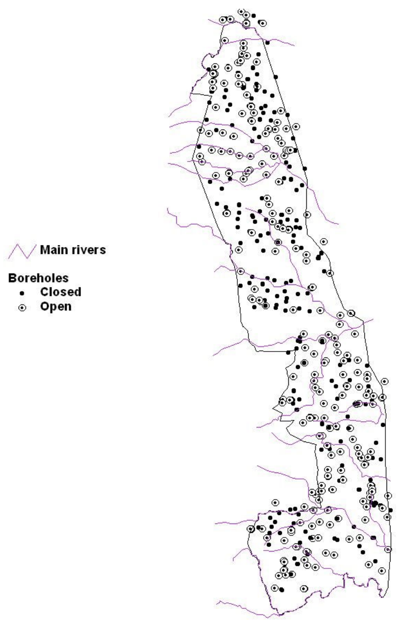


Table 1.The effect of borehole closure on the % area of the KNP at different distances from water.

Water distribution at end of dry season	**Dry season range**		**Wet season range**	
	< 1 km	**1 - 5 km**	**5 - 8 km**	**> 8 km**
Before borehole closure - during **normal** year	9,5%	73%	14,2%	3,4%
Before borehole closure - during **drought** year	9%	71,6%	15,5%	4%
After borehole closure - during **normal** year	7,1%	60,5%	22,1%	10,3%
After borehole closure - during **drought** year	6,6%	56,3%	23,2%	14%

Biodiversity consequences

Experience on the northern basalt plains in the KNP has shown that an even distribution of waterpoints can pose a threat to biodiversity. The more common water-dependant species such as zebra and buffalo may increase at the expense of rare species such as roan antelope. It has also been suggested that the lion population in the KNP has increased considerably, owning to the year-round availability of prey near permanent waterpoints (Smuts 1978). The rare ungulate species may thus be adversely affected by changed habitat conditions and/or predation pressure.

Management implications

It is suggested that more boreholes need to be identified for closure so that dry and wet season ranges are at least equal in size. A suggested area for the closure of more boreholes is along the western boundary between the Sabie and Olifants Rivers. These boreholes were sunk to provide water for the game when the western boundary fence was erected which cut the game off from their traditional dry season watering places. This fence has now been removed and game can again move westwards during winter and thus nullifying the need for boreholes here. It is imperative that a monitoring and modelling programme to identify and assess the consequences of the proposed water distribution policy should be implemented at the same time.

Where boreholes that are tourist viewing sites are designated for closure, confrontation could possibly be offset by providing additional tourist roads to existing boreholes in the vicinity and by launching a public relations campaign to inform the public of the reasons for the closure of certain boreholes and to point out the benefits that this could have for tourist viewing. Another possibility is to reduce the size of the drinking trough so that the borehole can only support a few individual animals but does not amplify large game concentrations.

ELEPHANT DISTRIBUTION RELATIVE TO ARTIFICIAL AND NATURAL WATER SOURCES

IZAK P.J. SMIT

Introduction

Various management options, including closing of artificial surface water sources, have been proposed to control the increasing elephant population of the Kruger National Park. However, no landscape-scale study has been conducted in the park to establish if elephants do indeed aggregate around theses artificial water sources that can be manipulated easily.

Methodology

I analysed part of the KNP aerial census data set (1987-1993) of dry season distribution of elephants in a Geographical Information System (GIS), comparing the observed spatial association that existed between elephants and water sources with association patterns expected under random conditions. Specifically, I compared the association patterns of elephants:

- around natural and artificial water sources (i.e. main rivers *vs* artificial waterholes),
- between mixed herds and bull groups, and
- on areas of high and low forage quality (i.e. basaltic *vs* granitic soils).

Results

- It was found that, in general, elephants aggregate around rivers, but not around artificial waterholes.
- Bull groups displayed a more even distribution with regard to surface water than mixed herds.
- Aggregation is more pronounced around rivers on the nutrient-rich basaltic soils than on the nutrient-poor granitic soils.

Discussion

- Not only the availability of surface water, but also the context of the water source, is important for elephants. Rivers, floodplains and the ecotones and sodic sites associated with these provide nutritional and habitat benefits that are not always found in the vicinity of artificial waterholes.
- Bulls are more evenly distributed with regard to surface water sources than mixed groups. This is consistent with previous work done in Africa and is probably due to differences in the nutritional requirements, avoidance of aggression and the increased mobility of bull groups compared to mixed herds.
- Aggregation is more pronounced around rivers on the basalts than on the granites, maybe due to the difference in nutritional quality that exists between the two geologies, with elephants having to travel further from their drinking resources to satisfy their feeding requirements on the nutrient-poor granitic soils.

Management implications

Considering that elephants are a very mobile species, that natural surface water is usually abundant in Kruger and that, except (weakly) for bulls on the granites, I did not detect aggregation around waterholes, I conclude that it is unlikely that changes in the spacing and density of waterholes in the park will dramatically influence elephant population growth.

Managers should therefore not rely on waterhole closure to reduce the numbers of elephants in Kruger. Instead, large-scale waterhole closure may compromise non-target species.

Reliability

The data suggests quite clearly that elephants prefer to aggregate around rivers, but rather surprisingly, not around artificial waterholes. However, it is important to be aware of the parameters and limitations underlying the data set and analysis:

- The data set represents (i) *seven snap-shots* of (ii) *day time* distribution of elephants in the (iii) *dry season*.
- Analysis is scale dependent. I followed a landscape-scale approach, and different findings may result if the analysis is repeated using different spatio-temporal scales.
- Ephemeral water sources and natural pans/dams were not included in the analysis, since the reliability and locations of these water sources were poorly documented. However, these water sources will probably also play a role in elephant distribution.
- *Main* rivers were defined as perennial rivers and large seasonal rivers which have reliable pools in the dry season. However, if *main* rivers were defined differently, slightly different outcomes might result.
- Even though elephants do not seem to aggregate around waterholes during day time in the dry months, it does not mean that waterholes are not at all important for elephant survival. For example, waterholes may be an important resource for elephants when they travel across vast areas that would have been waterless otherwise.

Biodiversity consequences

Elephants seem to aggregate more around the main rivers than around waterholes and therefore elephant-induced biodiversity changes, positive or negative, may be more pronounced closer to the rivers than the waterholes. Furthermore, surface water manipulation should never be seen as a tool to exclusively manage elephants. Conservation managers should always consider other species that may also react to waterhole closure before a water provision policy is drafted or reviewed. It is possible that non-target species like zebra and wildebeest, as well as the rare grazers (roan, tsessebe, sable) may react to large-scale waterhole closure before the elephant population is suppressed.

Future research

Future research should investigate the association patterns of elephants on other spatio-temporal scales than the scales employed here, *inter alia* including data from the wet season.

Conclusions

Elephants do not aggregate around waterholes in day time during the winter months, but prefer to occur in close proximity of the main rivers of the KNP. Bull groups seem to be more evenly spaced with regard to water sources than mixed herds. These findings, together with the fact that elephants are a mobile species, suggest that large-scale waterhole closure may not be a very effective management option for suppressing Kruger's elephant population.

Key publication

STOKKE, S., J.T. DU TOIT. 2002. Sexual segregation in habitat use by elephants in Chobe National Park, Botswana. *African Journal of Ecology* 40(4): 360-371.

DISTRIBUTION OF ELEPHANT IMPACTS ON RIPARIAN WOODY VEGETATION IN RELATION TO SURFACE WATER DISTRIBUTION

ANGELA GAYLARD

Introduction

There is a concern that increasing numbers of elephants in KNP will adversely affect the vegetation of the KNP through the impacts of their feeding. However, elephants do not feed homogeneously across the landscape and the biodiversity consequences of their impacts may therefore be localised. In order to improve our understanding of how elephants influence the diversity of savanna landscapes, we therefore need to understand the spatial components of elephant feeding and how these change over time.

Methodology

I investigated elephant feeding behaviour in relation to surface water distribution by means of:

- behavioural observations (through radiotracking and following of feeding trails)
- vegetation surveys (at varying distances from surface water with different degrees of isolation from other water)

Specifically, I focused on elephant feeding in the riparian zones of ephemeral rivers in northern KNP in order to minimise the influence of fire on the existing vegetation composition and structure, without necessitating an exclosure study. In addition, seasonal rivers contain varying amounts of surface water at different times of the year, and riparian zones contain aesthetically important woody species of concern to management.

Results

- In the riparian zone, elephants of both genders preferred to feed near surface water. This spatial pattern of elephant feeding was consistent throughout the year, but became more pronounced as conditions became drier.
- The intensity and spatial distribution of elephant impacts on riparian woody vegetation was influenced by the particular spatial distribution of riparian surface water. Elephant impacts were moderate, but homogeneous across the riparian landscape, in areas where waterholes were closely-spaced (max distance between waterholes = ca. 2km). In contrast, elephant impacts were more intense, but patchy, in those areas of the riparian landscape where waterholes were further apart (max. distance between waterholes = 7km).
- The importance of the proximity to, and density of, surface water as a factor determining elephant impacts on riparian woody vegetation varied over time. These surface water distribution attributes were important determinants of elephant impact primarily during below average rainfall years.

Discussion

- Since riparian zones represent not only a source of water, but also an important source of evergreen vegetation for browsers, elephants are possibly minimizing their energy expenditure by acquiring forage and drinking water in close proximity to one another throughout the year. This is despite the fact that elephants in KNP do not appear to be particularly water-stressed, with the abundance of water in KNP leaving few areas further than 5 km from surface water. An advantage of using vegetation surveys to investigate patterns of elephant feeding is that it incorporates nocturnal feeding which cannot be assessed by means of aerial surveys.

- At the landscape level, a primary determinant of the spatial heterogeneity of elephant impacts on riparian woody species is the spatial arrangement of surface water. Water provisioning policies may reduce the distances between surface water, producing homogeneously distributed elephant impacts across the riparian landscape. In contrast, patchily distributed elephant impacts are produced in riparian landscapes that have greater distances between water sources. This is despite the fact that even the greatest distances between surface water in the far northern region can easily be covered by elephants during their daily search for food and water. Spatially patchy elephant impacts possibly provide areas of the landscape that act as refuges for impact intolerant species.
- Temporal heterogeneity in elephant impacts on riparian woody species is provided by a change in the importance of proximity to, and density of, surface water over time which appears to be related to rainfall. This potentially represents refuges from elephant impact in time for impact-intolerant species.

Implication for management/decision-making

The presence of surface water plays an important role in focusing elephant impacts in particular parts of the landscape, despite the fact that surface water is relatively abundant in KNP. In addition, despite the relatively short distances (for elephants) between the most isolated surface water in this area, the spatial arrangement of surface water determines the patchiness of elephant impacts on riparian trees. I therefore predict that further closure of boreholes will:

- restore the natural spatial and temporal variability of surface water distribution, thereby
- restoring the natural spatial and temporal heterogeneity of elephant impact distribution
- this heterogeneity of impacts potentially provides spatial and temporal refuges for impact-intolerant species, thereby mitigating against the adverse consequences of elephant impacts for biodiversity

An important implication of this study is that it also represents an alternative means of decision-making regarding elephant management. The coalescing of piospheres (zones of impact around waterpoints) represents homogenisation of elephant impacts across the landscape. Homogenisation of elephant impacts is an undesirable biodiversity consequence of surface water that is closely-spaced. However, piospheres may also begin to coalesce in landscapes with more isolated water if increased elephant densities force elephants to feed further and further away from water as the vegetation adjacent to water sources is decimated. Monitoring the coalescing of piospheres (rather than the traditional monitoring of elephant numbers) therefore represents an alternative decision-making tool that is in keeping with the paradigm shift away from a species-focus towards managing ecosystem processes for biodiversity. In other words, rather than trying to find a "carrying capacity" for elephants in such a variable environment, monitoring the spread of elephant impacts may provide a better "signal" for determining when elephant populations may have to be reduced to maintain biodiversity.

Reliability

Although perhaps surprising in an environment with so much natural and artificial water, the data from this study demonstrate unequivocally that surface water distribution still plays an important role in focusing elephant impacts in particular parts of the landscape, as well as in determining the intensity of these impacts in different parts of the landscape. This therefore represents established fact.

These results refer specifically to impacts on woody vegetation in the riparian zones of seasonal rivers. However, there is no reason to believe that the pattern should be different in the upland savanna, unless the effect of fire (which is negligible in riparian zones) exacerbates elephant impacts on trees in this area. Extrapolation of these results outside of the riparian zone therefore requires further investigation.

The coalescing of piospheres around closely-spaced water has also been demonstrated unequivocally by the results of this study, and therefore represents established fact. However, it has not yet been established whether piospheres also coalesce in landscapes with isolated water when elephant numbers increase. This therefore represents important and interesting conjecture that requires further investigation before it can be used as an alternative decision-making tool for elephant management.

Biodiversity consequences

The results of this study suggest that reducing surface water distribution through closure of artificial sources of water may:

- reduce the local compositional and structural diversity of riparian trees in the vicinity of isolated riparian surface waterpoints, BUT
- increase the landscape-level compositional and structural diversity of riparian trees by providing refuges for impact-intolerant species in the patches between intact (non-coalescing) piospheres

Future research

Future research should focus on:

- whether the patterns found in the riparian zone are repeatable in the upland savanna;
- whether piospheres around isolated waterholes begin to coalesce when elephant densities increase; and
- spatially-explicit computer models should test various elephant density and surface water distribution scenarios to explore which combinations of elephant numbers and surface water distribution result in the highest plant diversity (over multiple spatial scales simultaneously)

Conclusions

Surface water distribution plays an important role in focusing elephant impacts of varying intensities in particular parts of the landscape. This results in piospheres (zones of impact) which coalesce between closely-spaced waterpoints, but remain intact between more isolated waterpoints. Coalescing of piospheres represents homogenisation of elephant impacts at the landscape level, which is undesirable for ecosystem management. Increased elephant numbers are predicted to cause a similar coalescing of piospheres even in landscapes with isolated waterpoints. Monitoring of the coalescing of piospheres is therefore recommended as an alternative to carrying capacity as a decision-making tool for reducing elephant populations in order to maintain biodiversity.

Key publications

WALKER, B. H., R. H. EMSLIE, R. N. OWEN-SMITH, AND R. J. SCHOLES. 1987. To cull or not to cull: lessons from a southern African drought. Journal of Applied Ecology 24: 381-401.

OWEN-SMITH, R.N. 1996. Ecological guidelines for waterpoints in extensive protected areas. *S. Afr. J. Wildl. Res.* 26:107-112.

THE ROLE OF WATER PROVISION ON ELEPHANT EFFECTS ON VEGETATION

NORMAN OWEN-SMITH

Water is a crucial factor governing the local distribution of elephants, and hence their impact on vegetation components and biodiversity. The threatened tree species prevalently grow in uplands, where surface water generally does not persist much beyond the rainy season. The provision of artificial water sources in such uplands can constitute a major threat to vulnerable tree species, particularly through attracting bull elephants into such regions during the dry season when most damage to trees occurs. I have in mind particularly the Satara region, and notably the waterpoints established along the pipeline bringing water from the Olifants River to Satara camp.

Trees growing in bottomland regions and along riparian corridors seem less threatened, perhaps because they have deep roots accessing the water table. An extreme example is the lack of severe elephant damage to acacia trees growing along dry rivers traversing the Kunene region of Namibia.

The extent of Kruger Park seems too narrow to preclude elephants from occupying most parts at least seasonally, even if all artificial waterpoints were to be closed. Nevertheless, the local distribution of elephants and their impacts could be manipulated by closing those waterpoints that draw them into proximity with threatened tree species or vegetation components at the times of the year when these plants are most vulnerable. This would locally reduce the threat to tree regeneration.

Piospheres are a source of concern mostly around point water sources, notably Aruba Dam in Tsavo. Impacts linearly spread along perennial or seasonal rivers do not seem of much concern.

WATER, VEGETATION AND ELEPHANT IMPACT: RESULTS FROM PRIVATE NATURE RESERVES ADJACENT TO THE KNP

MIKE PEEL & RINA GRANT

Draft document – Elephant workshop SANPARKS 15-17 March 2005.[1]Agricultural

Introduction

The living requirements of wild animals include food, water and cover. Large herbivores are limited by the amount of nutrients and forage available to them. In addition to this, herbivore species differ in their dependence on surface water. The spatial and temporal distribution of water therefore plays a major role in determining the distribution of herbivores and by extension their impact on the soils and vegetation.

Goodman (1982) divides herbivores into three classes relating to their dependence on water. The first group includes species that have fairly small home ranges, are dependent on surface drinking water, and whose densities drop off significantly at around 5km from water. These are termed non-mobile water dependent species (5km), then there are mobile water dependent species (10km) and finally relatively water independent species (may be independent of surface water for relatively long periods).

The sub-division of land and the fencing off of conservation areas in the savannas of the north-eastern Lowveld of South Africa began in the late 1960's. This broke the natural east-west herbivore migration and, because many of the fenced off areas did not have perennial water, artificial water points had to be constructed. The result was

a network of artificial water points in the Lowveld supplying excessive surface water in these areas. In the Klaserie Private Nature Reserve (KPNR), Zambatis (1980) recommended that water points (excluding the Klaserie and Olifants Rivers and natural pools) should be spaced at a minimum of 3km apart (and preferably 5km).

This is equivalent to one water-point per 1 000ha and one water-point per 2 200ha respectively). In recent studies in the Private Nature reserves adjacent to the KNP the mean density of water points varied from one per 270ha (Umbabat Private Nature Reserve - UPNR) to 1 per 710ha (Sabi Sand Wildtuin - SSW). Such an over supply of water has led to an eruption of relatively water dependent herbivore species such as impala, wildebeest and zebra around such water points, the higher concentrations of animals resulting in increased grazing, trampling, dunging and urination which in turn affects water infiltration, run-off, grass cover, species composition, the tree: grass ratio, and ultimately carrying capacity and biodiversity.

Many artificial water points therefore may have a negative impact in terms of resource degradation that is directly related to increased animal activities (Owen-Smith, 1996; Thrash, Nel, Theron & du P. Bothma, 1991; Thrash & Derry, 1999; Brits, van Rooyen & van Rooyen, 2000).

The mean distance that elephant may walk per day in the summer in the Kruger National Park (KNP) is 17.5km and in the winter 8.4km (Young 1970). This indicates that there is a surplus of water available for elephants in the private nature reserves adjacent to the KNP (SSW, Manyeleti Game Reserve (MGR), TPNR, UPNR and KPNR).

Savanna systems are characterised by a structure that can best be described as a wooded grassland where the woody vegetation comprises mature trees and shrubs and where the herbaceous (or non-woody) layer is dominated by perennial grasses.

A comparison of the 1944 and 1986 aerial photographs of the Lowveld exhibit a pattern of increasing woody plant density over extensive areas (Appendix A). In the SSW anthropogenic impacts were highlighted by Tinley (1979) who described the underlying causes of so-called ‘bush-encroachment’.

The resulting management approach that was adopted in many areas was to clear selected areas of trees and shrubs. Large tracts of the Lowveld adjacent to the KNP have thus been cleared/thinned over the past 20-25 years using a variety of chemical and mechanical methods.

The encouraging consolidation of properties in the Lowveld has facilitated the movement of elephant back into the reserves to the west of the KNP thus extending the range of elephant in the region once again. With the removal of the fence between the KNP and the adjacent Private Nature Reserves in 1993 there was a dramatic increase in the number of elephant in the area, particularly in the SSW.

Large herbivores such as elephant generally dominate in terms of biomass in savanna areas. Owen-Smith (1992) states that their nutritional requirements therefore have a greater impact on vegetation than other species in the community. In addition they have an additional impact through trampling and breakage. The consequences of such utilisation vary depending on the species selected, the levels of damage inflicted, season of impact, elephant densities, period of the impact, and the effect of the interaction with other factors such as rainfall, soil, fire, other herbivores, the provision of artificial water and bush control. Within the constraints of time and money, it is therefore important to quantify the impact of elephant on the natural resource base.

In addition to the fact that elephant enhance the tourism potential of ‘Big Five’ reserves, they are also essential role players in the ecological functioning of savanna ecosystems. This is illustrated by a few examples:

1. Elephant have the ability to have a large impact on vegetation by opening up densely wooded areas. This may have positive and negative spin-offs. Positive impacts are such that there is an improved tree:grass ratio thus improving conditions for grazers. A more competitive grass layer will also facilitate the use of fire once again (thus reducing the need for bush control programmes). Elephant may also reduce the woody layer to a height class that is accessible to browsers feeding at lower levels. On the other hand, as mentioned above, elephant may open areas (destroy trees) to such an extent that other browser species are placed at a disadvantage. The continued existence in certain areas of uncommon species may also be threatened;
2. Elephant play an important role in the dispersal of seed, the dung forming an ideal germination medium for seeds that escape mastication and then pass undigested through the elephants alimentary canal (Hanks 1979); and
3. At times they provide water for other species by digging holes in the sand. In addition to this when they paddle in clay depressions they compact the soil and thus trap rainfall.

So while the expansion of range by the elephant from the KNP is natural, under present conditions, with a no-cull policy in the KNP, there is a concern that there is overutilisation of habitat within adjacent private nature reserves.

Methods

The study area

The study area falls entirely into the Savanna Biome of the eastern Lowveld (Acocks (1988) and Low & Rebelo (1996)). This area is dominated by ancient granitoid rocks of Swazian and Randian age, which are grouped together as Basement complex such as gneiss and granite (Venter, 1990). Timbavati Gabbro (Intrusive Rocks) interrupts the Basement complex and shows at the surface as intermittent sills and dykes (Venter, 1990). Figure 1 shows the position of the study area and the distribution of the ecological monitoring sites.

Elephant numbers

Elephant numbers for the SSW, MGR, TPNR, UPNR and KPNR were obtained from the annual aerial game counts done in these areas by staff members of the reserves, the Range and Forage Institute and South African National Parks (awaiting outstanding data for MGR).

Elephant impact assessment

The following describes the elephant impact assessment that forms part of an ongoing vegetation-monitoring programme. The following parameters are measured:

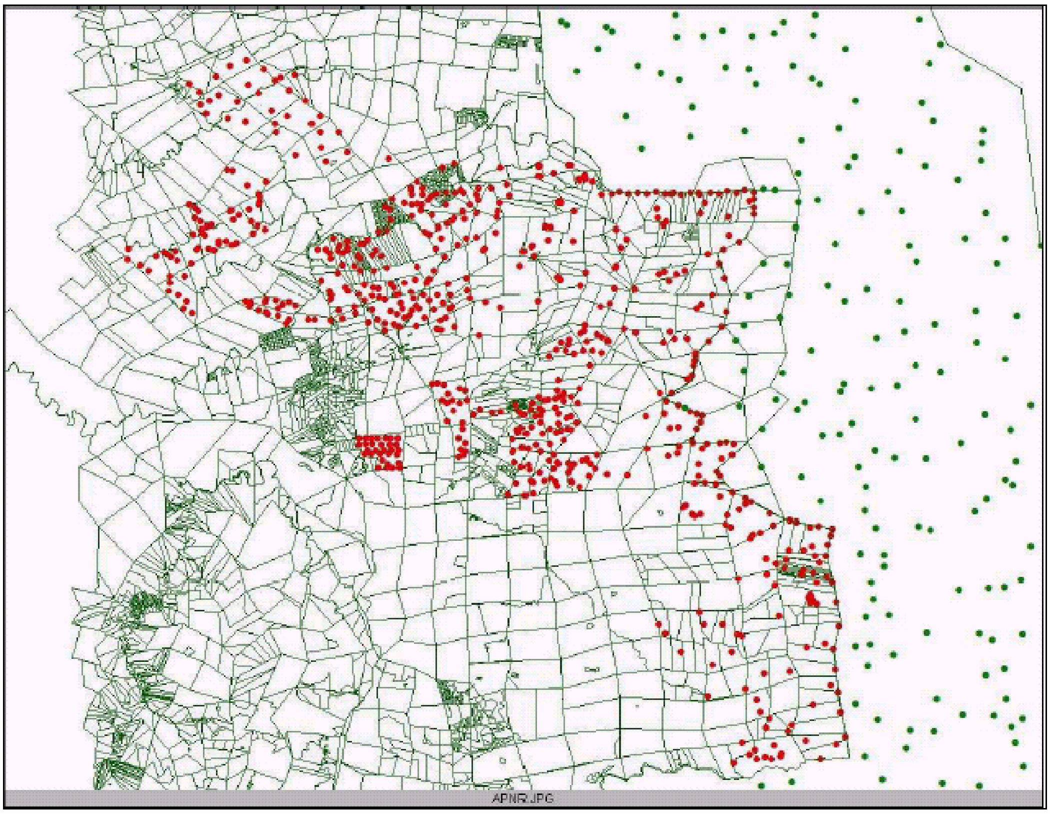
1. Damage severity on an eight point scale where 0=no damage; 1=1-10%; 2=11-25%; 3=26-50%; 4=51-75%; 5=76-90%; 6=91-99%; and 7=100%;

2. Proportion of damage measured per species surveyed (e.g. % of *Combretumapiculatum* trees measured which were impacted upon);

3. Relative impact on a species basis (e.g. *Combretum apiculatum* trees impacted upon as a % of all trees impacted upon); and

4. Damage per height class.

Figure 1 The study area Red dots (private nature reserve ecological monitoring sites), green dots (KNP ecological monitoring sites).



The above should be looked at in the context of Threshold's of Potential Concern (TPC) the philosophy of which requires that a particular form of management will continue until it becomes clear that a certain variable (in this case elephant density) is negatively impacting on an important ecological indicator (in this case the vegetation).

Water point distributions were obtained from staff members of the reserves, SSW (Jonathan Swart), TPNR (Scott Ronaldson – from aerial survey), UPNR (Scott Ronaldson – from aerial survey), KPNR (Colin Rowles) and MGR (Heath and Ilonka Cronje).

RESULTS AND DISCUSSION

Elephant Density

With the removal of the fence between the KNP there has been a general increase in elephant densities in the adjacent private nature reserves. This increase has been most dramatic in the SSW (Figure 2 top). In the MGR, TPNR and KPNR the trend is also positive (Figure 2 second, third and fifth graphs). In the UPNR the trend after increasing in the 1990's has declined in recent years (Figure 2 fourth graph).

Damage Severity

We have isolated two of the impact categories, viz. zero damage and percent tree mortality related to rainfall and grass standing crop.

Consider:

Rainfall is associated with grass production of which grass standing crop is a function.

The SSW data show that the 2002/03 drought resulted in a poor grass standing crop (Figure 3 top and bottom), a decline in the percentage of trees **not** impacted on by elephant (Figure 3 top) and an **increase** in tree mortality (Figure 3 bottom). The 1997/98 drought does not reflect large declines in grass standing crop although there appears to have been a slight increase in mortality (Figure 3). This may be due to the excellent 1995/96 rainfall season (MAR 944mm SSW) despite a dry 1996/97 rainfall season. This illustrates the effect extreme events in this case, the wet 1995/96 season having sustained the grass sward for more than one season.

Figure 2 elephant densities in the private nature reserves adjacent to the KNP.

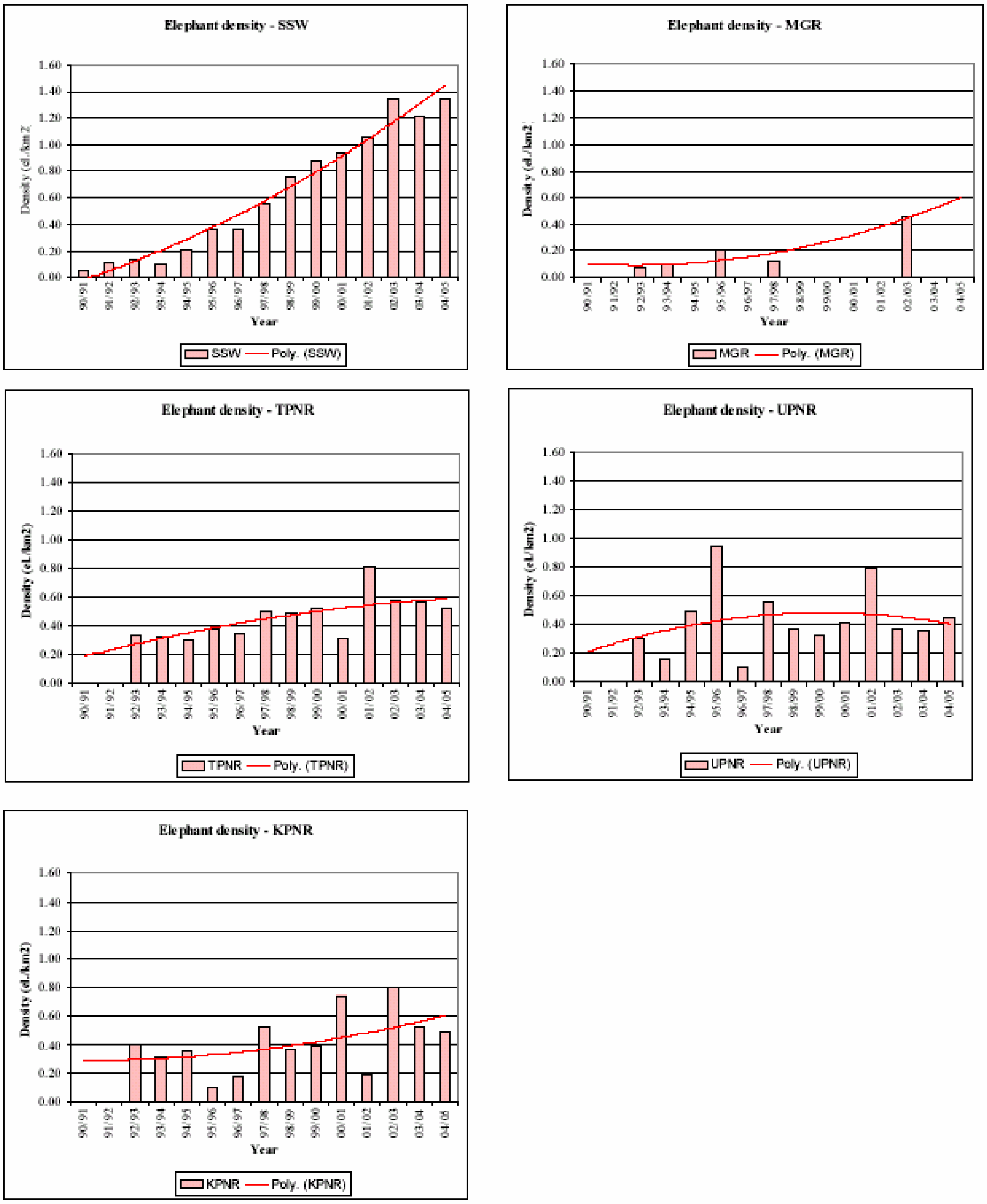
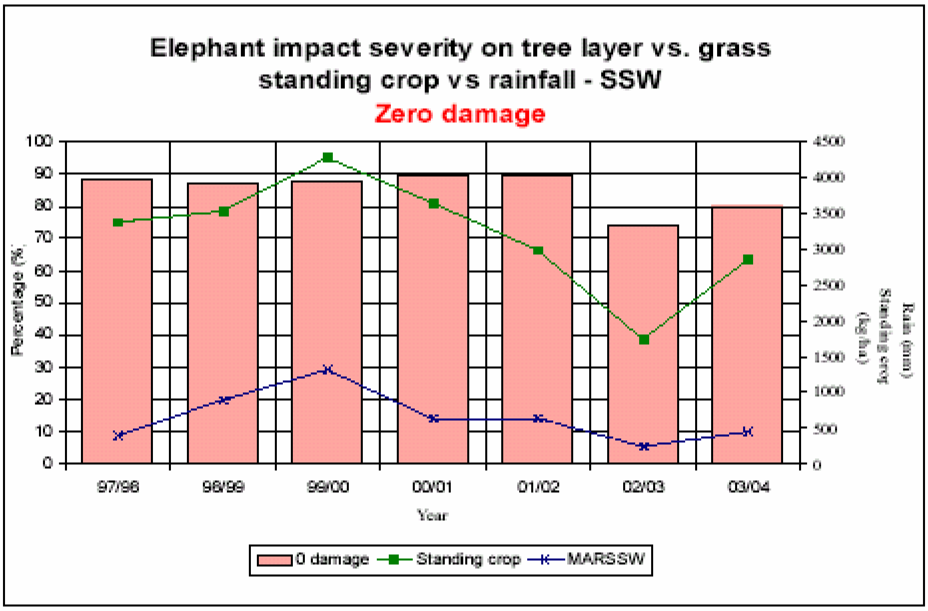
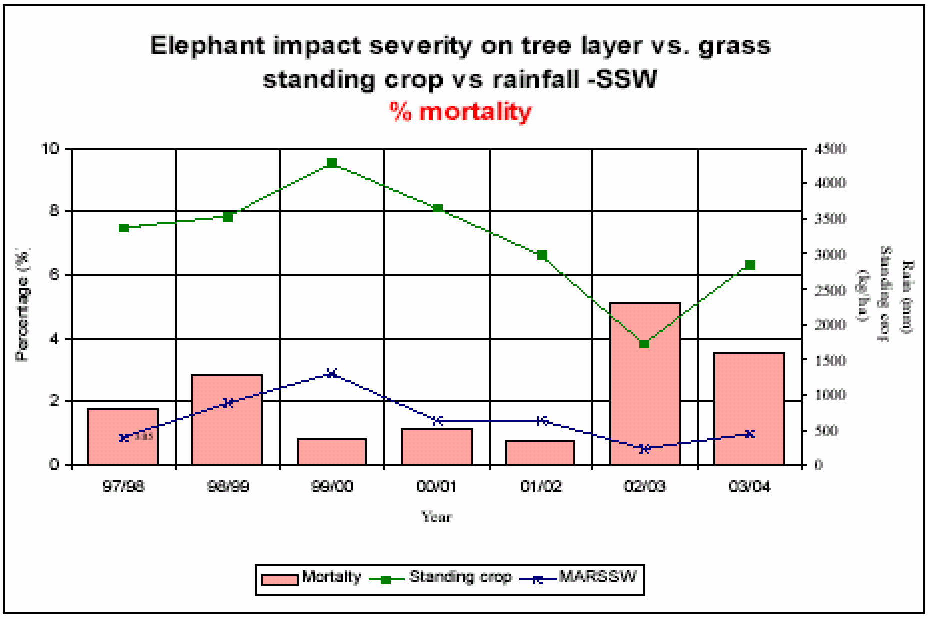


Figure 3 Elephant impact severity vs. grass standing crop vs. rainfall (SSW top – no damage bottom -mortality).





In addition to this the elephant density was at this stage still relatively low (Figure 2). The same pattern of declining grass crop and higher tree impact may be inferred for the TUPNR and KPNR (although the data sequence is too short to make conclusive statements and the elephant density increases were not as steep) (Figure 4).

Elephant impact per height class

It is important that the structure of the vegetation not be homogenised (dominated by a single height class).

Consider:

It is apparent that elephant are targeting the taller height classes in all of the reserves for which results are presented (Figure 5). What is the effect of physiognomic homogenisation of vegetation on ecosystem function and ultimately biodiversity?

Canopy cover

Are elephant having an impact on ecosystem function and biodiversity by reducing the proportion of canopy cover that is important in determining the occurrence of shade-loving, productive palatable perennial grass species?

Consider:

There appears to have been a decline/reduction in the tree canopy cover for all the reserves (Figure 6) – what is the role of elephant in this regard? In the theme of Thresholds of Potential Concern, we may aim to set a minimum limit for canopy cover (e.g. never lower than X% of its highest ever value and never higher than Y% its lowest ever value for a given area).

Figure 4 Elephant impact severity vs. grass standing crop vs. rainfall (TUPNR/KPNR top - no damage bottom -mortality).

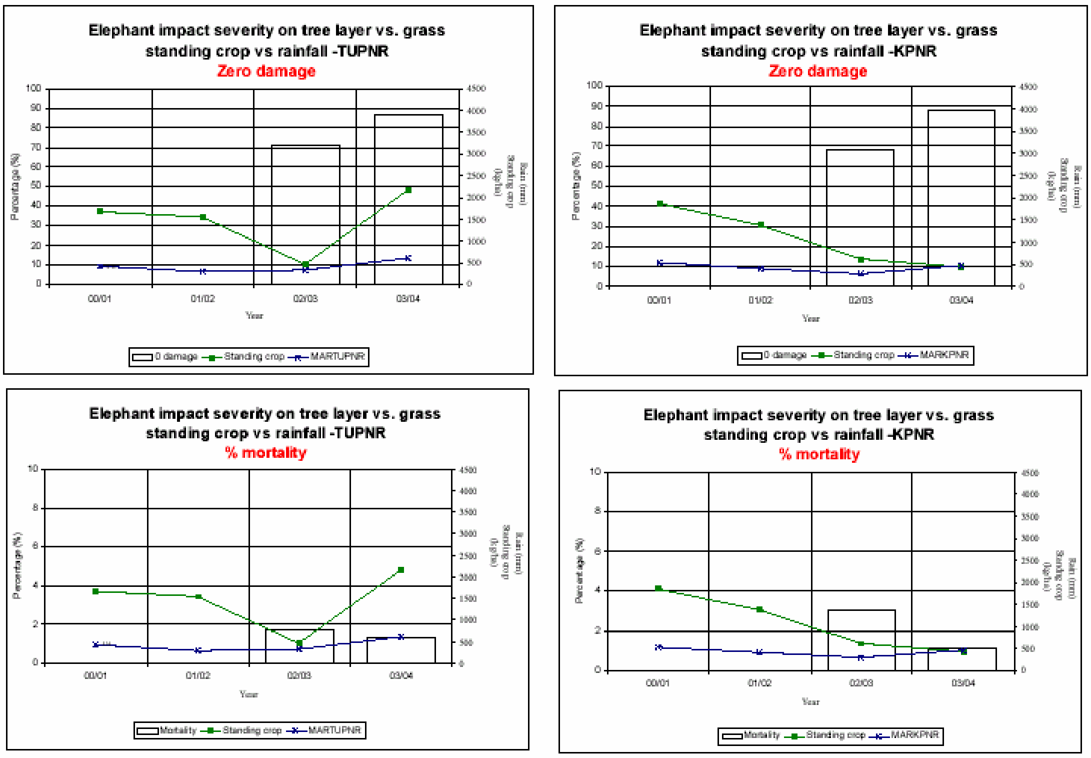


Figure 5 Elephant impact per height class for 5 private nature reserves (TPNR and UPNR combined).

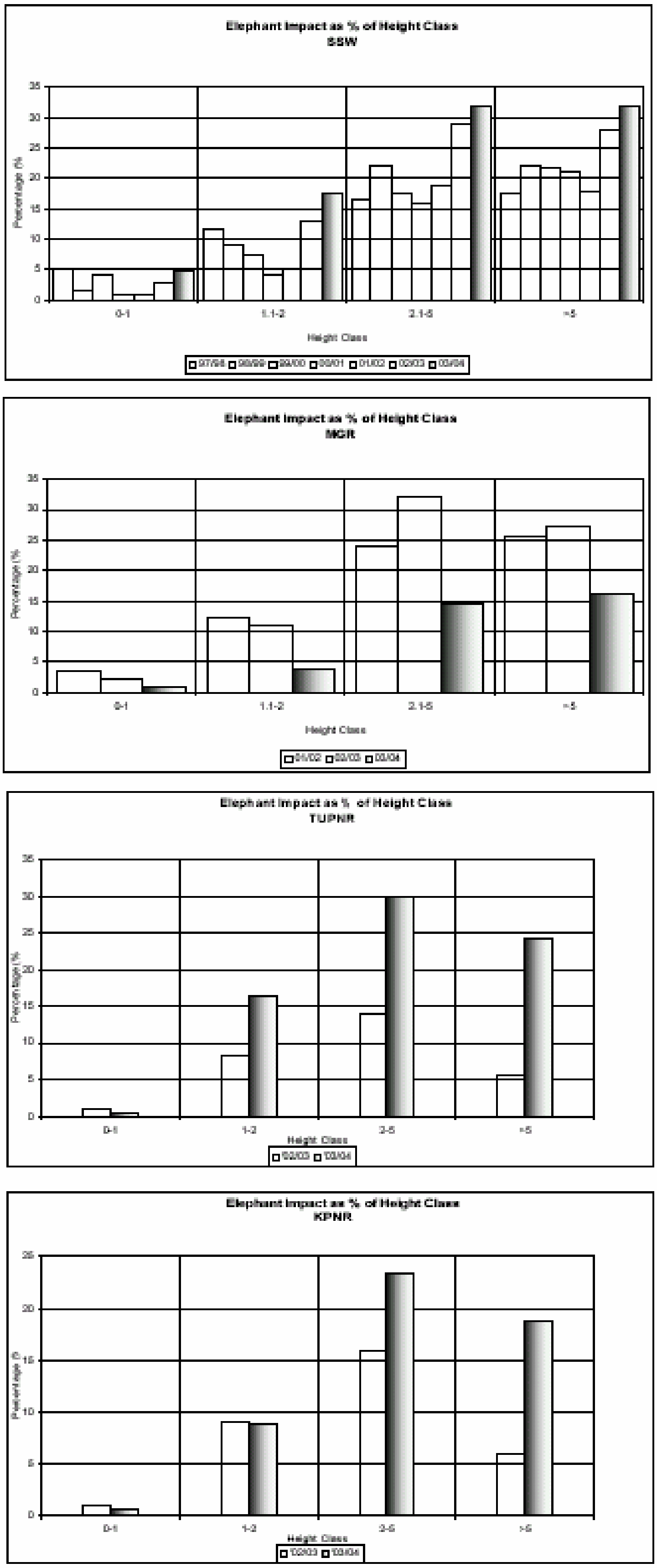
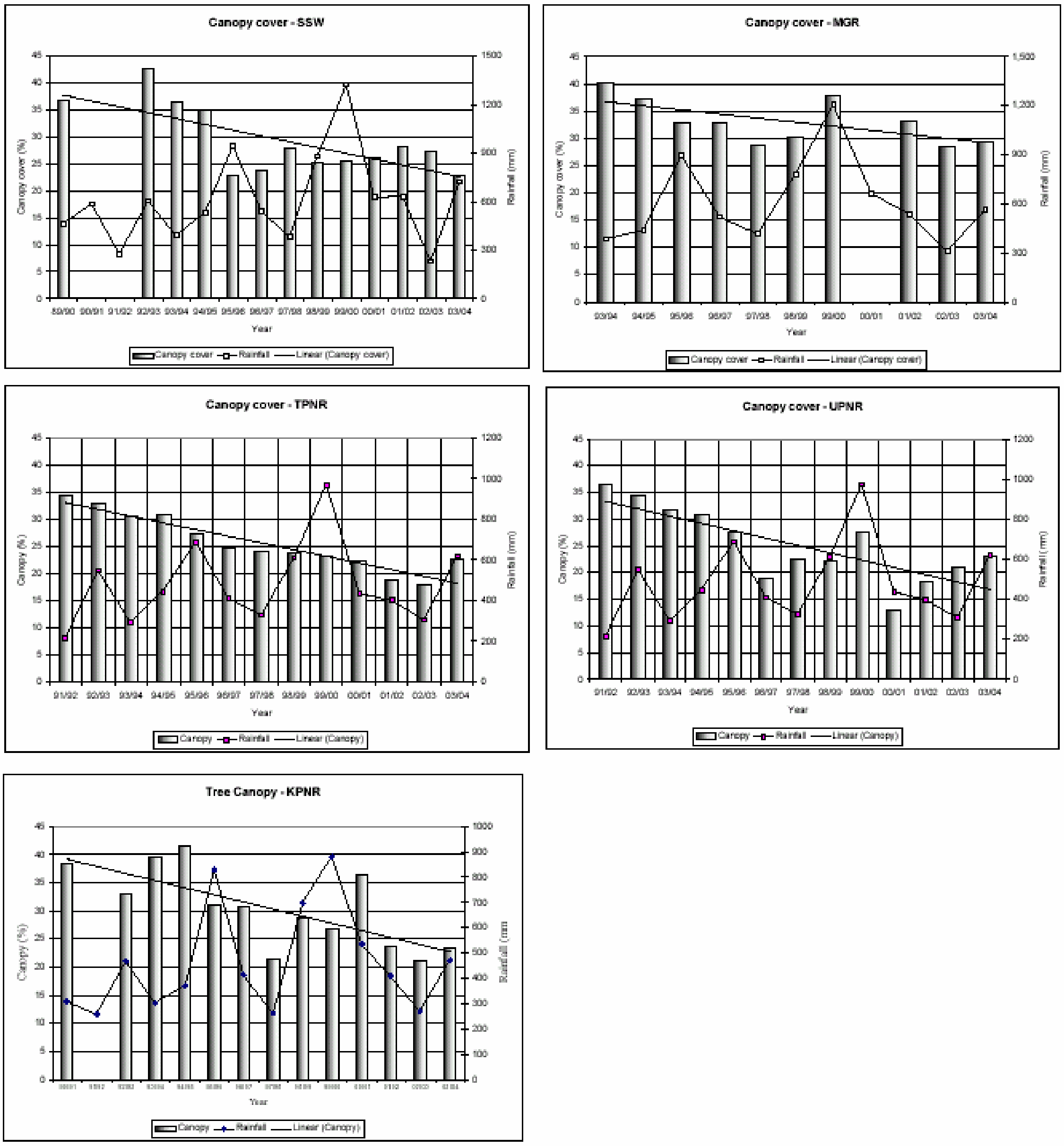


Figure 6 Tree canopy cover trends in 5 private nature reserves.



Elephant impact per species sampled

Are characteristic or sensitive species being targeted (removed) from the system and if so is this significant in terms of system functioning, biodiversity etc.?

Consider:

There was a degree of overlap in the targeting of woody species from south to north (SSW through, TUPNR through KPNR). Relatively higher proportions of the following species were impacted upon in all of the reserves (Figure 7a):

Acacia nigrescens (favoured species) and *Combretum apiculatum, Sclerocarya birrea, Grewia* spp. (higher proportions utilised in the TUPNR and KPNR possibly because there are less “favoured” woody species and less grass available and also because elephant densities have increased at a slower rate in these reserves) and *Albizia harveyi*. In addition to the above species there is a south to north gradient of utilisation among the following species (Figure 7b): *Dichrostachys cinerea, Terminalia sericea, Ziziphus mucronata, Combretum zeyheri, Pterocarpus rotundifolius* and *Terminalia prunoides*.

Relative percentage of elephant impact per species sampled

This section is aimed at illustrating the relative species utilisation in the various reserves. As in the above section it is important to determine whether characteristic or sensitive species being targeted (removed) from the system and if so is this significant in terms of system functioning, biodiversity etc.?

Consider:

The following species made up significant proportions of the total impact within the reserves (Figure 8a):

Acacia nigrescens (favoured species throughout the reserves) and *Combretum apiculatum* and *Grewia* spp. (favoured throughout but higher proportions utilised as one moves north - probably because there are less “favoured” woody species and less grass available and also because elephant densities have increased at a slower rate in the TUPNR and KPNR). *Sclerocarya birrea* is utilised at relatively low levels throughout while, as expected *Colophospermum mopane* makes up a relatively high proportion of all impact in the northern areas (TUPNR and KPNR) (Figure 8b).

Figure 7a Elephant impact per species sampled (selected target species).

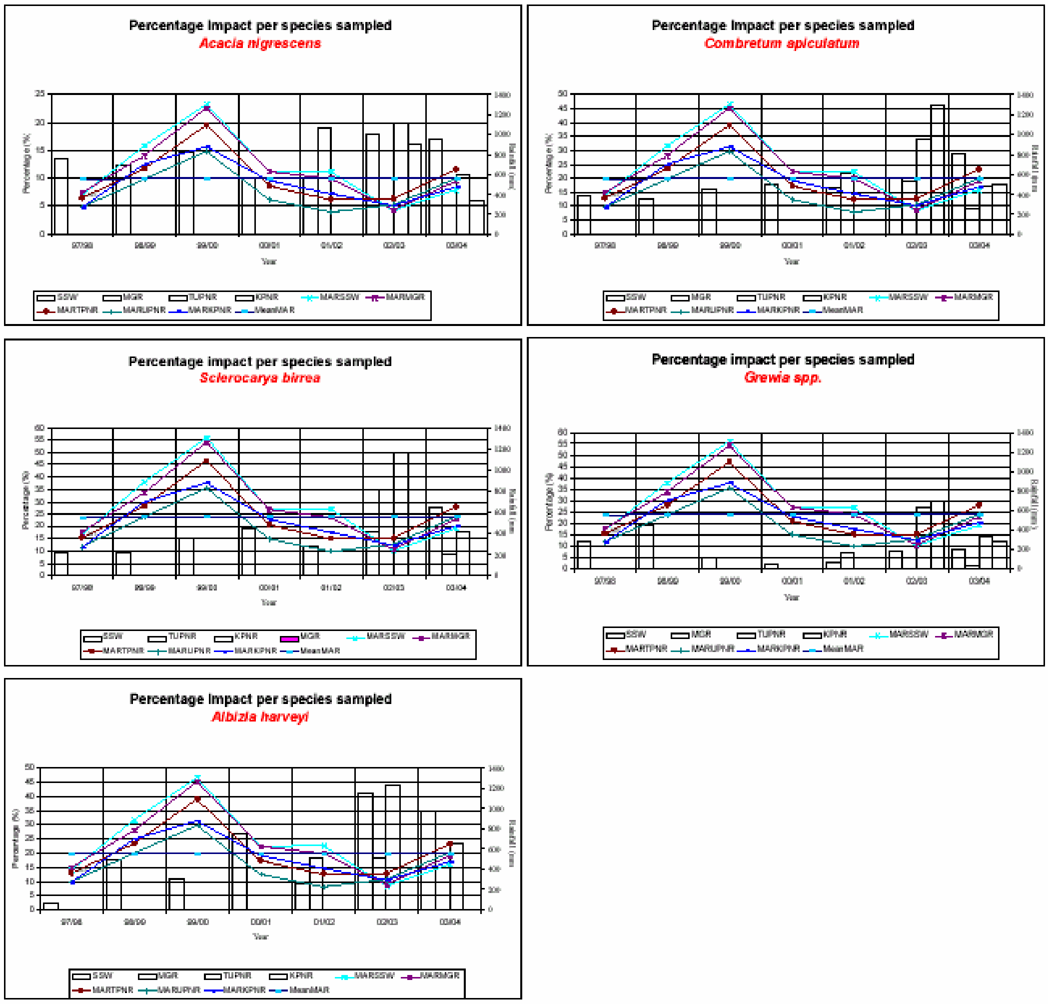


Figure 7b Elephant impact per species sampled (some other target species)

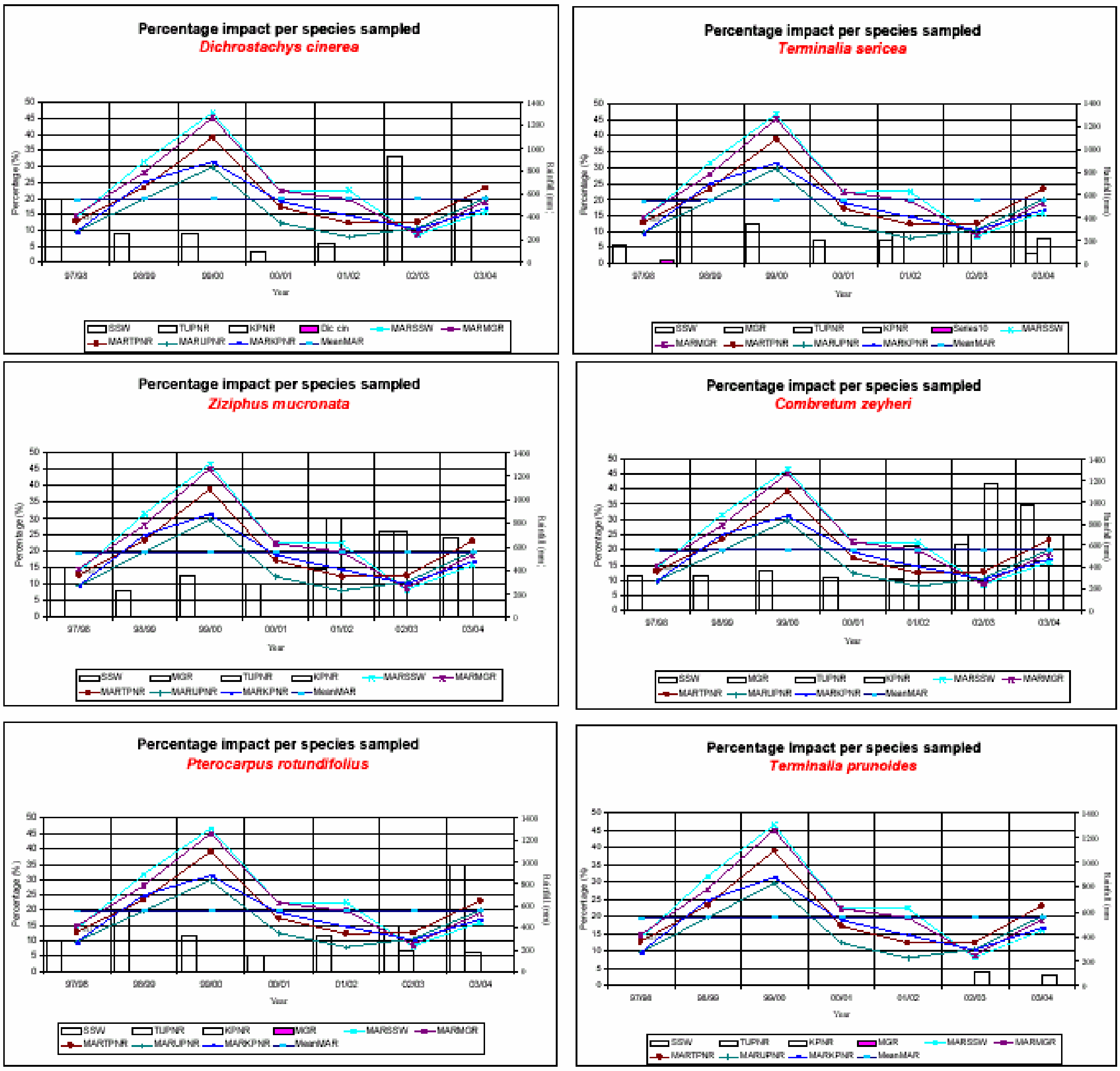


Figure 8a Percentage species impacted upon (selected target species).

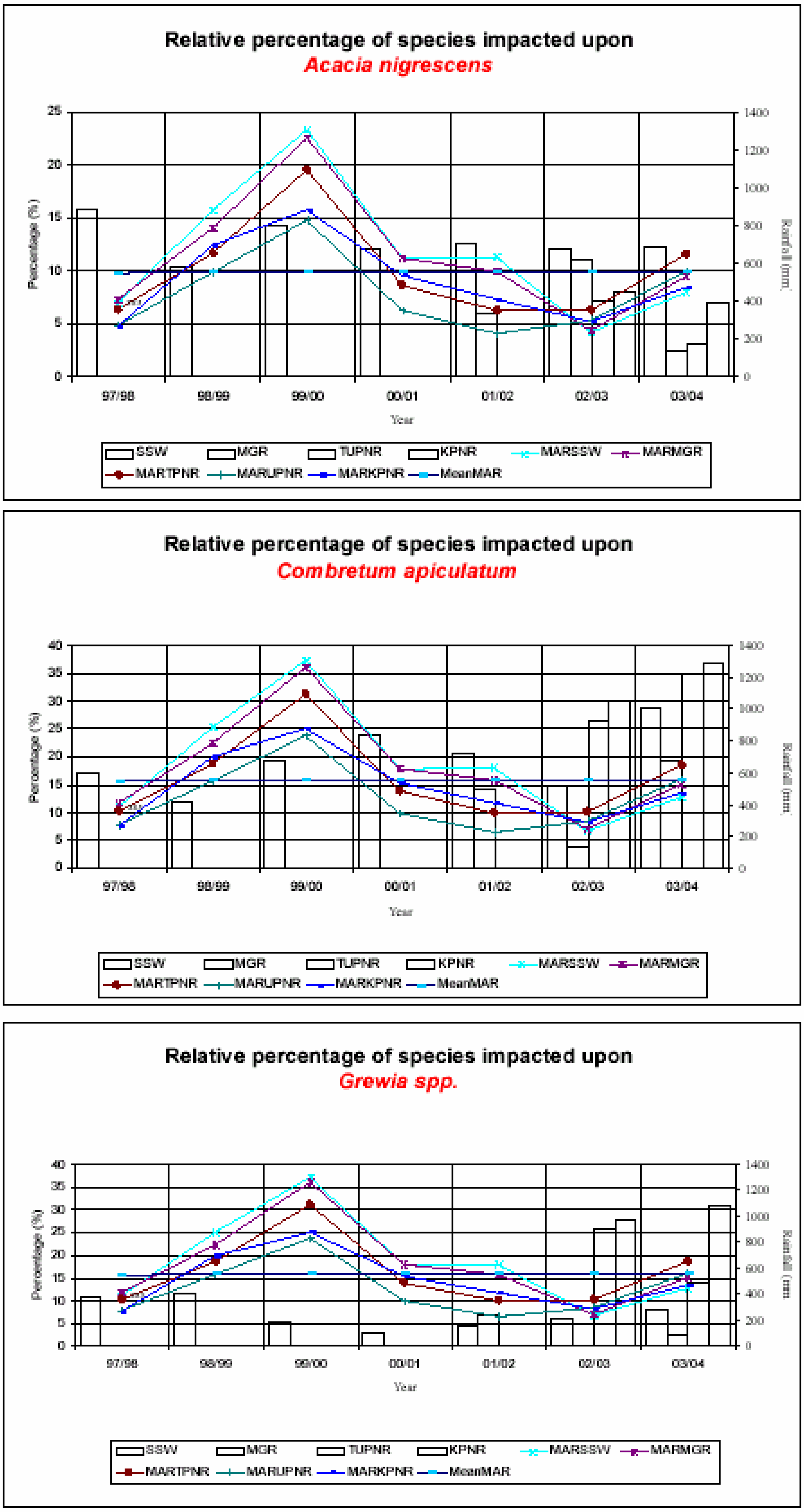
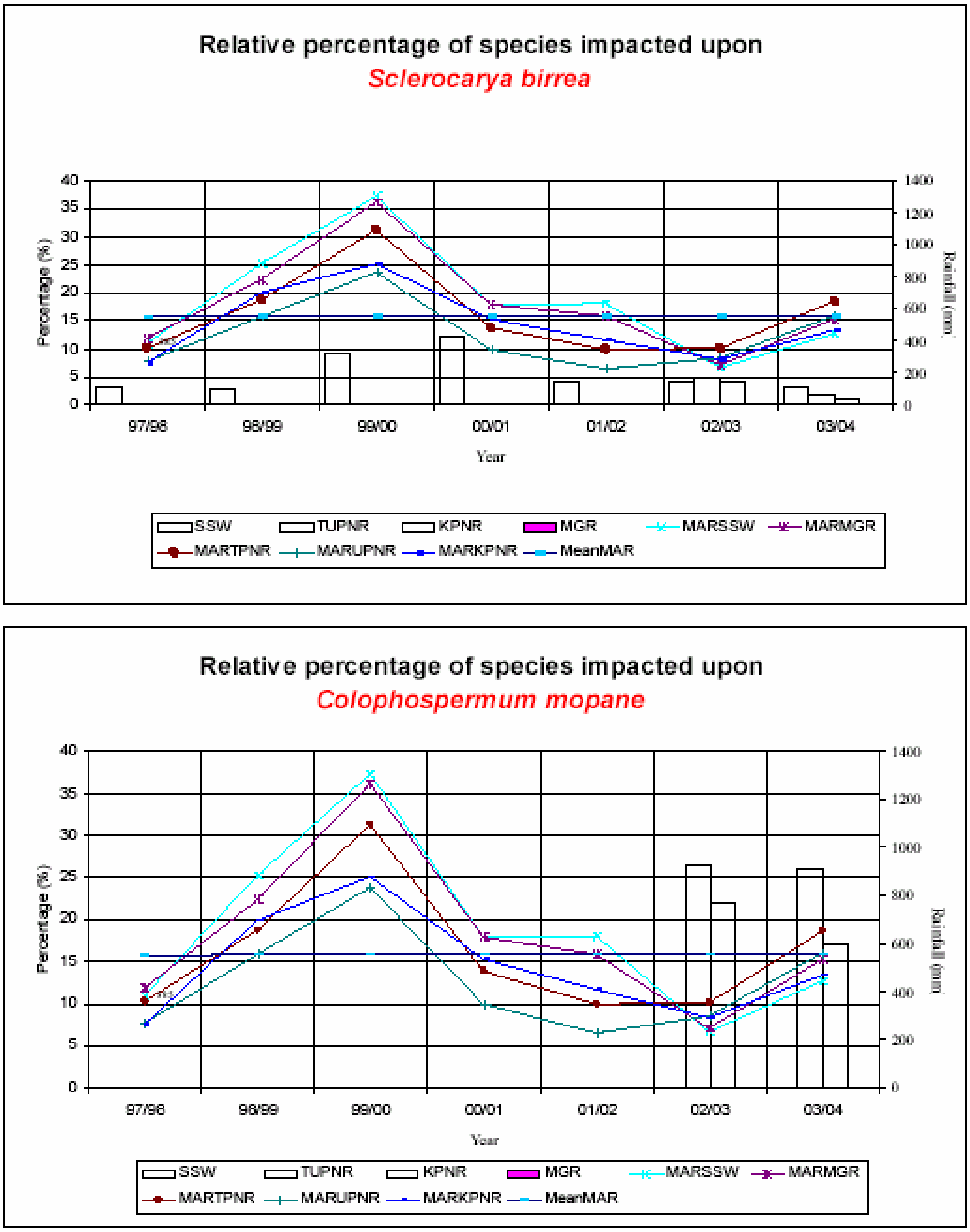


Figure 8b Relative percentage of species impacted upon (other target species).



Results also indicate a wider selection of tree species by elephant in the south (SSW and MGR), as reflected in the higher number of species making up the majority of utilisation in the SSW and MGR compared to the TUPNR and KPNR (Figure 9). This may be due to the presence of a greater variety of target tree species in the south and in the case of the SSW relatively low elephant density up until the late 1990's.

Thresholds of Potential Concern (TPC's)

The Kruger National Park (KNP), while differing in size to adjacent private nature reserves, although sometimes functioning at a relatively small scale, provides valuable pointers to elephant management. After Whyte, Biggs, Gaylard and Braack (1999) these include:

1. A management policy where the elephant population is beeing managed according to measured impacts on some ecological parameter rather than on absolute numbers of elephants;

2. Continuing with an elephant management policy until there is clear evidence that the prevailing density of elephants is having a negative impact on one or more **important** defined ecological parameter;

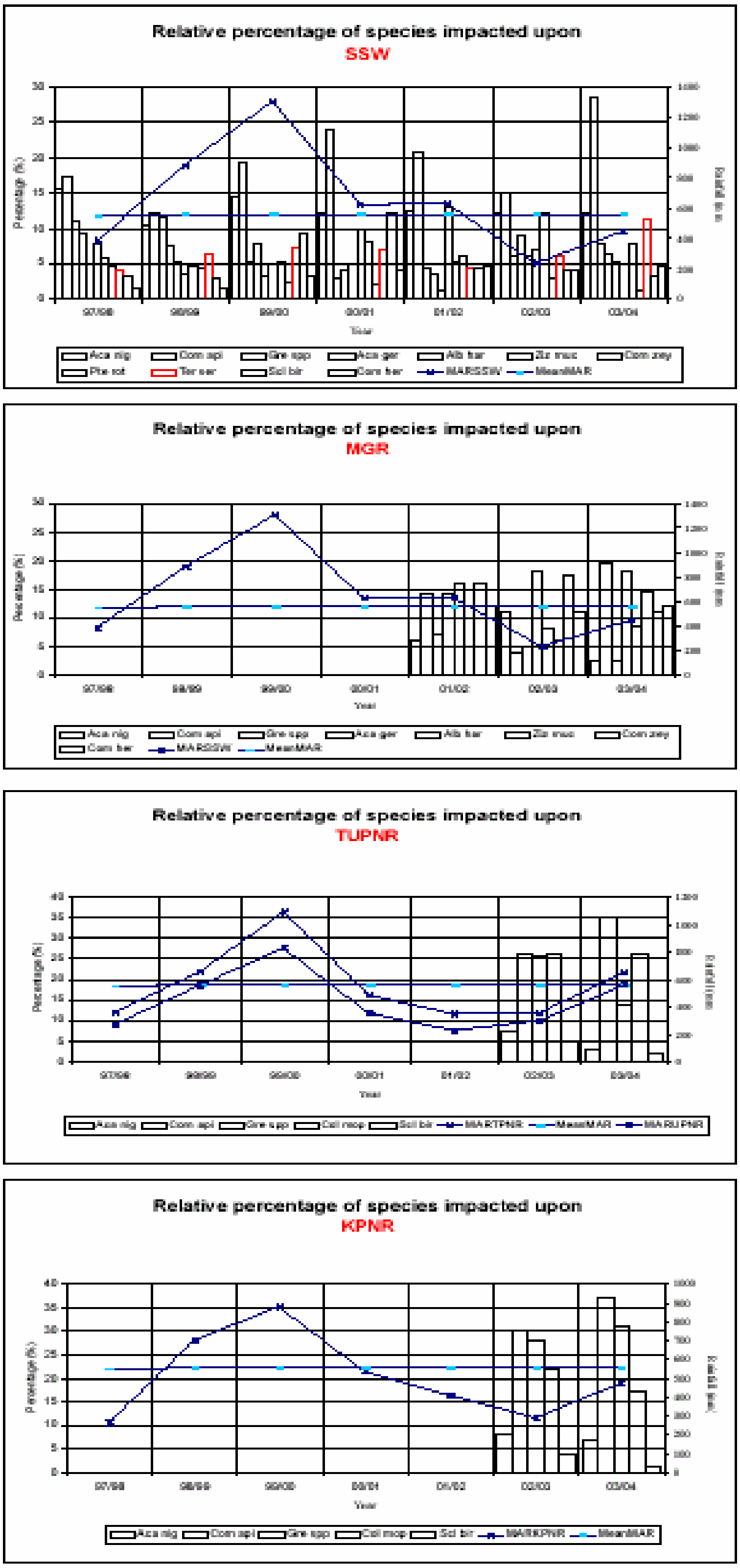
3. The above can be referred to as a "Threshold of Potential Concern" which is basically those upper and lower levels along a continuum of change in a selected environmental indicator which, when reached, prompts an assessment of the causes which led to such an extent of change, and results in either:

- management action to moderate such cause(s), or

- re-calibration of the threshold to a more realistic or meaningful level.

TPC's should initially be established at somewhat arbitrary levels on "best-availableknowledge-and-experience". It is absolutely necessary when deciding to use such TPC's that it must be accompanied by monitoring at appropriate intervals, and that there must be considerable understanding of the factors causing change in the parameter being monitored. These need to be identified specifically for the adjacent private nature reserves that, while a part of the KNP, have different objectives and management requirements (spatial scale is important). TPC's have the advantage that management has definite proactive objectives or parameters within which to manage a system, in contrast to previous practices where management was largely reactive.

Figure 9 Relative percentage of target species impacted upon per reserve – note number of species making up the majority of the impact per reserve.



Nevertheless, TPC's should be challenged as to their appropriateness or validity, and adaptively modified with increasing knowledge and experience;

1. Any one TPC reached should act as a significant warning sign on its own, and although evaluated in overall context with the rest, must be taken seriously in its own right.

Monitoring elephant impact in the private nature reserves should include:

The animal

1. Assessing ‘carrying capacity’ - stocking rates and species mix ratios are determined from game count data in conjunction with the ongoing vegetation-monitoring programme. Current dogma states that in this area 0.17 - 0.22 elephant per km^2 is recommended (Limpopo Department of Agriculture and Environment). This requires testing as Figure 2 shows that this number is currently exceeded in adjacent private nature reserves for which data are available - the big question is

whether having reduced numbers of elephant will reduce impact on for e.g. sensitive species? Re elephant sex and age structure consider that one aims at maintaining family groups with low proportions of young males as they may become problem animals later; and

2. Elephant movements (seasonal distribution etc.) and feeding behaviour to be monitored so that management action can be taken timeously in the event of a TPC being reached.

The vegetation

1. The types and degree of impact need to be stipulated (8-point scale) and TPC’s may include the following defining parameter limits (after Whyte *et al.* 1999):

- Grass/bush/bare ground ratios (set a minimum limit for the woody layer e.g. never lower than X% of its highest ever value and never higher than Y% its lowest ever value for a given area (maybe differentiate between granite and clay);

- Percentage perennial grasses – look at very broad scale – This is done on each of the vegetation monitoring sites in the private nature reserves;

- Percentage bare ground should not exceed X% or be less than Y% in any area (maybe differentiate between granite and clay) - This is done on each of the monitoring sites in the private nature reserves;

- Tree density – Partly covered by the above and by structure (below) – densities may be monitored along the lines of highest ever value and lowest ever values for given areas (maybe differentiate between granite and clay) - we need to decide whether this would be looked at generally or at a species level looking at dominant or threatened species – partly covered in the current vegetation monitoring programme;

- Structure/age class – look at structure in 4 height classes – monitor for homogenisation of structure e.g. a change from 4 to 2 classes – we need to decide whether this would be looked at generally or at a species level – currently covered in the vegetation monitoring programme;

- Characteristic or sensitive species (e.g. the Aloes) – e.g. accept local loss as long as there is 99% chance of the survival of the species in the long (100y) term (address complimentarity); and - Erosion/piosphere issues. X and Y values to be inserted once the plan is implemented.

Management of the elephant population

Once a Threshold/s of Potential Concern has been reached, it will be necessary to implement some management action. As this issue is highly emotive, the utmost care must be taken when considering methods of reducing the population. The following provides some suggestions in this regard:

1. The population should be carefully managed to ensure that acceptable limits of change to the natural resources are not exceeded. In the event of removal becoming necessary, family groups must be moved together;

2. The possibility of contraception may be considered to delay the onset of mating and the potential threat of attracting bulls from neighbouring

properties. The latter may prevent damage to fences and retard the rate of increment within the population;

3. The hunting of bulls; and

4. The donation of elephant to other suitable areas (currently saturated?).

A note of caution (after Walker B.H. in Payne K. 1998):

1. What evidence is there that irreversible habitat damage is occurring?

2. What is the shape of the habitat recovery curve if you reduce elephant pressures?

3. Will management action have the predicted effect?

4. What other management actions must be implemented in conjunction with elephant management?

5. How do we assess whether the management was successful?

Please see this as a working document/straw doll put together at quite short notice – we look forward to comments

Acknowledgements

Sandra MacFadyen, Gavin Hulett, Jonathan Swart, Scott Ronaldson, Colin Rowles, Andre Jacobs, Theresa McDonald and John Peel for help in gathering and collating the data at short notice.

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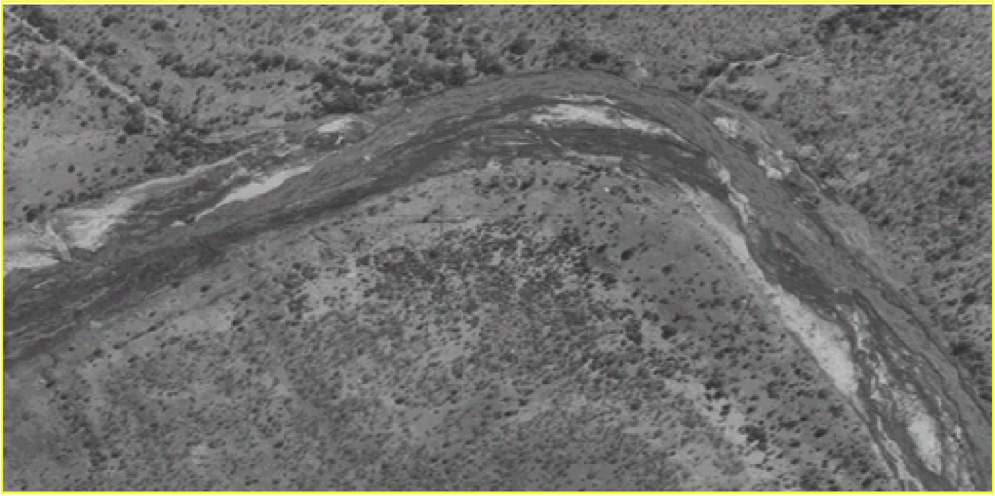
Appendix A

Changes in woody density (top 1944 – bottom 1986)



CHAPTER SUMMARY AND CONCLUSION

LAURENCE KRUGER AND RINA GRANT

A) Elephant water requirements and distribution in relation to surface water

Water requirements:

Elephant adults drink on average every 43hrs, with the longest period in between drinking episodes, aproximiately 72hrs. Breeding herd adults drink up to 86.61*l* at a time, and bulls twice that amount (Young, 1970).

Distribution around a water source

Distribution around waterholes is similar for wet and dry season, although herds move larger distances in the wet period. Adults walk on average 17.5km/day (Young, 1970) (15km, O'Connor *et al.* in press), while a weak calf can cover around 5km/day. If a mother only has to drink every 43hrs, a calf should survive if waterpoints are less than 6km apart (Young, 1970).

Implications for water provisioning in Kruger

Foraging range for elephants is limited to approximately 15km from water (O'Connor *et al.* in press), although Young (1970) would suggest that this would be closer to 31km. However in KNP, even during the dry periods, few surface water areas are further than 5km apart (Fig. 2). Therefore, given the current spatial and temporal availability of water, elephants in KNP are unlikely to be water stressed and their distributions are unlikely to be water limited.

B) Water availability and the influence on elephant distribution and feeding behaviour

i. Season of rainfall

Feeding behaviour: Elephants preferentially feed on herbs and grasses, browse (leaves and branches) and finally bark and roots at the end of the growing season after leaf fall (O'Connor *et al.* in press). Being preferential grazers (Codron, vegetation chapter) they will only switch to browse in the dry season when the quantity and quality of appropriate graze becomes limited. The reliance on browse is exacerbated during drought periods, especially in semi-arid regions, where grass production is reduced. Furthermore it is predicted that the use of bark and roots will occur earlier in the dry season as leaf fall will occur earlier. Therefore elephants will have a greater impact on woody vegetation in semi arid areas (O'Connor *et al.* in press).

Distribution: Overall, small differences between the elephant distance-to-water distributions in wet and dry years were observed (Redfern *et al*. 2003). However, during the dry season, elephants may have smaller home ranges than in wet periods (Young 1970; Stokke & du Toit 2002).

ii. Natural surface water

In a study conducted in riparian vegetation in the northern basalts, Angela Gaylard found the following:

- In riparian zones, male and female elephants preferred to feed near surface water. This spatial pattern of elephant feeding was consistent throughout the year, but became more pronounced as conditions became drier;

- Riparian areas are both a source of water and important source of evergreen vegetation, and foraging within these would represent a saving of energy, as they can acquire forage and water in close proximity. This occurs despite the fact that Kruger elephants do not seem water stressed;
- The importance of the proximity to, and density of, surface water as a factor determining elephant impacts on riparian woody vegetation varied over time. These surface water distribution attributes were important determinants of elephant impact primarily during below average rainfall years.

iii. Artificial waterpoints:

Izak Smit analysed aerial census data dry season distributions of elephants (1983 – 1993) and compared these to the spatial distribution of water points. The following are key results:

- Elephants aggregate around rivers, but not around artificial waterholes, except to some degree bulls on granites (see also Norman Owen-Smith). Provision of artificial water therefore doesn't seem that important an influence on elephant effects on vegetation. However, rivers, floodplains and the ecotones and sodic sites associated with these provide nutritional and habitat benefits that are not always found in the vicinity of artificial waterholes, and will probably attract animals even in the absence of permanent water.
- Bulls are more evenly distributed with regard to surface water sources than mixed groups. This is consistent with previous work done in Africa and is probably due to differences in the nutritional requirements, avoidance of aggression and the increased mobility of bull groups compared to mixed herds.
- Aggregation is more pronounced around rivers on the basalts than on the granites, maybe due to the difference in nutritional quality that exists between the two geologies, with elephants having to travel further from their drinking resources to satisfy their feeding requirements on the nutrient-poor granitic soils.

Limitations of analysis: Data are restricted to seven, day time, dry season snapshots. Analysis was conducted at landscape level (none at a finer scale) and ephemeral water sources were used in analysis.

At a finer scale in Angela Gaylard's assessment of elephant impact in riverine vegetation on northern granites:

- Found that intensity and spatial distribution of elephant impacts on riparian woody vegetation was influenced by the spatial distribution of riparian surface water. Elephant impacts were moderate, but homogeneous across the riparian landscape, in areas where waterholes were closely-spaced (max distance between waterholes = ca. 2km). In contrast, elephant impacts were more intense, but patchy, in those areas of the riparian landscape where waterholes were further apart (max. distance between waterholes = 7km).
- At some point piospheres (zones of impact around waterpoints) may coalesce further exacerbating the reduction in landscape heterogeneity,

Artificial waterpoints and elephant distribution: In Kruger, the home ranges of elephants do not increase in the wet season as might be expected. Seasonal variation in elephant distributions has been affected by the homogenous distribution of permanent water points across the landscape. The distance between water sources is no longer affecting the movement of breeding herds. An increase in the density of water points reduces home range area and increases the intensity of patch use. An increase in patch use intensity may be detrimental for local vegetation and may be incorrectly ascribed to high population density (Grainger *et al*. unpublished).

iv. Elephant densities, riverine vegetation, borehole densities and loss of tall trees: Analysis at a Landscape unit level

In a recent preliminary analysis, we assessed the relationship between elephant densities and riverine vegetation, borehole densities and the proportion of trees lost from the system (Based on Holger Eckhardt's fixed point photographs).

To summarise:

- We found no discernable relationship between elephant densities (bulls, breeding herds and total densities per km^2) and total area of riparian vegetation (Figs 1a-c);
- We found no relationship between elephant densities (bulls, breeding herds and total densities per km^2) and borehole density within KNP (Figs 2a-c). When combining borehole and elephant density of Sabie Sands, Unmabat and Timbavati, the relationship improved, but borehole density only explained 24% of the variation in elephant density ($p < 0.001$) (Fig 2d);
- Again, we found no real relationship between the density of elephants and the proportion of trees that have died over a 26yr period (data from Holger Eckhardt's fixed point data) (Figs 3a-c);
- Lastly, we did find a significant, but weak correlation between borehole density and percentage mortality of tall trees (Fig 4a). However, a great deal more data would need to be collected to suggest that artificial water provisioning may have an influence on tree mortality. On a cautionary note, the data for tree mortality are very limited, and cause of death has not been either investigated or confirmed. The photographs would suggest, though, that large trees are dying, although no direct blame can be apportioned to elephants.

C) Water and elephant utilisation/impact

i. Case studies

Impact on Limpopo Riparian forests: The Tuli elephant population, which once migrated between Botswana, Zimbabwe and South Africa, has been compressed into a limited area within the Tuli block by agricultural development and border fences. A study of elephant damage to *Ficus sycamorus, Faidherbia albida, Acacia xathophloea* (preferred by elephants) and *Croton megalobotrys* (not preferred by elephants) from 1999 and 2003 yielded the following:

- Decrease in the density of all species over 6 year period;
- Small trees of *F. sycamorus, F. albida* and *A. xanthophloea* disappeared;
- Decline in tree numbers is accompanied by an increase in elephant damage;
- The percentage damage to the preferred tree species (76-90%) and *C. megalobotrys* (<10%).

Management recommendations: It is evident from the decrease in tree species density that the elephant populations exceeds their forage supply. Given the increased agricultural development and planning of future dams (further blocking of migratory routes, controlling of elephant numbers is mooted as the best management option (de Beer & Burger, 2003).

ii. Risk assessment: a framework for assessing the impact of elephants

Risk assessment techniques have been extensively used internationally for disaster management and has recently been applied to the assessment of the vulnerability of fire protection associations (FPAs) in South Africa. The technique has many advantages in that it attempts to roughly quantify both the threat and the probability of the threat occurring, and ultimately, by combining the two, providing a risk assessment. O'Connor *et al.* in press, have provided the following theoretical background to the assessment process.

a. Threat (Risk):

Local extirpation of a plant species results when adult mortality is greater than recruitment. They are influenced by the following:

Adult mortality: Elephant impact including breaking of branches, stripping of bark, pollarding and toppling of trees. Risk to the plant is influenced by the attractiveness of the plant species, the ability of a plant to cope with the impact (shearing strength of the stem, tensile strength of the roots etc) and if damaged, the degree of damage and how well the plants can sprout (coppice).

Recruitment: Seemingly elephants have little impact on recruitment of many woody species (O'Connor *et al.* in press), although Owen-Smith would dispute this.

b. Probability of an encounter

Mortality depends also on the probability of the elephant encountering a tree (O'Connor *et al.* in press). This is largely dependent on the density of elephant populations and the environment (especially availability of water and ruggedness of terrain).

Influence of water: Elephant foraging distance from water is estimated at being between 15km (O'Connor *et al.* in press) and 17.5km (Young, 1970). Owen Smith (1988) suggests elephants may occur 15-24 km from water sources in dry periods. The vulnerability of a species depends on its distribution in relation to water. The probability of an elephant encountering it will decrease with distance from water due to energetic constraints on foraging distance (O'Connor *et al.* in press) i.e. the greater the distance between water sources the more secure the woody component should be from elephant damage.

By combining the threat and the probability of encounter we can calculate the risk associated with elephant in a given environment. This would be an effective way of assessing the relative risk of each of the issues and thereby providing a ranking of each.

D. Key management options: Implications for SANParks

Closure of water-holes

Opinion is divided on the relative importance of the artificial provisioning of water:

- Smit suggests that elephants are highly vagile and natural surface water sources are abundant, so consequently they are not found to aggregate around waterholes (except, to some degree, bulls on northern Granites). He suggests that the closure of waterpoints will have no impact on elephant numbers. Large scale closure of waterpoints may have compromise non-target species.
- However, Owen-Smith suggests that the provision of artificial waterpoints in the uplands would have an impact, as many of the vulnerable species are found in these

areas. Generally natural water does not persist in the uplands beyond the wet season. These waterpoints are likely to be visited late in the dry season by bulls. Thus provision of these in uplands would constitute a significant threat to tree species vulnerable to elephant damage.

- Angela Gaylard would suggest that the presence of waterpoints has more of a significant impact, as they would focus elephant impacts on vegetation, and significantly reduce habitat heterogeneity.

Removing all boreholes during dry years increases the percentage of area that occurs beyond 5 km of water sources from 9% to 28% in the northern region and from 5% to 13% in the southern region (Fig. 2), although little area more than 10 km from water sources is created in either region (Fig. 2) (Redfern *et al.* in press). While these distances may not result in calf mortality it could however, result in increased heterogeneity of elephant impact on vegetation. Furthermore, Norman Owen-Smith suggests that the closure of waterpoints may result in the relaxation of pressure on vulnerable species as bulls would not be attracted to these areas during at a time when these tree species are at their most vulnerable.

Advantages:

- Although closure of water points may not significantly influence the number of elephants, the water points themselves would act as bridging gaps between rivers and facilitate elephant movement across areas they were previously unable to access due to water constraints. Removal of these would limit the movement of elephants in the reserve and therefore improving patch heterogeneity in the KNP landscape;
- Restoring the natural spatial and temporal variability of surface water distribution would restore natural heterogeneous elephant impacts, thereby providing spatial and temporal refuges for impact intolerant species;
- The reduction in water points may reduce the probability of an elephant encountering vulnerable species;

Disadvantages:

- If small reserves don't close their waterpoints (quite likely, according to Mike Peel) then elephants will potentially, at some point, congregate in these areas and possibly cause even greater damage to the vegetation in these confined areas.
- Closing of waterpoints will affect water dependent species and may also effect rare antelope as their distribution seems to be closely linked to artificial waterpoints (Izak Smit in prep).

Further studies

The following have been suggested by contributing authors as data worth collecting in future:

- Wet season elephant counts;
- Finer scale impacts (across landscape units, land types and/or vegetation communities) in addition to the data collected by Angela Gaylard in the Northern Plains;
- Elephant-related piosphere effects around water-holes in KNP;
- Spatially explicit analysis to determine the optimal relationship between elephant density and surface water distributions, to maintain highest plant diversity

- Monitoring the rate of expansion of piospheres may also be used as an indicator signal for TPCs i.e. determine the relationship between elephant densities and rate of piosphere coalescence.

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Appendix: Elephant density, Riverine vegetation and borehole density analyses

Table 1. *Summary table: mean elephant densities (1985 – 2004), total riverine vegetation and borehole density*

	LANDSCAPE	Area (Ha)	Total Riverine	Bull density (km^2)	Herd density (km^2)	Total density (km^2)	Borehole density (km^2)
1	Lowveld Sour Bushveld of Pretoriuskop	37243.72	2202.80	0.06	0.27	0.32	0.008
22	*Combretum / Colophospermum mopane* Rugged Veld	80525.73	6153.25	0.10	0.45	0.55	0.019
11	Tsende Sandveld	151149.56	4801.41	0.05	0.34	0.39	0.013
3	*Combretum collinum / Combretum zeyheri* woodland	45033.15	2707.36	0.04	0.38	0.41	0.027
5	Mixed *Combretum / Terminalia sericea* woodland	148306.81	4359.73	0.04	0.32	0.36	0.019
4	Thickets of the Sabie & Crocodile River	124111.86	12103.19	0.05	0.59	0.64	0.014
18	Dwarf *Acacia nigrescens* savanna	34320.56	151.73	0.05	0.19	0.23	0.023
23	*Colophospermum mopane* shrubveld on basalt	199411.52	1530.26	0.10	0.17	0.26	0.012
20	Bangu Rugged Veld	20658.98	0.00	0.04	0.14	0.17	0.015
19	Thornveld on gabbro	72992.11	3329.32	0.04	0.28	0.32	0.030
13	*Acacia welwitschii* thickets on Karoo sediments	48580.42	2298.68	0.05	0.73	0.78	0.027
15	*Colophospermum mopane* Forest	33277.05	1701.98	0.13	0.78	0.91	0.018
17	*Sclerocarya birrea* subspecies *caffra /Acacia nigrescens* savanna	134988.12	8345.51	0.07	0.24	0.31	0.034
24	*Colophospermum mopane* shrubveld on gabbro	30555.43	575.10	0.06	0.30	0.36	0.031
2	Malelane Mountain Bushveld	47289.23	2350.85	0.09	0.43	0.52	0.017
6	*Combretum / Colophospermum mopane* woodland of Timbavati	40016.22	560.54	0.05	0.55	0.60	0.015
7	Olifants River Rugged Veld	50438.33	5101.11	0.03	0.79	0.83	0.010
8	Phalaborwa Sandveld	39903.37	0.00	0.08	0.30	0.38	0.033

	LANDSCAPE	Area (Ha)	Total Riverine	Bull density (km^2)	Herd density (km^2)	Total density (km^2)	Borehole density (km^2)
9	*Colophospermum mopane* woodland / savanna on basic soil	40583.08	11.20	0.11	0.54	0.65	0.025
10	Letaba River Rugged Veld	59738.15	5994.70	0.05	0.65	0.69	0.005
12	*Colophospermum mopane / Acacia nigrescens* savanna	103590.27	5531.88	0.10	0.38	0.48	0.016
14	Kumana Sandveld	11541.77	202.33	0.06	0.25	0.30	0.000
16	Punda Maria Sandveld on Cave Sandstone	19272.32	1483.76	0.05	0.43	0.47	0.068
21	*Combretum / Acacia nigrescens* Rugged Veld	23884.37	2472.11	0.04	0.46	0.50	0.008
25	*Adansonia digitata / Colophospermum mopane* Rugged Veld	80803.60	3368.90	0.05	0.51	0.56	0.008
26	*Colophospermum mopane* shrubveld on calcrete	10689.76	0.00	0.04	0.38	0.42	0.013
27	Mixed *Combretum / Colophospermum mopane* woodland	33050.54	0.00	0.05	0.23	0.28	0.003
28	Limpopo / Luvuvhu Floodplains	9547.61	3025.61	0.07	0.46	0.53	0.035
29	Lebombo South	77901.86	3597.91	0.06	0.39	0.45	0.009
30	Pumbe Sandveld	2540.60	0.00	0.01	0.00	0.01	0.000
31	Lebombo North	55332.88	2527.66	0.02	0.22	0.24	0.000
32	Nwambiya Sandveld	15749.48	0.00	0.02	0.17	0.19	0.028
33	*Pterocarpus rotundifolius / Combretum collinum* woodland	15225.15	207.36	0.12	0.49	0.61	0.016
34	Punda Maria Sandveld on Waterberg sandstone	32166.18	1879.44	0.10	0.33	0.42	0.019
35	*Salvadora angustifolia* floodplains	16619.18	5424.59	0.18	0.60	0.78	0.054
	Sabi Sand					1.175	0.141
	Timbavati					0.977	0.286
	Unmabat					0.779	0.374

Table 2. *Mean elephant density (1985 – 2004), borehole density and proportion of tall trees lost.*

Landscape Unit	Landscape	Mean bull density (km^2)	Mean breeding herd density (km^2)	Mean elephant density (km^2)	prop dead trees	n	Borehole density (km^2)
1	Lowveld Sour Bushveld of Pretoriuskop	0.06	0.27	0.32	0	1	0.008
3	*Combretum collinum / Combretum zeyheri* woodland	0.04	0.38	0.41	0.17	2	0.027
4	Thickets of the Sabie & Crocodile River	0.05	0.59	0.64	0.18	3	0.014
5	Mixed *Combretum / Terminalia sericea* woodland	0.04	0.32	0.36	0.17	5	0.019
11	Tsende Sandveld	0.05	0.34	0.39	0.14	2	0.013
13	*Acacia welwitschii* thickets on Karoo sediments	0.05	0.73	0.78	0.64	2	0.027
15	*Colophospermum mopane* Forest	0.13	0.78	0.91	0.67	2	0.018
17	*Sclerocarya birrea* subspecies *caffra /Acacia nigrescens* savanna	0.07	0.24	0.31	0.68	14	0.034
18	Dwarf *Acacia nigrescens* savanna	0.05	0.19	0.23	0.22	2	0.023
19	Thornveld on gabbro	0.04	0.28	0.32	0.44	8	0.030
20	Bangu Rugged Veld	0.04	0.14	0.17	0.35	3	0.015
22	*Combretum / Colophospermum mopane* Rugged Veld	0.10	0.45	0.55	0	1	0.019
23	*Colophospermum mopane* shrubveld on basalt	0.10	0.17	0.26	0.33	14	0.012
24	*Colophospermum mopane* shrubveld on gabbro	0.06	0.30	0.36	0.75	1	0.031

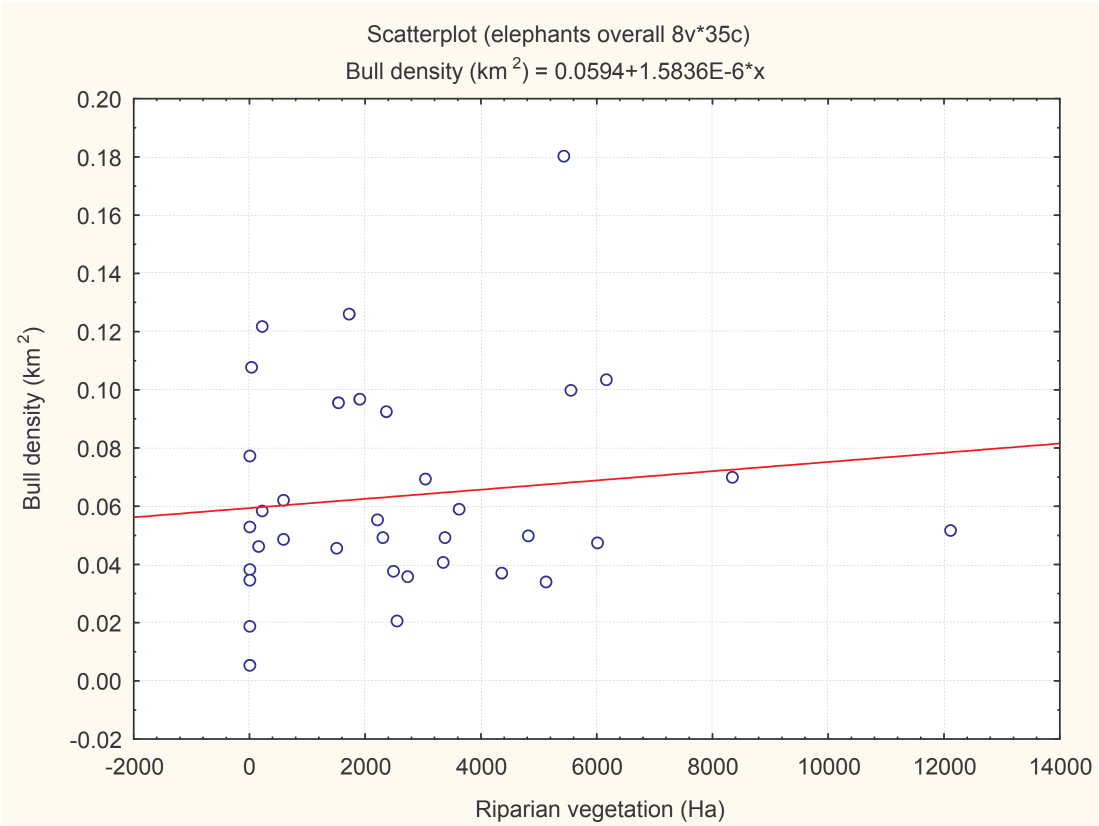

***Figure 1a**. Relationship between bull elephant density and area of riverine vegetation.*

$R^2 = 0.0149$, $p < 0.001$, $n = 35$.

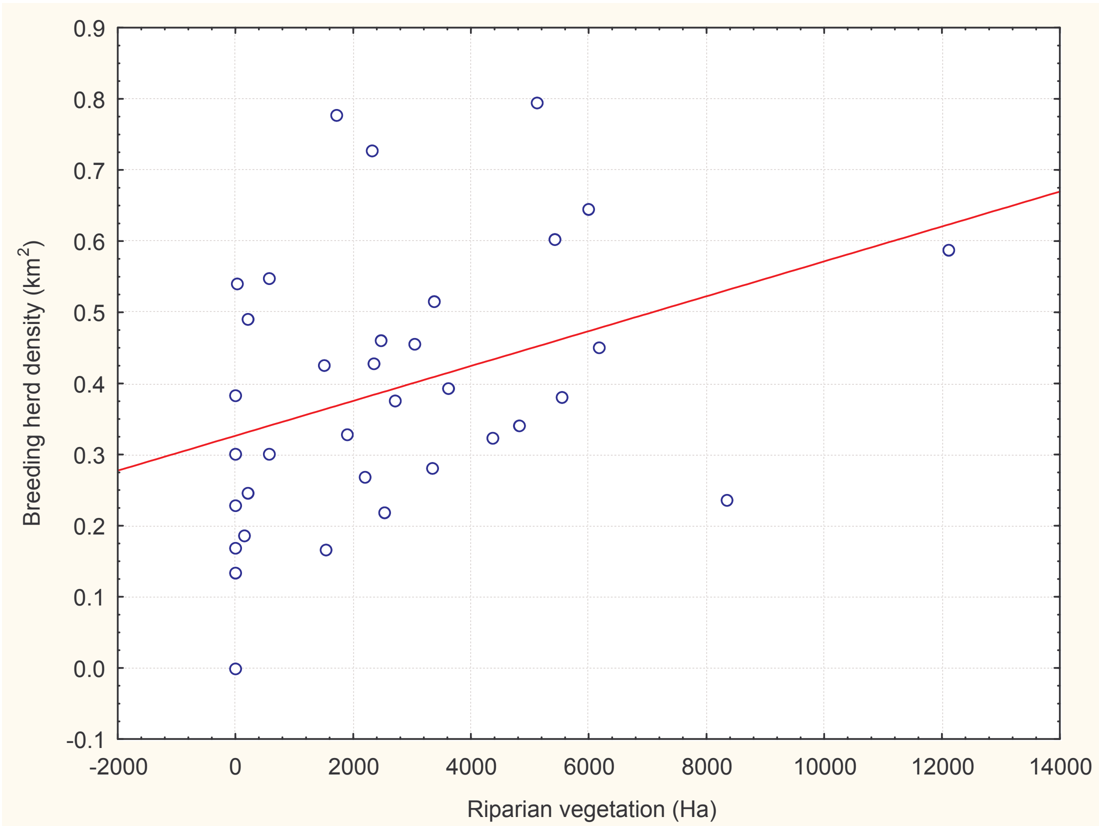

Figure 1b. *Relationship between breeding herd density and area of riverine vegetation.*

$R^2 = 0.131$, $p < 0.001$, $n = 35$.

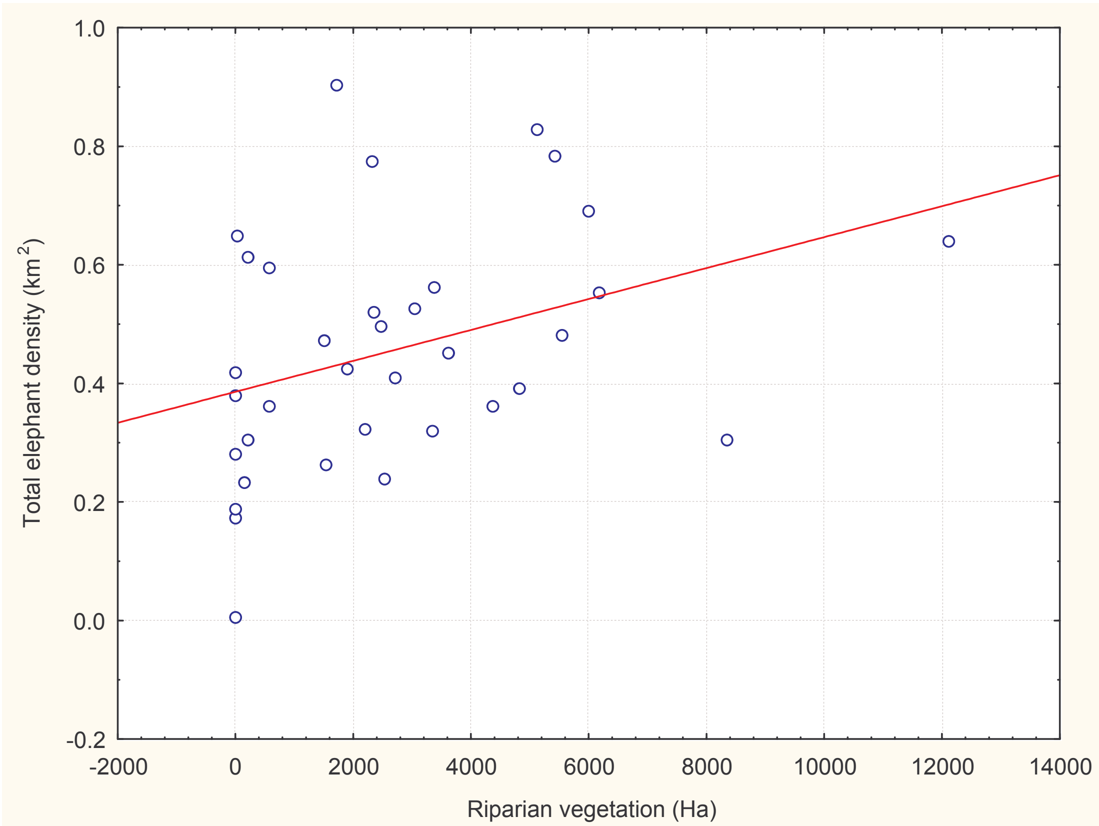

Figure 1c. *Relationship between total elephant density and area of riparian vegetation.*

$R^2 = 0.1264$, $p < 0.001$, $n = 35$.

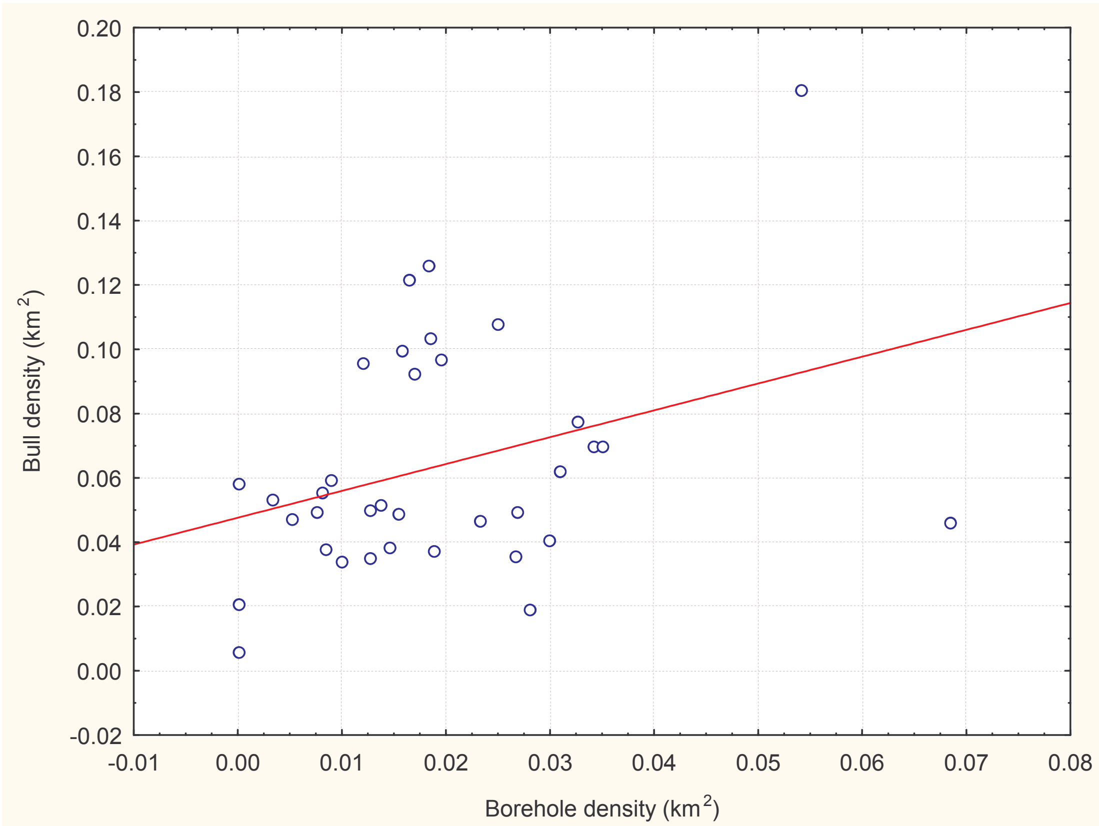

Figure 2a. *Relationship between elephant bull density and borehole density.*

$R^2 = 0.1148$, $p < 0.001$, $n = 35$.

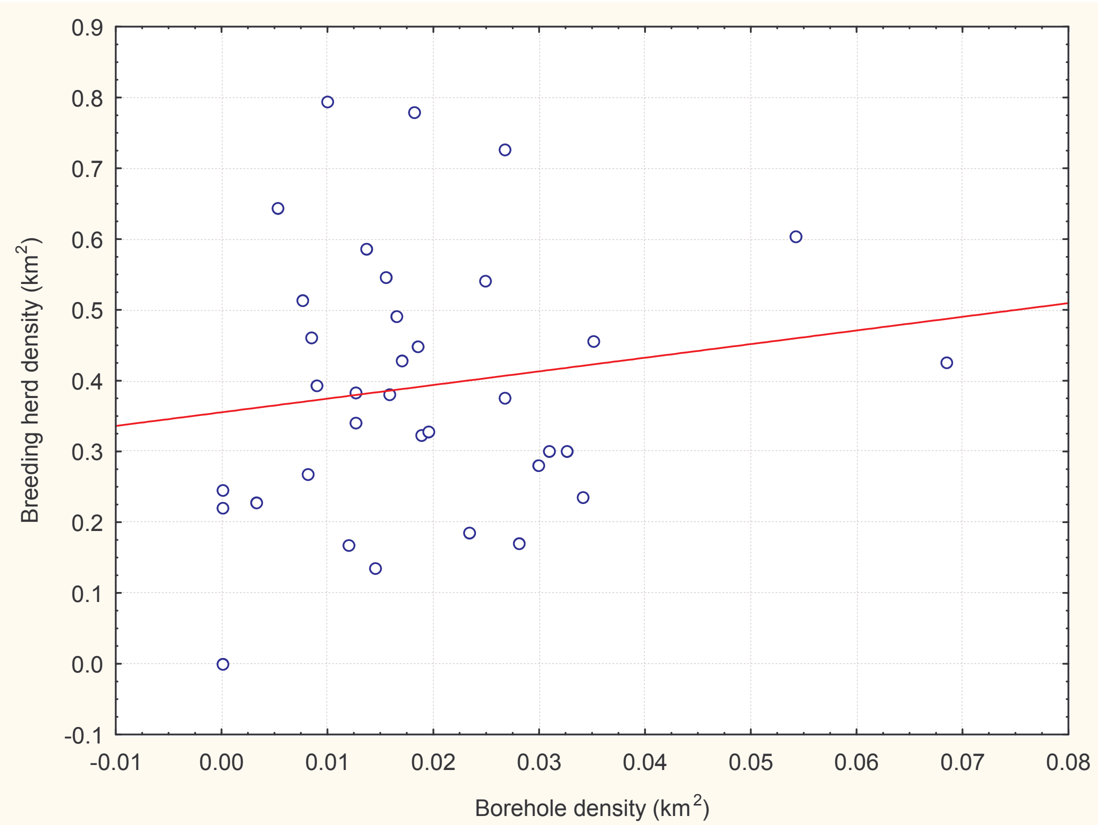

Figure 2b. *Relationship between breeding herd density and borehole density.*

$R^2 = 0.0226, p < 0.001, n = 35.$

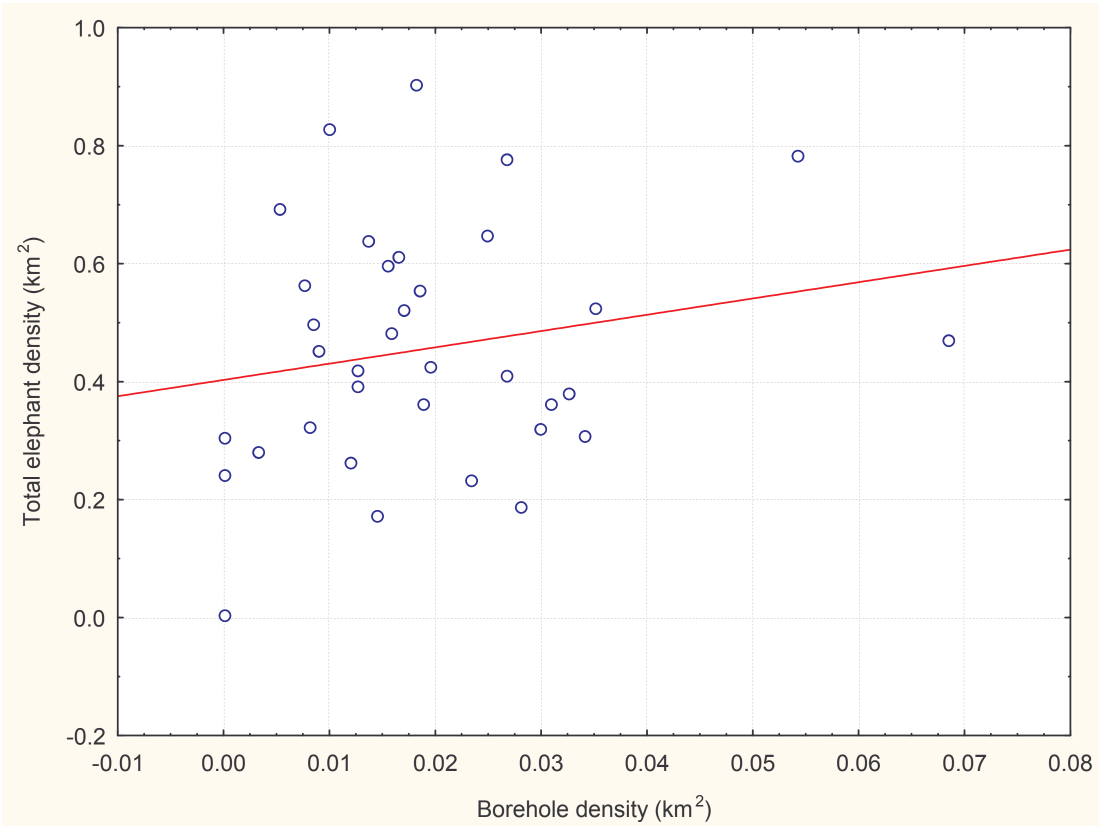

Figure 2c*. Relationship between elephant density and borehole density (KNP).*

$R^2 = 0.0393$, $p < 0.001$, $n = 35$.

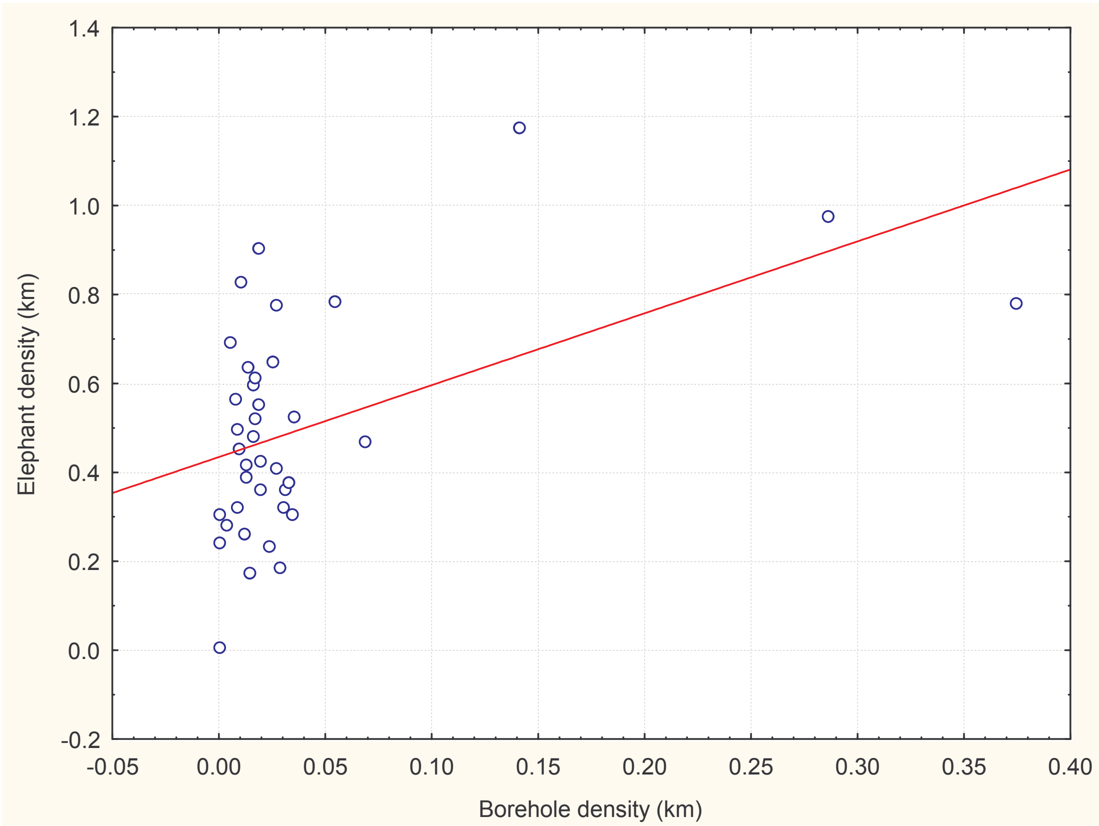

Figure 2d. *Relationship between elephant density and borehole density (KNP and small reserves). R2 = 0.2415, p < 0.001*

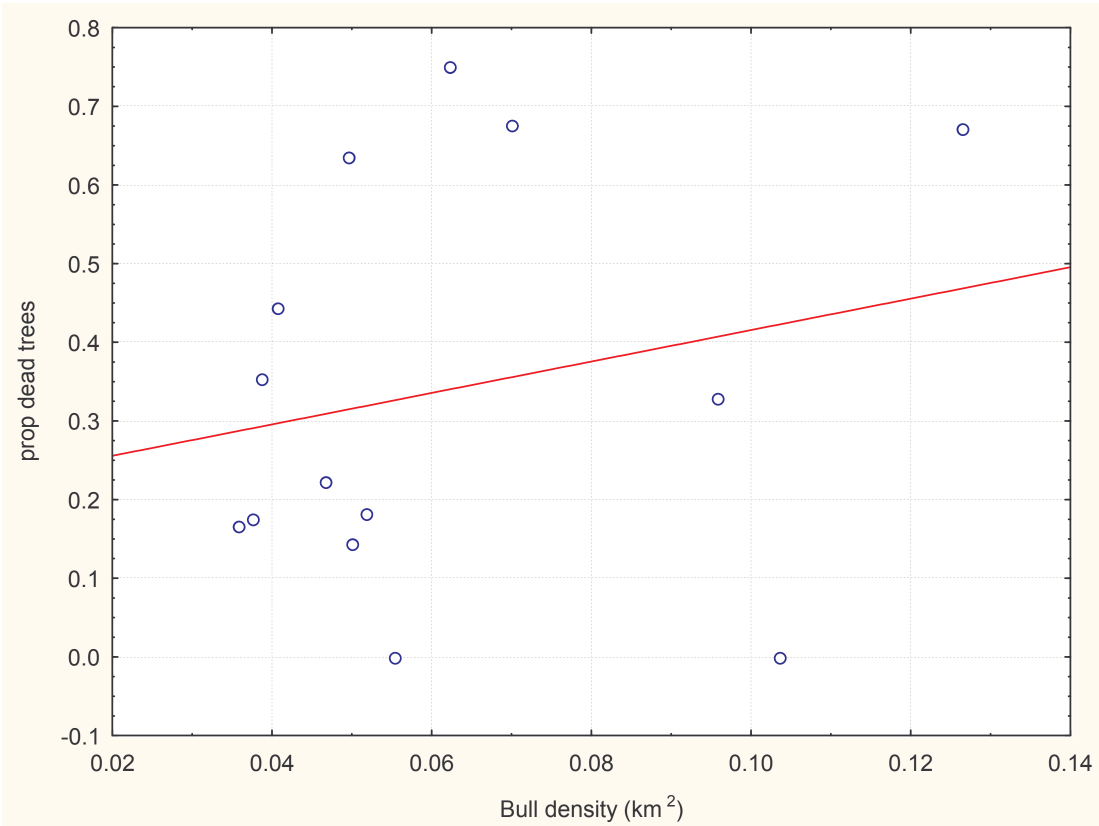

Figure 3a. *Relationship between elephant bull density and proportion of dead trees (fixed point photograph data).* $R^2 = 0.0468$, $p = 0.248$, $n = 14$.

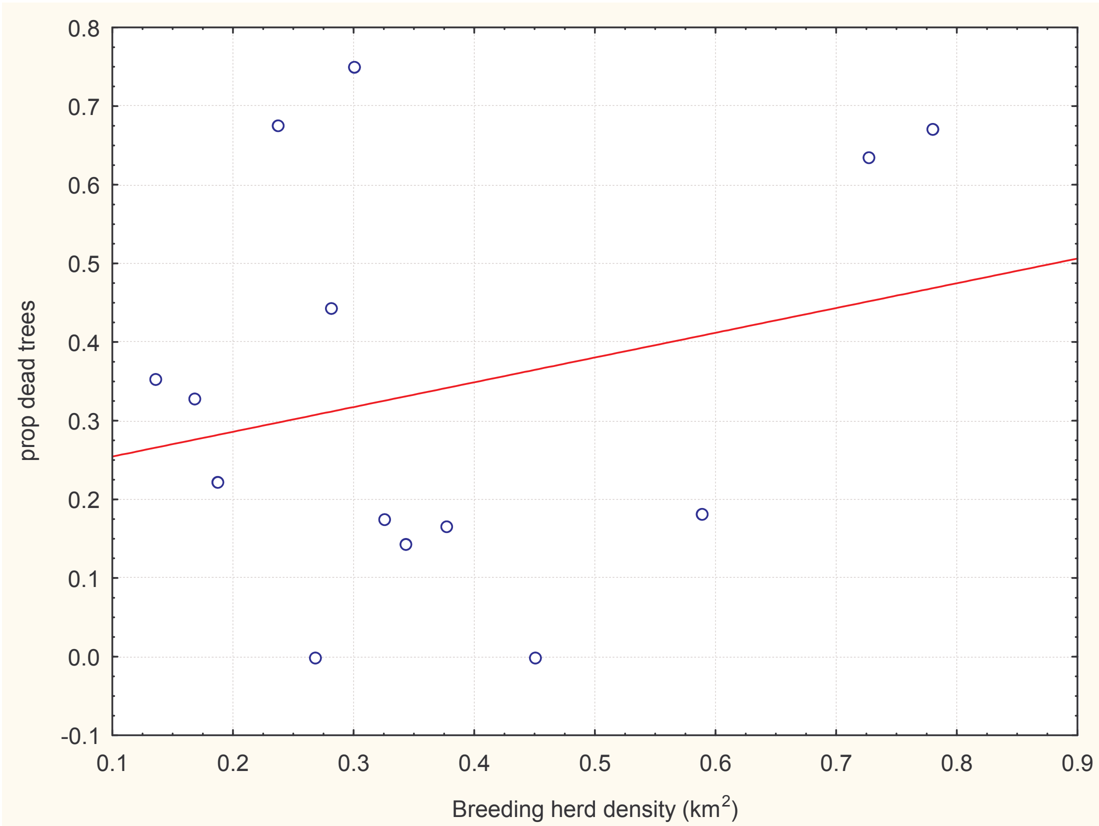

Figure 3b. *Relationship between breeding herd density and proportion of dead trees (fixed point photograph data).* $R^2 = 0.0604$, $p = 0.1607$, $n = 14$.

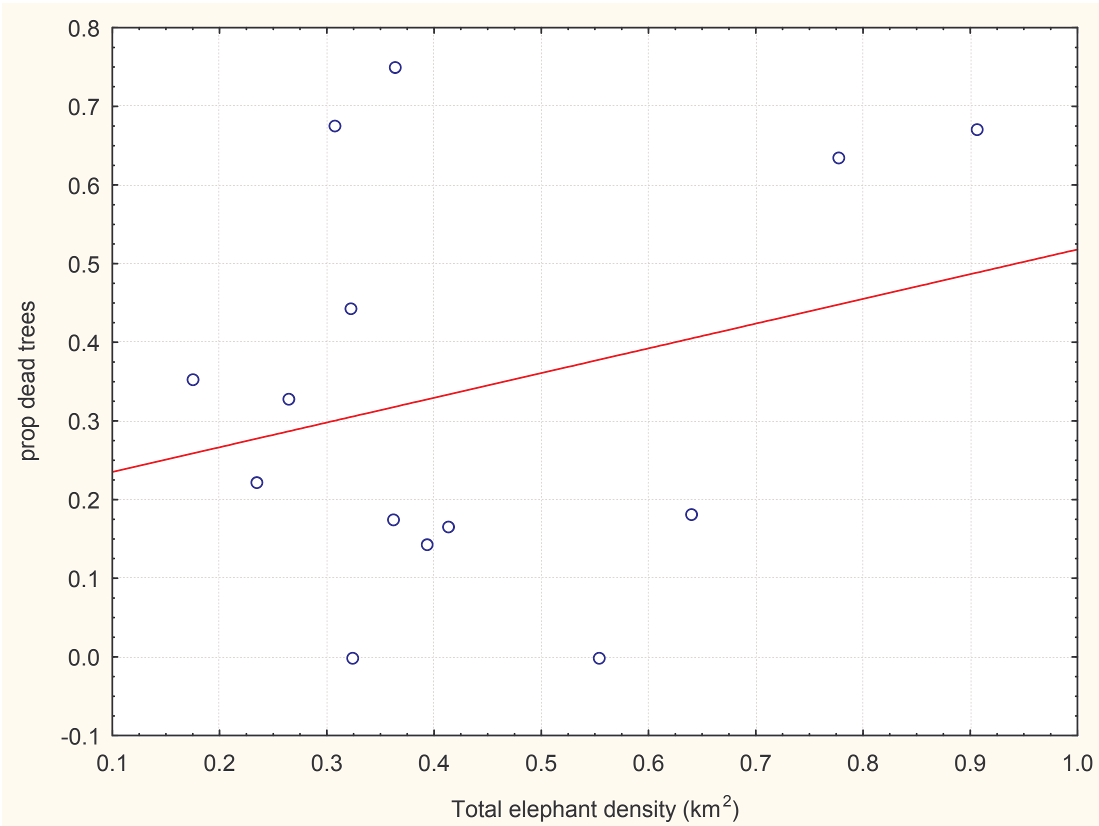

Figure 3c. *Relationship between total elephant density and proportion of dead trees (fixed point photography data).* $R^2 = 0.0676$, $p = 0.228$, $n = 14$.

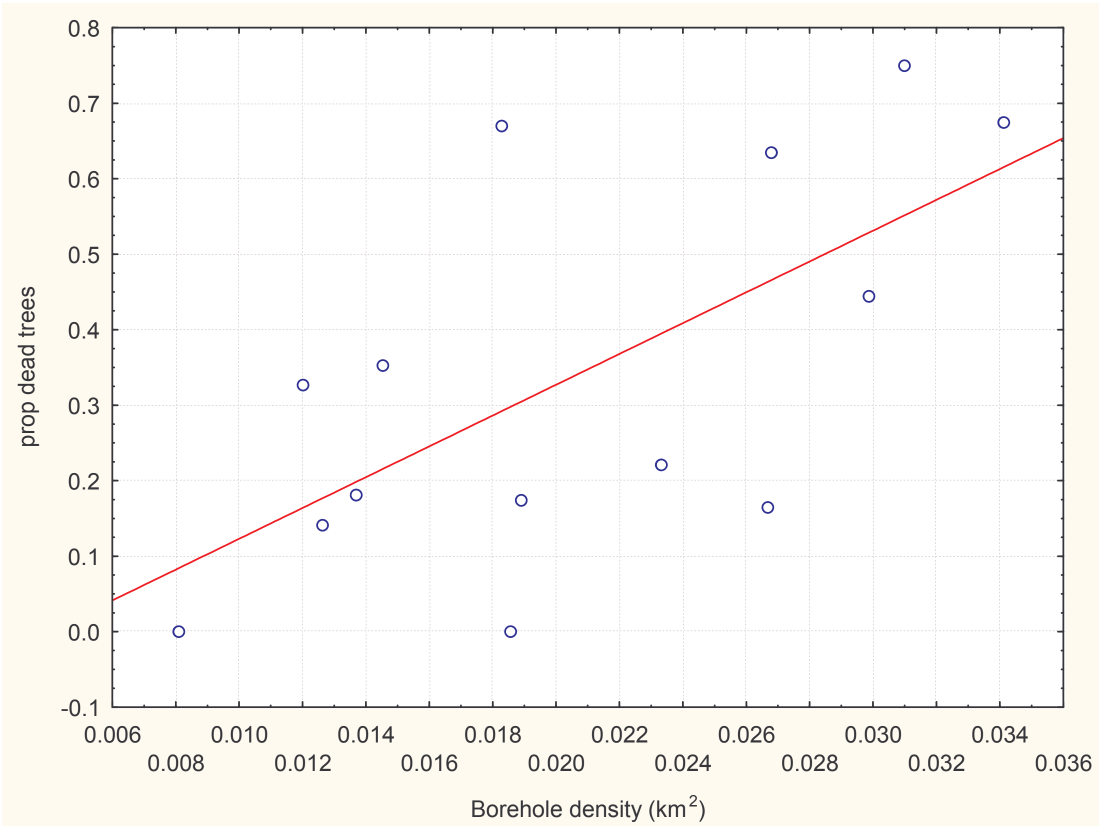

Figure 4a. *Relationship between borehole density and proportion of dead trees (fixed point photograph data).* $R^2 = 0.413$, $p = 0.013$, $n = 14$.