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IMPACT OF ELEPHANT ON THE LARGE TREES OF CLEVELAND, 2014 to 2016

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7th November 2016

SUMMARY

- The effect of elephants on the biodiversity of Cleveland Game Reserve has been a concern to Palabora Mining Company for many years, as is the case for mangers of other protected areas in the region, including the Kruger National Park.
- Tall trees were selected as the best indicator of the impacts of elephants on biodiversity. In order to assess such impacts, hundreds of tall trees were geotagged in transects throughout Cleveland and a benchmark site in the Kruger National Park (KNP).
- Damage and loss of tall trees were no greater in Cleveland than in KNP, with no net loss of tall trees in riparian areas over a two year period. In contrast, there was a substantial loss of tall trees over the two-year study period in dryland (non-riparian) areas in both sites.
- These results indicate that elephant impacts on biodiversity are not currently a concern. While elephants are undoubtedly reducing the abundance of tall trees in Cleveland, this is not happening across all habitats, and is not happening more rapidly than in comparable conservation areas.
- On-going monitoring, combined with research to determine how key components of biodiversity would be affected by reduced tall trees densities, will greatly improve the design and implementation of any future management interventions.

Background

The impact of elephants on the biodiversity of PMC properties, particularly Cleveland Game Reserve, has been a concern for many years. This reflects a more widely held concern about the increasing elephant populations in almost all protected areas in the region, including the Kruger National Park. As elephants move with little restriction between the greater Kruger National Park and Cleveland, there is little that can be done to reduce their impacts in Cleveland to a level below that which is currently occurring within the region. And as long as ecological changes on Cleveland that result from elephant impacts do not exceed those of neighbouring protected areas, then PMC should not be judged to have been negligent in terms on mitigating any negative impacts that elephants have on biodiversity. However, due to the proximity of Cleveland to hard boundaries that restrict elephant movements (the mining areas to the west, and the urban areas to the north), it is possible that that elephants spend more time on Cleveland compared to the more open areas of the neighbouring protected areas. Therefore, it is possible that elephant impacts on Cleveland are higher than in neighbouring areas.

Elephants can potentially impact a wide range of ecological processes, as well as the abundance of other species. Both positive and negative impacts of the overall biodiversity of a savanna ecosystem can occur (Guldemond & Van Aarde 2008), depending on the nature of the ecosystem and density and movement patterns of the elephants living within in. As a thorough study of all the ecological impacts of elephants on Cleveland is not currently feasible, the focus of this project was the tall trees. Tall trees (arbitrarily defined here as trees taller than 10m) are the component of vegetation most impacted by elephants. Furthermore, losses of tall trees are likely to have cascading impacts on a range of species, including some rare and endangered bird species such as the Endangered Martial Eagle *Polemaetus bellicosus* and the Critically Endangered White-backed Vulture *Gyps africanus* (Taylor *et al.* 2015). Therefore tall trees are considered a good indicator of elephant impacts in general (Scholes & Kruger 2011).

The abundance of tall trees has been declining in many parts of the Kruger National Park (KNP) for decades, which is at least partly due to increasing elephant impacts (Eckhardt *et al.* 2000; Asner & Levick 2012; Vanak *et al.* 2012). To determine if tall tree losses are occurring at comparable rates in Cleveland, and in order to establish a baseline of data to monitor future elephant impacts, a new monitoring project was established for the tall trees on Cleveland. A nearby area of the Kruger National Park, of a similar area and with similar habitats, was included as a benchmark site against which changes in Cleveland could be assessed (referred to as "KNP" hereafter). The riparian zones of the Olifants and Selati Rivers were not included here, as the trees in these unique habitats are being monitored in a separate project and will be reported on separately.

The following responses variables were included:

1. The **density** of tall trees. A lower density may indicate that elephant impacts have been higher in the recent past, and declining density provides the most compelling evidence of elephant impacts.
2. The **rate of loss** of tall trees. High rates of loss are likely to be the result of elephant damage, as the mortality of undamaged trees appears to be very low. Note that mortality is not the only form of loss – reductions in height to below 10m, resulting from dieback of the canopy or snapping or pushing over of trunks, also results in an effective loss of a tall tree, even though the tree may remain alive and might regrow to above10m in the future.
3. **Damage** to tall trees from elephants. Greater rates of damage could be used as an early warning of future reductions in density, and can be used to understand and predict changes in the abundance of individual species.
4. Mortality and damage to **recruiting trees**, i.e. trees that are less than 10m but are still growing and will eventually become tall trees. Death or recurring damage to these trees will ultimately result in a reduction in tall trees, regardless of tall tree loss rates.

Methods

Large trees were geo-tagged by walking long transects of 5 m width and taking a GPS record of every tree taller than 10m. This was completed between June and August 2014. Transects varied in length between 1.8 and 6.8km, with a maximum of 26 trees sampled per transect. The species of each tree was recorded, the height measured using a laser clinometer, and a photograph taken. Any elephant damage was recorded according to the following categories:

- branches broken,
- trunk broken above the first branch,
- trunk broken below the first branch,
- trunk snapped or pushed (and degree to which pushed),
- debarking of the trunk (including an estimate of the percentage of the circumference removed, and the percentage of the height between the ground and the first branch removed).

For each tall tree sampled, the nearest tree of a height between 5 and 10m was recorded in the same way (height was measured using either a telescopic height pole for trees less than 8.5m tall, as this method proved more accurate than the laser clinometer). This was done to get an estimate of damage to juvenile trees that might one day replace the existing tall trees.
Eight transects were sampled in Cleveland, and eight in KNP (see Figure 1). All the previously recorded trees were then relocated and reassessed for elephant damage, from June

to August 2016. Of the 786 trees tagged, 27 (~3.5%) could not be relocated in 2016. Each transect was divided into sections of riparian or non-riparian (dryland) habitat, using current Google Earth imagery.

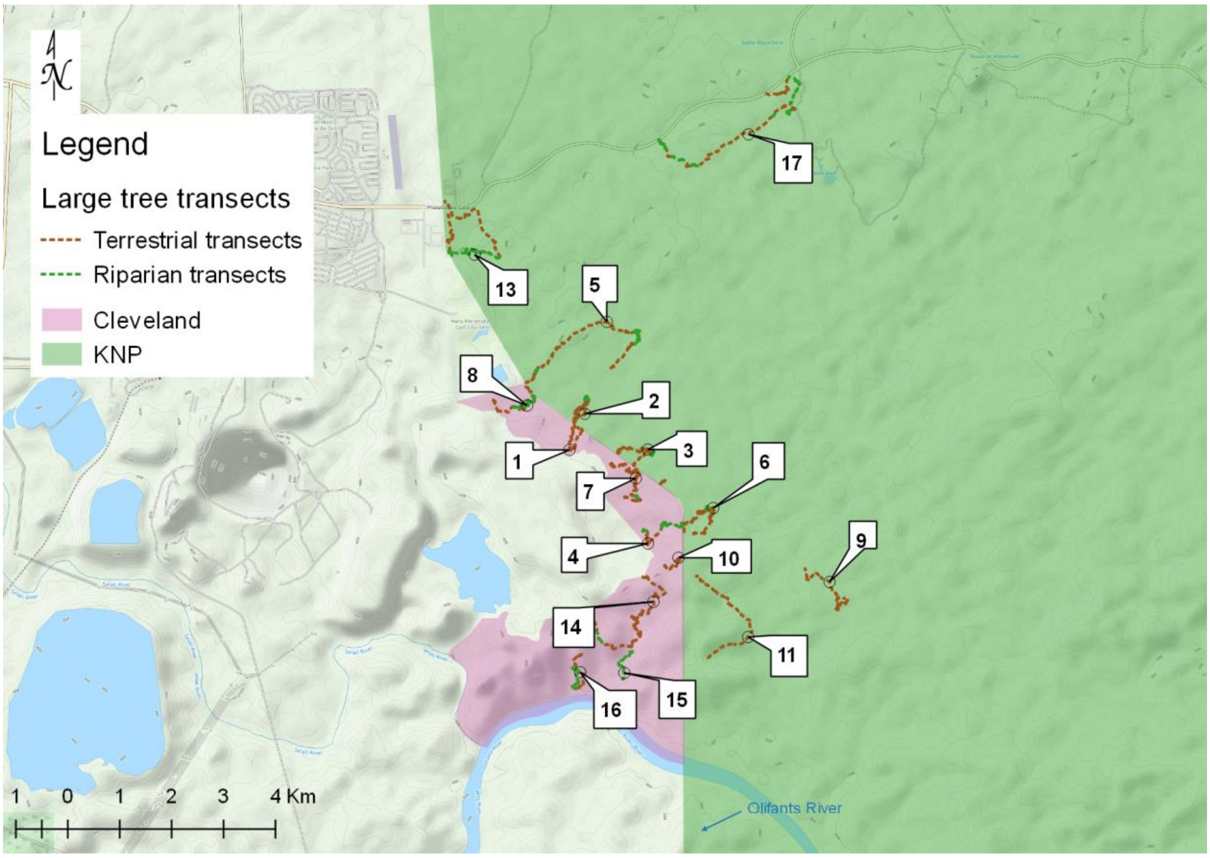

Figure 1. A map showing the location of the transects in the Cleveland and a neighbouring part of the Kruger National Park. The location of trees taller than 10m is shown by dots, with green dots indicating riparian trees (i.e. those growing alongside drainage lines or rivers) and brown dots indicating trees growing in dryland areas upslope of riparian zones.

Results

Tall tree densities

Throughout the study area, the density of tall trees was far higher in the riparian zones along than in dryland habitat, and for both habitat types there were considerably more tall trees in Cleveland than in KNP (Figure 2).

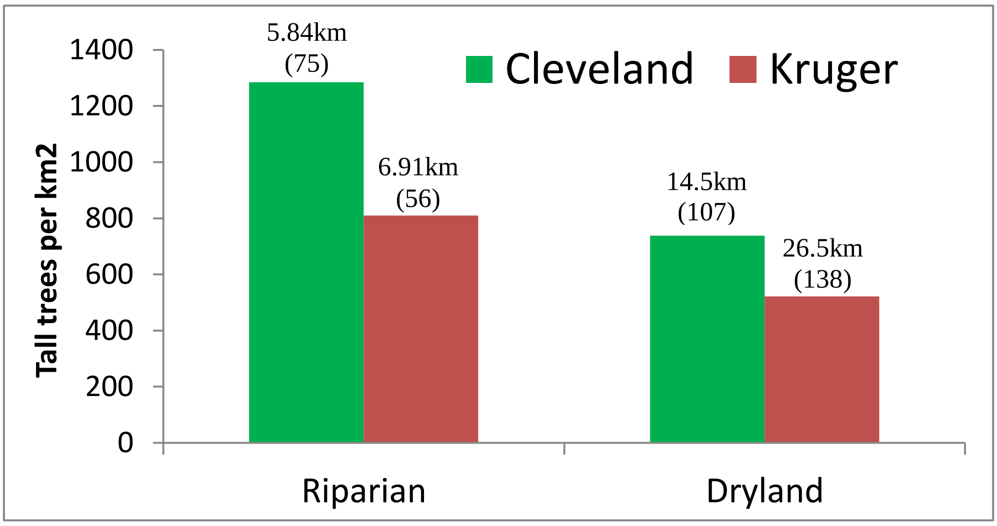

Figure 2. The density of tall trees in the 8 transects in Cleveland and in KNP, for the initial sample in 2014. Trees are grouped according to habitat where they were located: riparian or dryland (non-riparian). Numbers above each bar show the total transect length sampled, as well as the number of trees recorded (in parentheses).

Loss of tall trees

Of the 387 trees taller than 10m recorded in 2014 and relocated in 2016, only 5 had died by 2016. Most of these were on Cleveland (Figure 3a). However, only one of the deaths could be positively attributed to elephants (a Knob-Thorn, , which was pushed over). One of the others showed minor debarking, while no major damage was recorded for the remainder. Considering the very low rainfall for the summers of 2014-15 and 2015-16, it is likely that drought was the cause of the mortality of the others. In addition to mortality, many tall trees were reverted to a height of less than 10m. This occurred almost exclusively in dryland habitats, and occurred more frequently in KNP than in Cleveland. Combining mortality and reversion, the overall loss of tall trees was similar for both sites (7.4% in Cleveland, and 7.6% in KNP).

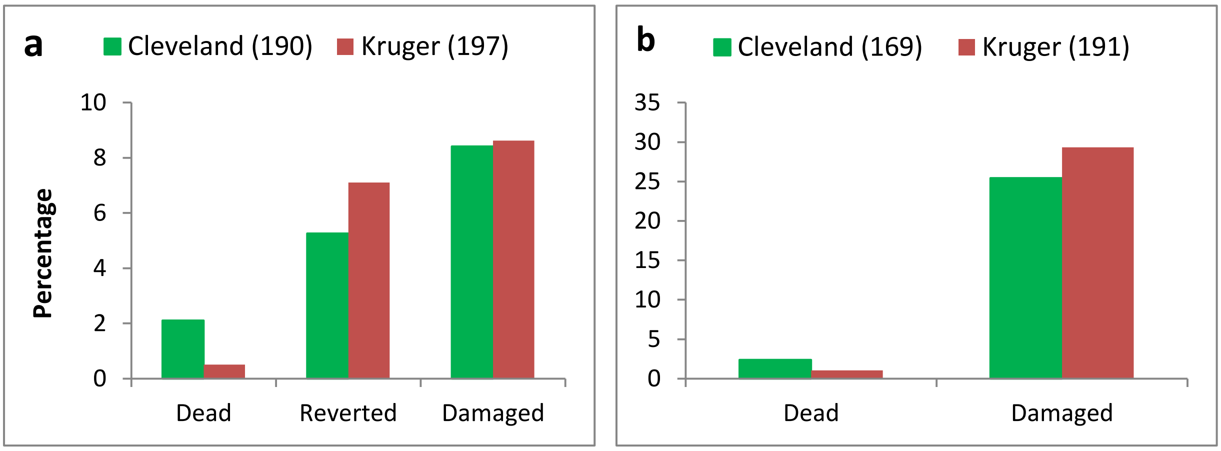

Figure 3. Mortality and damage to trees in Cleveland and KNP between 2014 and 2016. **a)** The percentage of tall trees that died, were reverted from a height of above 10m to less than 10m, or suffered elephant damage of any type. **b)** The percentage of tagged trees of 5-10m height in 2014, that died or were damaged by elephant. In the legends, numbers in parentheses indicate the number of trees included in the sample for each height category at each site. Elephant damage included debarking and pushing or snapping of trunks, but excluded trees which only suffered breaking of branches.

Elephant damage

When considering all forms of elephant damage, including trees reverted to less than 10m and others that were damaged but maintained their height, the incidence of damage was very similar for Cleveland and KNP (Figure 3a). For recruiting trees (trees between 5 and 10m tall), patterns of mortality and damage were similar, with mortality higher in Cleveland and damage slightly more common in KNP (Figure 3b).

Comparisons between Cleveland and KNP were checked for the potentially confounding effect of distance to water. As transects in KNP were spread over a large area than those in Cleveland, it is possible that some were located further from water and that this resulted in an underestimate of elephant damage. In other words, the benchmark area in KNP may not have been representative of the environmental conditions (pertaining to elephant damage) in Cleveland. However, there was no relationship between the distance of a transect to the nearest permanent water source, and proportion of tall trees on that transect damaged by elephants (Figure 4a). Transects nearest to water showed an overlap in damage values for those in Cleveland and KNP, and transects farthest from water actually had the highest damage values. A similar pattern was found when considering trees 5-10m. Similarly, no effect was found when a similar analysis was done using the distance of individual tall trees to water. Figure 4b shows which water sources were used for calculation of these distances.

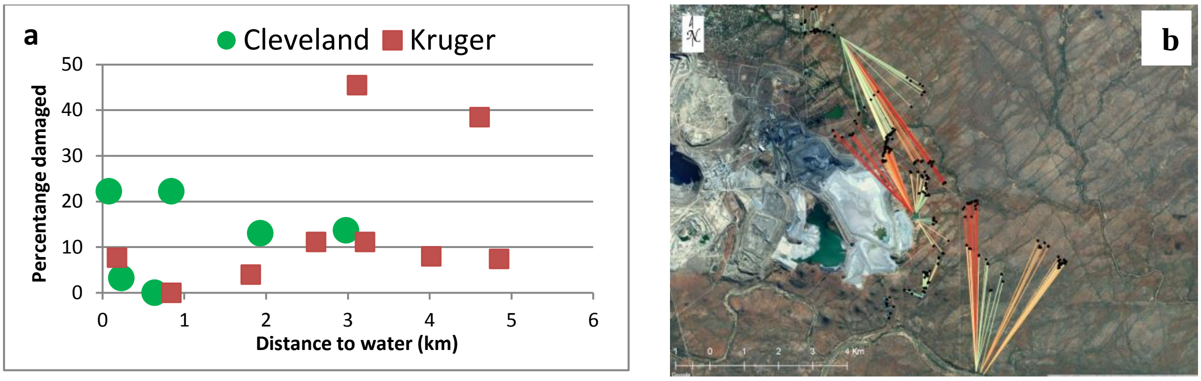

Figure 4. The effect of distance to water on the frequency of elephant damage: **a)** the proportion of tall trees with elephant damage for each transect, versus the distance of the transect to the nearest permanent (perennial) water source. **b)** a map showing the nearest water for each tall tree tagged (black dots) in dryland habitat (the same water sources were used for calculating distances for the riparian trees). For each transect, the mean of the distances for each tree was used to calculate a single "distance to water" value.

Changes in density

Despite the widespread damage, a number of recruiting trees were found to have grown taller than 10m by 2016. Most of these were in riparian habitats, and as a result the density of tall trees had actually increased in riparian sections of the transects, with a substantially greater increase in Cleveland than in KNP (Figure 5). This was not the case in dryland areas, where losses exceeded recruitment, and to a greater extent on Cleveland.

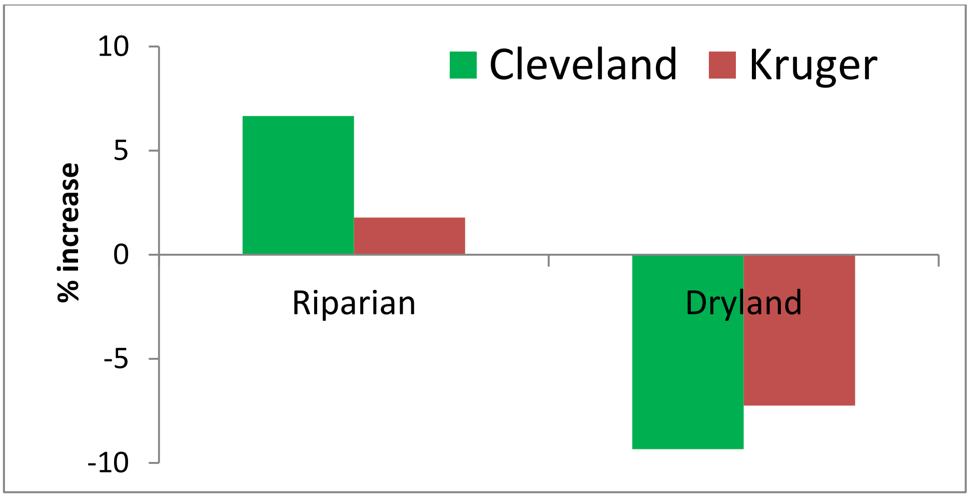

Figure 5. Change in the density of tall trees between 2014 and 2016 (as a percentage of those present in 2014), for the riparian and dryland habitats sampled in each site.

Species differences

Differences in damage amongst species were also considered, for a better understanding of the tall tree population processes, and to investigate whether elephant impacts may be causing the loss of particular species. A total of 16 tall tree species were recorded (Table 1), with two species (Mopane and Leadwood) making up over two thirds of all tall trees in both sites. In Cleveland, the Tamboti was the third most common species, being abundant in riparian habitats and occurring at a similar density to the Leadwood when considered across both habitats. In contrast, the Apple-leaf was the third most common tall tree species in KNP, and the dominant species in riparian zones, while Tamboti was absent. The remainder of the species made up only 13% of all tall trees recorded.

There was little difference in the proportion of individuals damaged by elephants, for any of the common species, for both tall trees and recruiting trees. For two of the most common riparian trees (Apple-leaf and Tamboti) there was no significant elephant damage.

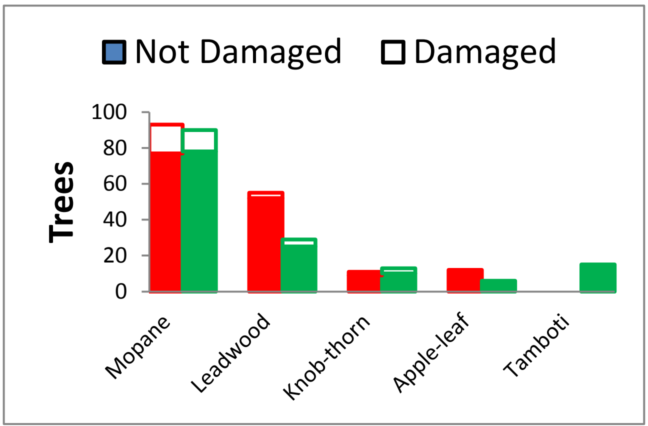

Figure 6. The number of tall trees (>10m tall) recorded in the 8 transects in KNP (red bars) and Cleveland (green bars). Solid shading indicates trees for which no elephant damage was evident in either the 2014 or 2016 survey, while open bars indicates the number of trees with some form of damage. Cleveland and KNP.

Table 1. The abundance (as a percentage of total per site) of all tall trees recorded in Cleveland and KNP, in 2014.

Common name	Scientific Name	Cleveland	KNP
Mopane	*Colophospermum mopane*	50.6	47.9
Leadwood	*Combretum imberbe*	16.3	28.4
Tamboti	*Spirostachys africana*	8.4	0
Knob-thorn	*Acacia nigrescens*	7.3	5.7
Jackle-berry	*Diospyros mespilliformis*	5.1	1.0
Apple-leaf	*Philenoptera violaceae*	3.4	6.2
Weeping Boer-bean	*Scotia brachypetala*	2.8	0.5
Marula	*Scelrocarya birea*	2.2	3.6
Brown Ivory	*Berchemia discolour*	1.1	1.0
Nyala Tree	*Xanthocercis zambesiaca*	1.1	1.0
River thorn	*Acacia robusta*	0.6	0
Torchwood	*Balanites maughamii*	0.6	0
Purple-pod Cluster-leaf	*Terminalia pruniodes*	0.6	0
Russet Bushwillow	*Combretum heroreonse*	0	4.1
Sycamore Fig	*Ficus sycomorus*	0	0.5
Total Tall Trees		178	194

Discussion and implications for management.

Overall, these results indicate that despite high levels of elephant utilization of trees in Cleveland, tall trees are not declining at a faster rate than a comparable area in the Kruger National Park, and are apparently not declining at all along the seasonal rivers and drainage lines of Cleveland. However, in non-riparian (dryland) densities of tall trees declined substantially over the 2 year monitoring period. These declines were not much greater in Cleveland than in KNP, and may represent unusually high rates due to the severe drought that occurred over the study period. It is possible that declines would be slower in years of average or above-average rainfall, although there would have to be a large difference for changes in density to reach zero or become positive. Even at lower rates of decline than those found here, tall trees will be eradicated from Cleveland and KNP at some stage in the future - it is simply a question of when (at current rates, it would take 140 years).

The lack of decline in tall trees in riparian areas, where most tall trees occur, was surprising. A great number of damaged and pushed-over trees are seen on Cleveland, and the perceptions of people who regularly visit the property or nearby parts of the Kruger National Park is that elephants are "destroying the trees". Furthermore, this result contradicts the results of similar studies in the Kruger National Park. For example, Eckhardt *et al.* (2000) found a decline in the cover of trees taller than 5m for range of sites in the southern half of the Kruger National Park, based on analysis of aerial photographs taken between 1940 and 1998. Another study, using a method very similar to the one used here, found a mortality of 10% for all trees taller than 5m, and 9% for trees taller than 9.6m (compared to <2% for both categories here) in the southern parts of the Kruger National Park between 2006 and 2008 (Vanak *et al.* 2012). However, losses of tall tree in these studies are acknowledged to be due to the combined effect of elephant and fire in the southern parts of the Kruger National Park, where rainfall and grass productivity are higher. The absence of fire on Cleveland may be a key factor explaining the persistence of the tall tree layer, at least in riparian zones. Results from another study conducted at a site in northern Kruger National Park, where soils, rainfall and fire regime are more similar to Cleveland, reported loss rates comparable to this study (Asner & Levick 2012). In this study, airborne LiDAR was used to map and resample individual tree canopies, and a loss rate of between 1.3% and 3%, depending on topographic position, was found between 2008 and 2010 (although this was for trees of all sizes).

Another factor that may be contributing to the stability of the tall tree layer in the riparian zones, is the more rapid growth of recruiting trees. The height growth of trees of 5-10m height, between 2014 and 2016, was surprisingly fast, particularly in Cleveland and particularly for Tamboti. The fairly unique topography of Cleveland, with many small watercourses draining between koppies within the broader valley of the Olifants River, appears to have created many habitats that are favourable for certain tall tree species. As elephants continue to transform the vegetation of the region, the watercourses and drainage lines of Cleveland may turn out to be one of the few areas where tall trees continue to occur, despite high elephant numbers in the area. This would mean that management interventions to limit elephant impacts may never be needed. Continued monitoring, to determine whether recruitment will balance losses into the future, is critical to test this idea. Furthermore, damage to the recruiting tree layer was high, averaging about 25% across both sites and both habitat types. It is possible that on-going damage at this level will reduce the rate of recruitment into the tall tree category, and ultimately lead to a decline of tall trees in the riparian zones as well. On-going monitoring of recruiting trees is therefore critical.

Differences in the densities and damage patterns of the different species making up the tall tree layer provide further insights into why tall trees may be more common, and less susceptible to elephant damage, in riparian zones. It is likely that elephants have all but eliminated the most palatable of tall tree species, such as the Marula and False Marula (Shannon *et al.* 2008), from Cleveland and the KNP site, as few of these were recorded in the transects. The Knob-thorn and Leadwood, which are apparently less palatable but are still selected by elephants, are still fairly common, but appear to be suffering higher loss rates, and high rates of damage to recruiting trees. In contrast, the Mopane, Apple-leaf and Tamboti appear to have low elephant-induced mortality and adequate rates of recruitment. The current impact of elephants therefore appears to be the replacement of more palatable tall trees by less palatable tall trees, with little effect on the overall density of tall trees. In other words, while the composition of the tall tree layer may well be changing drastically, the structure may not be. The implications of this for biodiversity in general, and for bird species of conservation concern in particular, are not known but seem unlikely to be significant.

Based on the above interpretations, as well as personal observations of change to the tall tree layer, it is concluded that tall tree losses in Cleveland are no greater than in a comparable benchmark site, that elephants are not impacting biodiversity significantly as yet, and that management intervention is not currently required to reduce elephant impacts. This is not to say that elephants are not changing the tree layer of Cleveland. The results indicate that while tall trees will persist in riparian zones for the foreseeable future, they will be reduced to very low densities in the dryland areas in between them. In addition, the species composition of the tall tree layer is likely to change considerably, with many previously common species (such as the Marula) disappearing from it. The consequences for biodiversity, of a tree layer where tall trees only occur in riparian zones, and where tall trees are comprised of only a few species, needs to be investigated. Furthermore, the elephant population of the Kruger National Park continues to increase, and monitoring should continue to detect if impacts are increasing. Finally, studies to determine a minimum threshold for tall tree densities in riparian zones, below which substantial losses to biodiversity would occur, would be invaluable for guiding future decisions to restrict elephant impacts

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