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Biodiversity Monitoring conducted on PMC properties, January to July 2011

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This report describes monitoring work conducted by the SAEON Ndlovu Node on the properties of the Palabora Mining Company (PMC), during the period 1 January to 31July 2011. The work was initiated in response to the need to monitor changes in biodiversity, in accordance with PMC's Biodiversity Action Plan.

1. Biodiversity features

1.1. *Plant diversity*

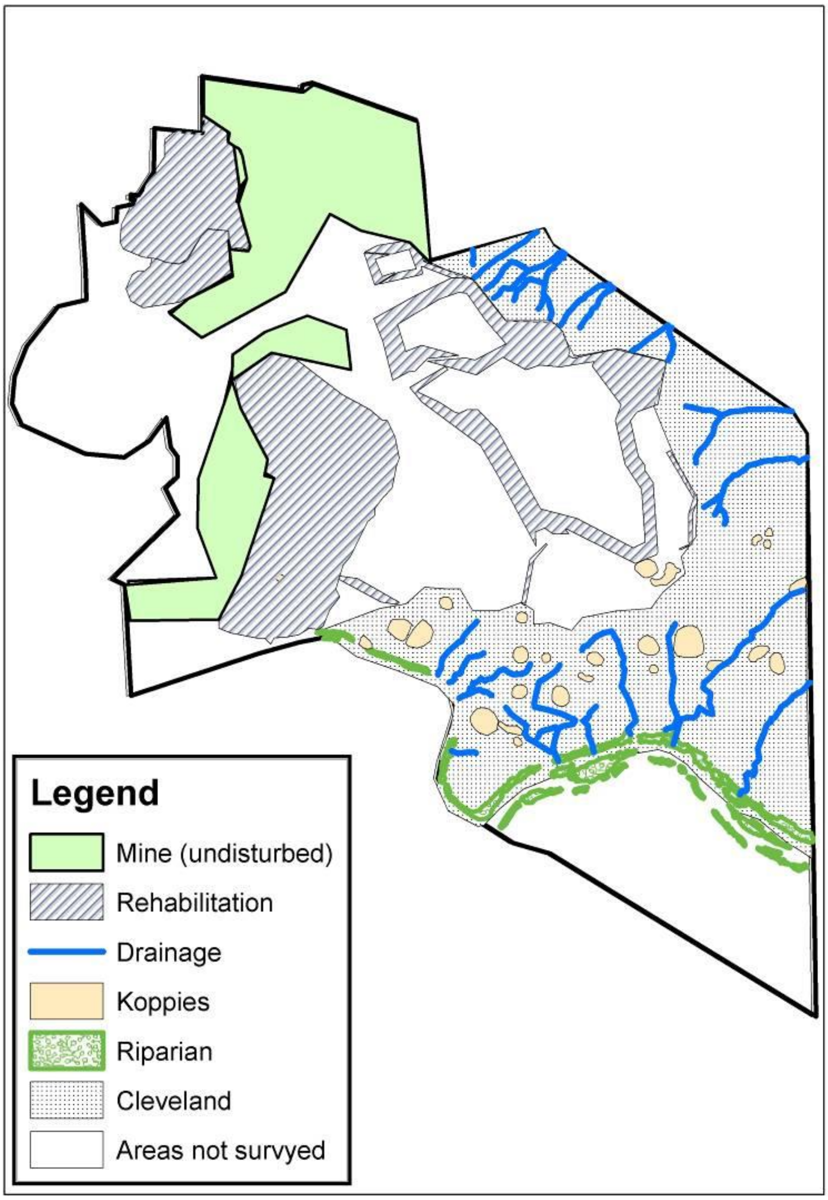
1.1.1. Spatial patterns of plant diversity

The maintenance (or even enhancement) of plant diversity on PMC requires that spatial patterns of diversity be established, to identify diversity "hotspots" and priority areas for management interventions. For this purpose, vegetation on PMC and Cleveland Nature Reserve was categorized into homogenous vegetation units, on the basis of high resolution aerial photography. Eight homogenous vegetation units were subjectively defined:

- i) **Cleveland (terrestrial):** terrestrial areas of Cleveland, excluding koppies, drainage lines and riparian vegetation
- ii) **Drainage lines**: vegetation associated with non-perennial streams on Cleveland
- iii) **Koppies**: vegetation occurring on the isolated seyenite intrusions on Cleveland, upslope from (and including) the band of *Croton gratissimus* trees that typically occurs at their base
- iv) **Rehabilitation:** rock dumps and the slopes of slimes dams, where vegetation is in a process of active or passive rehabilitation.
- v) **Mine (undisturbed):** areas within the mined area that have not been physically disturbed
- vi) **Riparian**: vegetation alongside perennial rivers on Cleveland (Olifants and Selati rivers)
- vii) **Wetlands**: vegetation around natural pans on Cleveland
- viii) **Artificial wetlands**: wetlands and fringes of dams within mined area

The distribution of these is shown in Fig 1.

Figure 1. The distribution of homegenous vegetation units on PMC mined area and Cleveland Game Reserve. **Artificial wetlands** and **Wetlands** are not shown due to their small size.



1.1.2. Plant species inventory

An inventory of plant species was collected for each vegetation type in February 2011, by an independent contractor (Brenden Pienaar). For **Koppies,** the nine largest koppies were surveyed, and species were recorded separately for each. This will allow for assessment of species loss (or gain) on these specific koppies in future years. Data for **Rehabilitation** were supplemented by a species list obtained from Dr Mike Peel (ARC-RFI) based on vegetation surveys conducted on the PMC dumps and dams between 1998 and 2009. All species recorded were categorized into the following functional groups, according to life form: **woody** (trees and shrubs), **grass**, **sedge**, **forb** (herbs and shrublets) and **vine** (including scramblers and creepers).

A total of 305 plant species were recorded across all eight vegetation units. 287 (94%) are indigenous to South Africa, although approximately 5% of are not indigenous to the region, and appear to have established on disturbed areas of PMC beyond the border of their natural range (more detailed study would be necessary to confirm the identity and number of these species). Only two of the recorded species are listed as being of "Conservation concern" by SANBI[1]: the tree *Elaeodendron transvaalense* listed as "Near threatened" and the tree *Balanites maughamii* listed as "Declining". None of the species recorded are listed as Threatened species.

Of the indigenous species, approximately 49% are trees or shrubs, 27% forbs and 23% grasses, with ferns, sedges and vines making up only about 1%.

The highest number of indigenous species were recorded in the **Cleveland (terrestrial)** and **Rehabilitation** units, as a result of their large area (Table 1). When accounting for differences in area, the **Drainage Lines** and **Wetlands**, support the greatest density of species, following by the **Koppies** and **Riparian.** 137 (45%) of the species occurred in only one of the eight vegetation units. The relatively high number of species unique to the **Koppies** make this unit of even greater importance that the other species-rich units. Within the local area, many of these unique species are only likely to be found in very small and isolated populations within the protected areas neighbouring PMC, on similar koppies, although they also occur further afield, in the far north of the Kruger National Park. While the **Rehabilitation** unit had a larger number of unique species, many of these are species that do not naturally occur in the region. **Cleveland, terrestrial** also had a large number of unique species, but most of these would be common in conservation areas surrounding PMC.

Table 1. The number of indigenous species recorded for the eight homogenous vegetation units on PMC mining area and Cleveland, February 2011.

					Species per functional group:					
Unit	**Area (ha)**	**Species**	**Species Density (/ha)**	**Unique Species**	**woody**	**grass**	**forb**	**sedge**	**vine**	**fern**
Drainage lines	2.5	87	35	8	41	18	26	1	1	0
Artificial wetlands	1	13	13	0	0	9	2	2	0	0
Wetlands	1	10	10	2	5	3	0	2	0	0
Koppies	79	123	1.6	33	73	17	31	0	1	1
Riparian	69	70	1.0	14	37	15	18	0	0	0
Rehabilitated	942	135	0.14	51	66	52	15	2	0	0
Cleveland,terrestrial	1602	138	0.09	27	68	25	44	0	1	0
Mine, undisturbed	1327	49	0.04	2	19	10	19	1	0	0

For Cleveland as a whole, data from this survey indicate a species density of about 0.1 species / ha. This is well below the more floristically diverse biomes in the region, such as fynbos and grasslands (where species densities can be as high as 82 species / ha [2]). However, it is high compared to the value for the whole of the Kruger National Park (roughly 0.001 species / ha). While species density would vary considerably within the Kruger National Park, and may be much higher for certain sections of a similar size to Cleveland, this result does still indicate that Cleveland is high in plant species richness relatively to other protected areas in the region. Furthermore the values for species richness presented here are crude, and most likely underestimate true values (particularly for the larger vegetation units). This survey was not exhaustive as the primary purpose was to compare plant species richness between the vegetation units. A brief comparison of data from this survey with records of species recorded by staff on Cleveland and by other consultants suggests that around many species (indigenous and alien) were missed in this survey. Nevertheless, the large differences found between vegetation units clearly reveal the disproportionately high diversity of plant species found in the **Wetlands**, **Drainage lines** and **Koppies**.

[1] SANBI Red List of South African Plants version 2011.1, http://redlist.sanbi.org, accessed on 18 August 2011.

[2] **Huntley B J**. (ed.) 1989 ***Biotic Diversity in Southern Africa - Concepts and Conservation*** Oxford University Press, Cape Town, 136-147.

1.2. *Faunal diversity*

1.2.1. Amphibians and reptiles

A survey of amphibians and reptiles was conducted by external contractors at SAEON's request in November 2010 and January 2011. The reptile survey was conducted by Marius Berger of Sungazer CC. The amphibian survey was started by Jerry Theron (Mpumalanga Parks and Tourism Authority) but finished by Marius Berger. A report with results was to be compiled by Marius Berger and sent to SAEON by March 2011, but is still outstanding. These consultants have not been paid, and the funds budgeted for this work are available to be spend on new surveys by different specialists.

Results from previous faunal surveys show that patterns of faunal diversity probably correlate well with the patterns of plant diversity for most faunal taxa. The 8 vegetation units described above will may therefore serve as useful units for the monitoring and management of faunal diversity as well. For example, amphibians show far greater species richness in the **Wetlands** and **Artificial wetlands** while reptiles are most diverse on the **Koppies**.

2. Biodiversity Trends

2.1. *Trends in plant diversity*

Systematic sampling of plant diversity would need to be repeated for a number of years before any accurate trends in plant diversity could be established. This would also require estimates of the abundances of each species, which was not included in the inventory work described above. However, three sources of vegetation survey work done previous on PMC allow for a cursory analysis of changes in plant species richness, i.e. an estimate of whether plant species have been lost (or gained) over the past decade: 1) a previous vegetation survey of Cleveland, 2) repeated sampling of herbaceous species composition on the rehabilitation areas of PMC, 3) repeated veld condition assessments on Cleveland.

2.1.1. Previous survey of Cleveland

A classic phytosociological survey was conducted on Cleveland and other undisturbed areas around PMC and FOSKOR by Nigel Beck in 1998, for the purposes of an Honours thesis on Wildlife Management. This is referred to here as Beck1998, and was compared to data from the SAEON species survey (referred to as Pienaar2011). For this comparison, only data for Cleveland from each survey were compared.

For all vegetation units on Cleveland, Pienaar2011 found a total of 127 species, while Beck1998 recorded 105 species. Only 53 of all these species were common to both surveys. 141 species recorded by Pienaar2011 were not recorded by Beck1998, and 52 recorded by Beck1998 were not recorded by Pienaar 2011. This implies that within a period of 13 years, 52 species went extinct on Cleveland, and an additional 104 species colonized the same area. This apparent changes include a lost of 21 woody species and a gain of 61 woody species. This is obviously incorrect, and only serves to illustrate the danger of using species lists as a means to monitor changes in biodiversity over time. These massive errors in species turnover would have resulted from errors in the identification of less common plants (during both surveys), differences in the season of sampling (resulting in short-lived annuals being overlooked), and differences in the size and location of the plots or areas surveyed.

Considering the longevity of most savanna plants, and the stable ecological conditions prevailing on Cleveland over the past decade or so, it is highly unlikely that more than a few species have been lost from Cleveland, and these would probably be annual forbs. However, one plausible change that is evident from this comparison is an increase in the number of alien plant species recorded in the riparian vegetation and along the large drainage lines: Beck1998 only recorded two alien species, while Pienaar2011 recorded 12.

2.1.2. Herbaceous species composition on the rehabilitation areas

Detailed sampling of the frequency of herbaceous plant species on over 100 sites on rehabilitation areas on the dumps and dams on PMC provide an opportunity to detect changes in community composition between 1998 and 2007. These data were initially collected by an unknown consultant, and then by Pete Zacharias and finally by Mike Peel and his team from the ARC. Raw data from these surveys is required, and this has been requested, but not yet received, from Mike Peel.

2.1.3. Veld condition assessments on Cleveland

Data on the frequency of species recorded during step-point surveys conducted by Mike Peel and his team provide an opportunity to detect changes in the herbaceous vegetation on Cleveland between

2002 and 2011. The method used is not rigorous enough to accurately measure the abundance of less common species, but might reveal changes in the abundance of dominant herbaceous species. Raw data from these surveys is required, and this has also been requested, but not yet received.

For 2011, Mike Peel was contracted by SAEON to repeat these assessments on the Cleveland and Pompey properties. Data and report from this work are still outstanding, but expected before year end.

2.2. *Functional diversity of the rehabilitation areas*

Landscape function analysis was initiated on the dumps and dams of PMC in 2009, by Mike Peel and his team. A total of 142 sites were sampled using standard LFA methods. This work was repeated in May 2011, by the same two ARC technicians who conducted the first sampling. Data are still to be captured, and are expected before year end. These will be compared to the 2009 data to analyze changes in the cover and functioning of the herbaceous plant community at these sites.

A pilot project was initiated at 5 of the LFA sites (located on the rock dump) to investigate the feasibility of monitoring grass production within the rehabilitation areas, and to determine whether the use of these areas by large herbivore abundances could be increased. This involved clipping a 10m x 10m plot around the selected LFA sites (plots were aligned to have the 10m LFA transect dissect them). For each selected site, and an additional plot located on a flat area directly below the LFA site was also clipped. The plots were clipped to stubble height, in an attempt to encourage large herbivores to graze on them in the following summer. Control sites were also selected to allow for measuring any increases in grazing and grass production that may result from this intervention.

Within each plot (clipped and control), 10 quadrats of $0.25m^2$ were clipped separately and the clipped material dried and weighed, after sorting current-year grass biomass from previous year’s growth. Some of this material is still being sorted, but preliminary data indicates that the net primary productivity of the herbaceous layer is around 320 g/m^2/year. This is considerably higher than values obtained for natural grass communities at a nearby site within the Kruger National Park, indicating that the rehabilitated areas of the rock dump are functioning well, at least in terms of primary production.

3. Threats to Biodiversity

3.1. *Alien plant species*

Alien plant species were recorded in all of the eight vegetation units surveyed by Brenden Pienaar. The **Rehabilitation, Riparian** and **Drainage lines** units harboured the most species (Table 2). The **Drainage lines** contained the greatest density of alien species by far, with a large number of species occupying a relatively small area.

Table 2. The number of alien plant species recorded in the eight homogenous vegetation units on PMC mining area and Cleveland, February 2011.

Unit	Alien Species	Alien Species Density (per ha)
Rehabilitated	10	0.01
Riparian	9	0.13
Drainage lines	8	3.2
Koppies	3	0.04
Cleveland,terrestrial	3	0.002
Mine, undisturbed	3	0.002
Artificial wetlands	2	2
Wetlands	2	2

In March 2011, patches of alien plant infestations were mapped on foot with a GPS by Brenden Pienaar. This aim was to identify areas that are most likely to serve as source areas for the spread of invasive species, and to guide clearing operations. Only patches with complete domination by one or more alien species were included. Fig 2 shows the location of the ten patches recorded. All patches were dominated by a single species, *Flaveria bidentis* (Smelters Bush). The patches covered a combined area of 76 ha but varied greatly in size (Table 3). The majority of this area was made up by a very large patch located in the southern end of the **Mine, undisturbed** unit.

Figure 2. The 10 largest patches of alien plant infestations on PMC and Cleveland, March 2011.

Table 3. The area of the largest patches of alien plants recorded on PMC mines and Cleveland, March 2011. All patches were dominated by *Flaveria bidentis* (Smelters Bush).

Patch	Area (ha)
1	5.69
2	0.77
3	0.84
4	1.43
5	0.86
6	0.97
7	7.04
8	50.00
9	6.88
10	1.53
Total	**75.99**

These patches of Smelters Bush have already eliminated almost all plant and faunal diversity within their boundaries. Even if cleared, it would take many years and probably significant rehabilitation measures for biodiversity to return to natural levels. The growth of these patches is therefore a considerable threat to biodiversity on PMC's properties. The potential for the multitude of other alien species to increase in density from scattered individuals to mono-culture infestations of this type is another significant threat. Finally the infestations of alien plants along the **Drainage lines** on Cleveland, probably serve as source for the spread of alien plant species into the neighbouring terrestrial areas of the Kruger National Park. Infestations on the PMC mining area may also be a source for spread into riparian areas along the Olifant's River in the Kruger National Park, via the Selati River. Therefore alien plants on PMC represent a threat to biodiversity beyond the boundaries of PMC as well.

3.2. *Elephant impacts*

Nine permanent tree monitoring plots were established in May 2011 on Cleveland, with the primary purpose of monitoring elephant impacts on vegetation structure. The sites were selected in areas that support a high diversity of trees, and where elephant impacts appear to be most severe. Fig 3 shows the location of these sites, six of which are on the slopes of two koppies, and three within the larger patches of riparian vegetation.

Plots are circular and marked with a steel bar hammered into the ground to mark the centre point. All woody species that were within a 5m radius extending from the centre, and were of 30cm high or taller, were marked with an aluminium disc and measured (basal stem diameter, height, canopy length and canopy width. Red spray paint was used to mark the place on the base of the stem were trees the diameter (or circumference) was measured, so that measurements can be done in the same place each year. Any elephant damage was also recorded. Some additional trees that were beyond 5m radius, but within 20m radius, were also marked and measured. These were selected in order to include a range of tree sizes, for species of interest. Within the 5m radius woody plants less than 30cm were counted, as were seedlings of woody species (seedlings being plants that had germinated the previous summer).

Figure 3. The location of the nine tree monitoring plots established on Cleveland in May 2011.

A total of 264 trees and shrubs were marked and measured in the nine plots Of these 167 (63%) had some visible sign of elephant damage, ranging from severe impacts such as the main stem (or trunk) pushed over and snapped, to the minor impacts such as the loss of leaves and twigs. 27 individuals had damage that appeared to be inflicted within the past year, indicating an approximate rate of 10% of woody plants impacted by elephants per year.

Elephant impacts varied considerably between the nine plots, but there was a rough pattern corresponding to topographic position (Fig 4), with impacts generally highest in the area between koppies and lowest in the plots located highest up the koppies.

Figure 4. The percentage of marked trees and shrubs damaged by elephants for plots grouped according to topographic position ("koppie, top" refers to the highest plots, located just beneath the start of the cliff faces on the koppies). Bars show the mean % for 2 or 3 replicate plots, and error bars show 1 standard deviation.

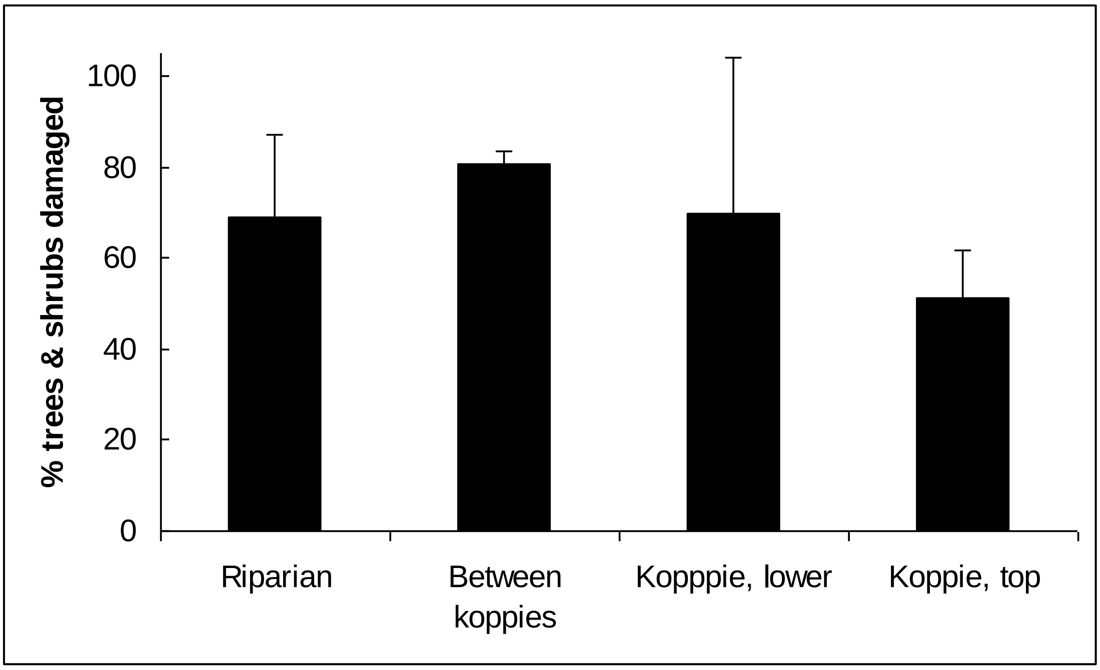
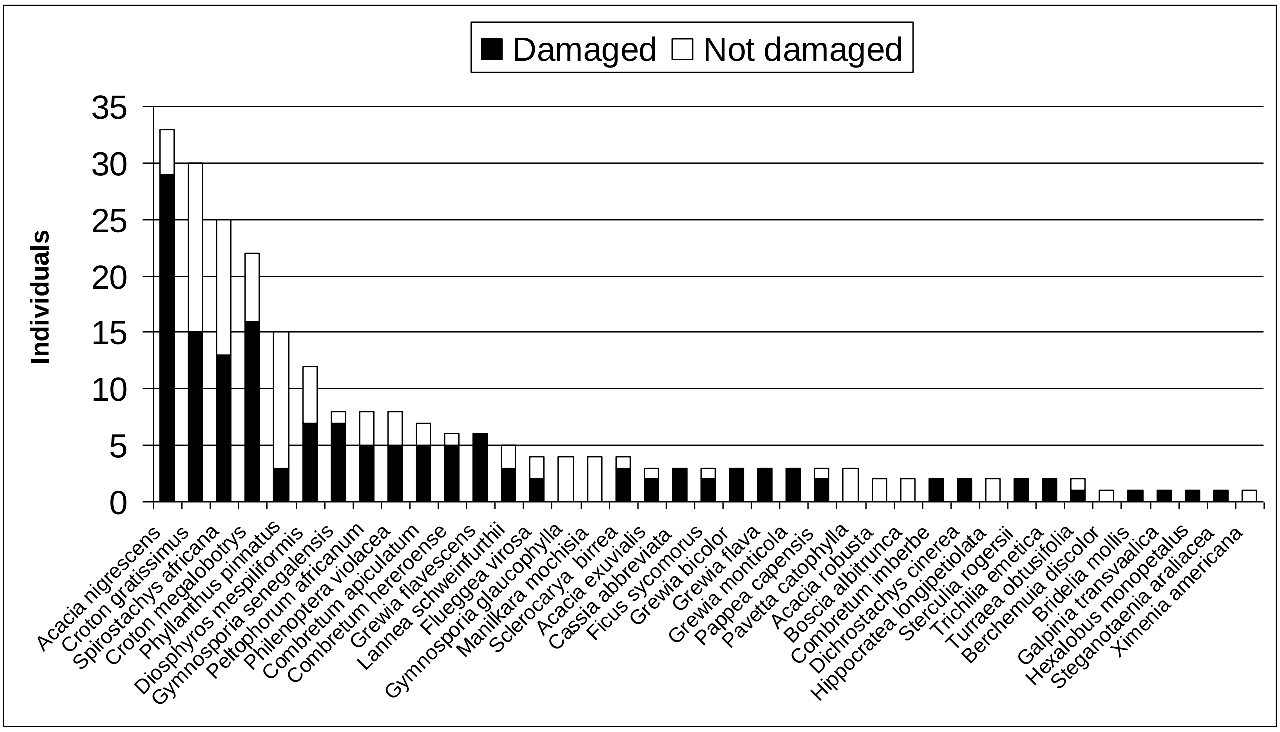


Fig 5 shows the frequency of individual species that were marked, as well as the proportion of these that have experienced some form of elephant damage. For most species, too few replicates were encountered to allow for accurate estimation of how elephant impact varies by species, or to detect changes in the population structure of these species in the future. Only the four most abundant species (*Acacia nigrescens, Croton gratissimus, Spirostachys Africana, Croton megalobotrys*) have sufficient replication for monitoring the impact of elephants on a species basis. Nevertheless, the results for these species indicate how widely elephant impacts differ by species – almost all *Acacia nigrescens* encountered had been impacted, only about 50% of *Spirostachys* Africana and *Croton megalobotrys*. A large number of dead *Acacia nigrescens* trees were also observed in some areas. Together these initial observations suggest that elephants may be in the process of changing the tree community composition Cleveland, with species less impacted by elephants slowly replacing the current dominant species. The consequences of this for the diversity of other species is all but unknown at this stage.

The establishment of a similar number of additional plots would allow for more of the common species to be included in this type of species-level monitoring. However, hundreds of such plots would be needed to monitor changes in the abundance of the rare species. An alternative method would thus be needed to monitor the potential loss of rare tree species that may result from elephant impacts in time.

Figure 5. The number of individual trees and shrubs per species marked and measured on Cleveland in the nine plots. “Damaged” indicates the number of trees with some form of elephant damage (old or recent).



<u>The loss of large trees</u>

These data provide a first step for making predictions about how the structure and diversity of the tree layer on Cleveland is likely to change in the future. Many more years of data collection will be required to make any meaningful predictions. However the data collected to date do allow for a preliminary assessment of one aspect of elephant impacts that is most concern to management, namely the loss of large trees. The lost of large trees is considered to be of immediate concern for the management of a conservation area such as Cleveland due to the perceived importance of tall trees for sustaining animal diversity (particularly through the provision of nesting sites for raptors and other birds), and due to their aesthetic appeal.

For the following preliminary analysis, tall trees have been arbitrarily defined as trees with the largest main stem (or trunk) being **15cm in diameter** or larger (note that the tree height is not useful for classifying tall trees, as trees resulting pushed over by elephants would be excluded).

Of the 267 trees sampled, 96 (36%) qualified as large trees. Undamaged trees in this category had heights in excess of 5m. 68% of these trees showed signs of some form of elephant impact, a similar percentage to that found for all trees combined. Elephant impacts of most concern are those that may lead to death of these trees, namely pushing over or snapping of main stems, and debarking (stripped of bark from main stems). 28% of the large trees showed one or more of these types of impact, with 5% appearing to have been impacted in this way within the past year. As many of the trees impacted in this way will survive for at least one year, the rate of loss that can be attributed to elephants is **less than 5% per year**. Whether this rate of loss is balanced by a similar rate of recruitment of trees into the “large tree” size class can only be determined with repeated sampling for many more years. Additional years of data collection will also allow for a more accurate estimate of the rate of loss of tall trees, as the fraction of trees that actually die from elephant impacts will eventually become clear.

Spirostachys africana was the most common species in the large tree category, and the only species for which enough replicates were marked to allow for detecting change in the future (Fig 6). The relatively small frequency of tall *Acacia nigrescens* most likely reflects previous elephant impacts, as many dead *Acacia nigrescens* were observed on the lower slopes of the koppies. Again, more replicate plots would need to be established to allow for accurate monitoring of elephant impacts of these species such as this.

Figure 6. The number of trees per species marked that qualify as "large trees" (i.e. with stem diameters of 15cm or more), and having signs of elephant damage on their main stems (either breakage or bark stripping).