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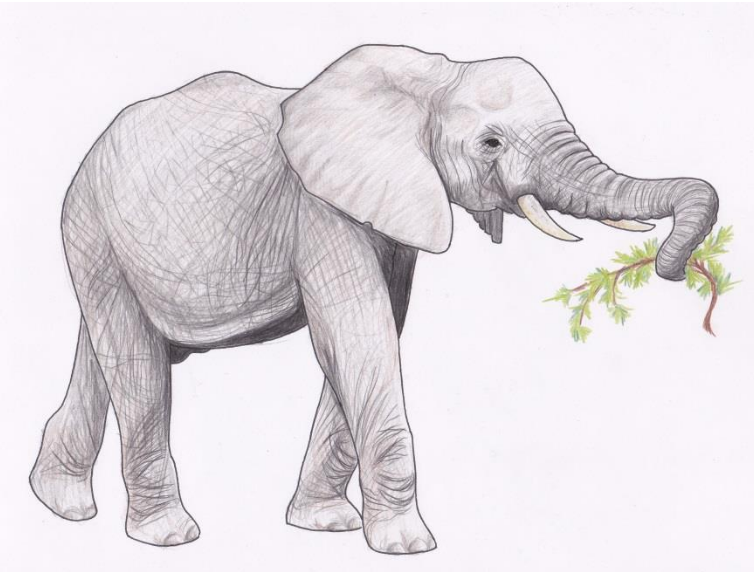
Elefantpåverkan på en hotad skogstyp i Sydafrika

Matilda Apelqvist



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Abstract

Elephants are known to have a big influence on the environment. Their browsing routine includes the breaking of stems and branches, toppling of trees, and bark stripping. This, in combination with other factors, can have negative effects on the vegetation. However, elephants are also important seed dispersers, and their impacts on vegetation can facilitate food availability for smaller herbivores. This study focused on elephant impact on and utilisation of a coastal scarp forest in Hluhluwe-iMfolozi Park (HiP), South Africa. Transects were laid out to quantify the elephants' use of the forest, and additional plots with paired controls were placed in areas with signs of high elephant impact. Elephant impact was recorded on the plots, and they were all fitted with a camera trap to determine what other mammal species were using the same areas. Overall, the elephant impact found was rather old, and there were few indications that the elephants had any major effect on either tree community or animal community in the measured plots.

Introduction

The African elephant (*Loxodonta africana*) is the largest terrestrial animal on earth. It is widely debated whether the African elephant consists of two separate species, the savanna elephant (*L. africana*) and the forest elephant (*L. cyclotis*) or if they are two subspecies (Johnson *et al.*, 2007; Blanc, 2008). Elephants occur in a range of different habitats, in semi-deserts as well as tropical forests (Laws, 1970). They are regarded as ecosystem engineers (Jones *et al.*, 1994), and they have a big influence on the habitats in which they exist (Codron *et al.*, 2006). In Africa in general, there is a high abundance of elephants in some regions, while they are still vulnerable to extinction in other areas (Blake & Hedges, 2004). By the year 1900, there were barely any elephants left in South Africa (Slotow *et al.*, 2005). However, in the 1960s, the elephant population in Kruger National Park (KNP) had increased drastically (Whyte *et al.*, 1999), and individuals were translocated to other state and private reserves in the country. Since all these reserves are fenced, there is no possibility for the elephants to immigrate or emigrate (Slotow *et al.*, 2005). The highest elephant numbers are found in conservation areas (van Aarde & Jackson, 2007).

Elephants are considered megaherbivores, meaning that, when fully grown, they are too large to be killed by available predators (Terborgh *et al.*, 2016); thus, their numbers are regulated by availability of resources, such as food and water. Due to this lack of top-down control, elephants could become quite numerous in both forests and savannas (Omeja *et al.*, 2014). Due to their body size, elephants are generalists; their diet is extremely varied, but depends on the diversity and composition of the plants (Campos-Arceiz & Blake, 2011). The diet also consists of various fruits (Campos-Arceiz & Blake, 2011). Due to this generalist diet, combined with the fact that they can reach high biomass densities, elephants can have a strong impact on the vegetation.

Elephants browse on trees by breaking branches and pushing the trees over, frequently killing them; larger trees are debarked, reducing their survival rates (Laws, 1970). Savanna elephants and forest elephants forage in different ways (Terborgh *et al.*, 2016). The savanna elephant often causes more damage by breaking branches and toppling trees (Kohi *et al.*, 2011), which forest elephants tend not to do (Terborgh *et al.*, 2016). Moreover, the impact of elephant on trees interacts with other factors. For example, gouging and bark stripping of trees leaves the trees more vulnerable to savanna fires as the functional tissues of the trees are exposed (Beuchner & Dawkins, 1961; Shannon *et al.*, 2011). Shannon *et al.*, 2008 conclude that elephants cannot be solely blamed for the decline of large trees; the mortality level of the trees is also determined by factors such as fire, draught and disease.

The impact of elephants on trees, possibly in interaction with fire, may have large impacts on savanna woody cover. For example, the elephants of Murchison Falls National Park, Uganda, were protected from hunting in the 1930s, and their population growth caused a decline by 55-59 % in large trees (Beuchner & Dawkins, 1961). In Chobe National Park, Botswana, elephants had a considerable effect on the woody species density, richness and alpha diversity (Rutina & Moe, 2014). Other studies also suggest that tree community composition is affected by elephant density (Morrison *et al.*, 2015; Rugemalila *et al.*, 2016). Due to these and other studies, there seems to be a generally negative view on elephant impact in the literature (Guldemond & van Aarde, 2008). However, Guldemond & van Aarde (2008), show a much more balanced view of elephant impact in a meta-analysis. According to them, many studies are biased towards a negative view on elephant impact, or conducted in such a manner that it is difficult to replicate them, or even lack a good experimental design. For example, many studies fail to include a control for the impacts of other browsers, hence attributing all impact to elephants (White & Goodman, 2010). Moe *et al.* (2009), however, show that reducing elephant numbers will not increase tree recruitment as long as the impala density remains, since the impala decreases the seedling survival. Lagendijk *et al.* (2011) found that only the exclusion of elephant *and* nyala increased the survival of individual trees.

Increasingly, studies show that elephant impacts also frequently play a positive role for savanna ecosystem structure and functioning. For example, a study by Kohi *et al.* (2011) showed that the elephants' foraging increased the habitat heterogeneity, possibly increasing biodiversity, and facilitated an increase in leaf biomass at the bottom layers (< 1m), which would increase food availability for smaller browsers (Rutina *et al.*, 2005; Makhabu *et al.*, 2006a). Even smaller vertebrates, such as amphibians and reptiles, benefit from the elephants' browsing routine as it, for instance, creates crevices for them to hide in (Pringle, 2008; Nasseri *et al.*, 2011).

Elephants are also important in shaping the vegetation through seed dispersal (Campos-Arceiz & Blake, 2011). Large frugivores are of high importance for plants with large seeds, since these cannot be dispersed by small animals (Holbrook & Loiselle, 2009). The bigger animals can also provide long-distance seed dispersal since they often move over larger areas (Fragoso *et al.*, 2003). According to Campos-Arceiz and Blake (2011), the African elephant is such an important seed disperser that it is not likely to be replaced if their populations decline. Some African plants are dispersed solely by elephants (Cochrane, 2003; Campos-Arceiz & Blake, 2011). It is thus critical to understand the impact elephants have on their environment, not only for the management of the elephants, but also for maintaining the species diversity and habitats found within protected areas (White & Goodman, 2010).

Most studies on the impact of elephant have been done in the savanna biome, while much less research has been done in forest environments. The elephants of Hluhluwe-iMfolozi Park (HiP), South Africa, are regarded as savanna elephants. They are thought to spend a lot of time in the scarp forest in the northern parts of the park. Scarp forests represent a transition between Afromontane forest and Indian Ocean coastal belt forests, the two main forest types in South Africa (Eeley *et al.*, 2001). This particular forest type often forms small patches and is naturally fragmented (Grass *et al.*, 2015). Despite this, it has a very high species diversity (Grass *et al.*, 2015), and therefore a high conservation value. Due to the expansion of agricultural land and urban areas, very few patches of scarp forest are remaining outside protected areas (Grass *et al.*, 2015). Scarp forests are therefore a threatened habitat type in South Africa and a specific conservation priority for Hluhluwe-iMfolozi Park. Possible impact of elephant on the scarp forest in HiP is thus of particular concern.

Purpose

The purpose of this master's thesis was to 1) identify intensely used patches or microhabitats within the forest; 2) quantify tree species, height class distribution, and elephant impact, inside intensely used patches/microhabitats compared with controls, and 3) determine what other mammals use the same areas, and if elephant impact could have an effect on their visitation rate.

Methods

Site description

Hluhluwe-iMfolozi Park is located in the northern KwaZulu-Natal Province of South Africa. The 900 km^2 fenced park was formerly two separate reserves, the Hluhluwe Game Reserve and the iMfolozi Game reserve, but today they form one connected reserve (Boundja & Midgley, 2010). The park is hilly with an altitude ranging from 60 m to 750 m (Boundja & Midgley, 2010). Most of the rain falls during the summer months (October-March), with a mean annual rainfall of 700-985 mm (Boundja & Midgley, 2010). The area hosts a diverse flora and fauna with about 1200 plant species (Boundja & Midgley, 2010). The vegetation in the park is highly diverse with savanna, grassland and forest (Boundja & Midgley, 2010). This thesis will focus on the scarp forest, which is limited to the higher slopes (>200 m) in the most northern part of the reserve. Dominant trees in this forest type are *Englerophytum natalense*, *Drypetes gerrardii* and *Celtis africana*.

Elephants were reintroduced to HiP from Kruger National Park in the 1980s (Slotow *et al.*, 2010), after having been absent for nearly 100 years. In 2010, the number of elephants in HiP was estimated at 350-425 animals, which is around the estimated carrying capacity of 300-350 animals (Boundja & Midgley, 2010). The current population estimate is close to 800 individuals (T. Kuiper 2016, personal communication, 2 December).

Data collection

Mapping elephant impact across the scarp forest

I laid out ten transects, placed 500 m apart, across the scarp forest along the northern border of the reserve in order to quantify the elephants' utilisation of the forest (see Figure 1). The distance between transects was chosen in order to cover as much of the forest as possible within the given timeframe, and without the risk of them overlapping. The beginning of each transect was located at the northern edge of the forest, and the end by the southern edge. Coordinates for start and end were obtained from Google Earth. All transects were walked in the same direction, from north to south, using a GPS. Elephant impact within five metres on each side of the transect was recorded for every 10 meters walked as: the number small broken stems (diameter < 5 cm), large broken stems (diameter > 5 cm), small broken branches (diameter < 5 cm), big broken branches (diameter > 5 cm), toppled trees, trees with signs of bark stripping, and dung piles. Other animal signs were also noted, such as game paths and signs of rubbing. For most transects, the end coordinates had to be changed, since the forest edge was reached earlier than expected, or there was some sort of obstacle in the way.

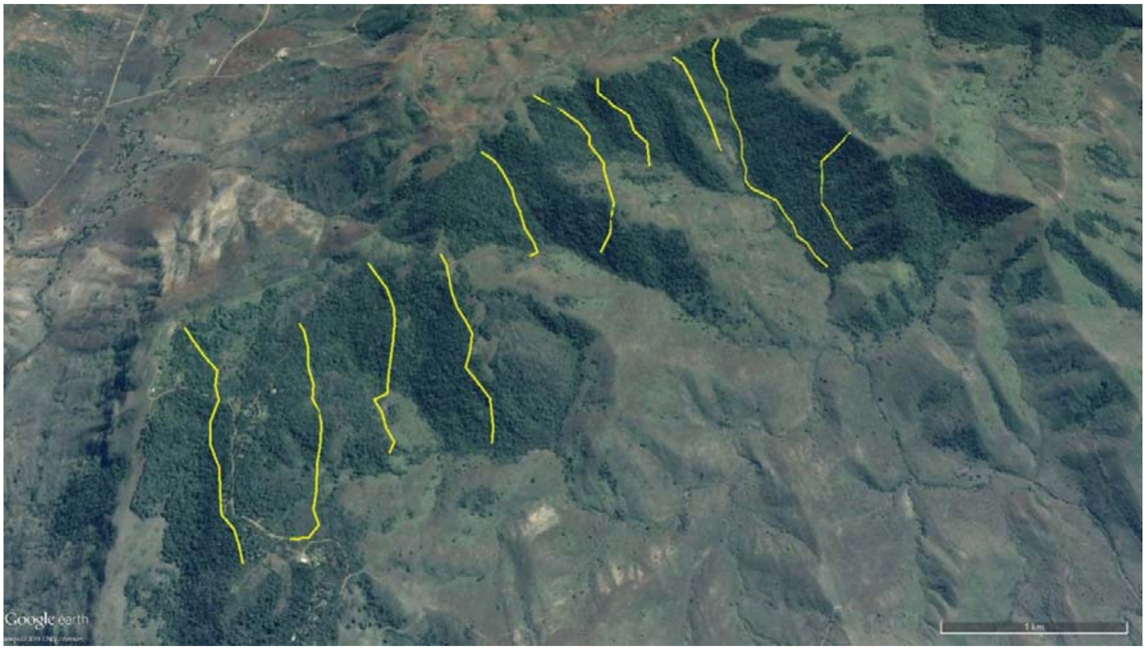

Figure 1: Map of the scarp forest with the ten transects marked as yellow lines

Description of elephant impact in intensely used versus control plots

I laid out nine plots in intensely used parts of the scarp forest to do more detailed measurements of the elephant impact. The original plan was to place all plots randomly along each transect, but because I also wanted to put up cameras to monitor mammal visitation (see below) I needed plots that were relatively easy to access, and therefore placed all plots in close proximity to the road. Each high impact plot had a paired control plot, which was laid out at a distance of 50-60 m away in the southern direction from the impact plot.

Within each plot, I described the woody plant component in terms of species composition, tree height, and elephant impact. Trees of different height classes were recorded in differently sized plots that were nested within each other (Figure 2).

The total size of each plot was 15x15 m. Each plot was laid out with a transect going through its middle, from north to south (see Figure 2). In a small square of 2x2 m at the northernmost end of the middle transect, all woody plants from 0.5 to 2 m high were recorded. From the middle transect to 5 m on either side of it, all trees between 2 and 4 m were sampled. From the middle transect to 7.5 m on either side of it, all trees higher than 4 m were sampled.

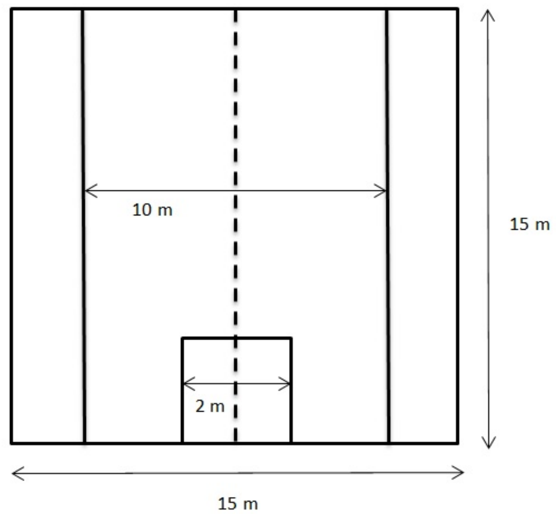

Figure 2: Plot layout with middle transect marked with a dashed line

In each 15x15 m plot, the number of stems of each woody plant individual and their diameter were recorded. Elephant utilisation was recorded as number of toppled trees, broken branches and stripped stems. I looked specifically for branches likely broken by elephants by looking at the way a branch was broken. If twisted, it was most certainly broken by an elephant. Also, if the broken branch was high up, no other animal would have been able to reach it; hence it must have been broken by an elephant. If a stem was broken or had been toppled, the height it would have been when standing was used, as long as the rest of the tree was still present. If the part of the tree that was broken off was missing, only skeleton height was recorded. The state of each tree was recorded as dead or alive. A tree was considered alive if there were still green leaves on it, or if it was re-sprouting from its base, even though the main stem was dead. Dead trees had no green matter left, and no new sprouts. Long dead trees that were toppled or broken were ignored, since the cause of the breakage was difficult to determine. If it could not be determined whether the impact had been caused by an elephant or not, it was not recorded. Other signs of animals, such as rubbing and dung piles, were also recorded. Presence of game paths, at or near the site, was noted as well, since they might indicate whether animals visit the area frequently.

Animal visitation in intensely used versus control plots

A camera trap (Bushnell trophy cam) was set up in each of the nine impact plots and paired control plots to quantify visitation rates of elephant and other mammals. In addition, I placed cameras on four of the transects at a spot that showed signs of high elephant impact. Cameras were set to take a sequence of three photos when activated by movement, and also to do a field scan once a day. The camera trap was set up so as to maximize the number of photos, by for example putting it up close to a game path. Cameras were located in such a way to avoid too much clutter from branches and other objects that could make it difficult to distinguish animals on the photos. Also, the camera had to be mounted on a rather thick tree for it to sit securely, something that influenced its position as well. Because of these reasons, cameras were put up in different places on each plot. The initial height of the camera, hip height, turned out to be a bit too high since the camera did not manage to capture animals of all sizes. The cameras that were put up later in the experiment were placed at a lower level. The camera cases used to protect the cameras did not all have a perfect fit, resulting in the case covering the lower part of the lens on a couple of cameras, which made it difficult to determine the animal species.

Data processing

For the analysis of camera trap photos, one photo from each sequence was selected to represent a capture event. Selected photos were chosen based on quality, and the number of animals on it; the photo with the largest number of individuals was always chosen. For the cameras that failed to take a sequence of photos, all single photos were included. For one camera it was difficult to tell if it had taken a sequence or not. In this case, photos taken within three seconds of each other were likely to belong to the same sequence. One photo from each possible sequence was then chosen, and the rest were excluded. Seven species were included in further analysis: baboon (*Papio ursinus*), buffalo (*Syncerus caffer*), bushbuck (*Tragelaphus sylvaticus*), bushpig (*Potamochoerus larvatus*), nyala (*Tragelaphus angasii*), red duiker and samango monkey (*Cercopithecus albogularis*). These were chosen because they had visited at least a third of the total number of plots. To obtain the average visitation rate for each species for every plot, the number of events per species was divided by the number of days each camera was working; only one camera had run out of batteries before it was taken down. The control cameras for plots C, D, and the impact camera for plot E all malfunctioned and did not take any photos. These plots, and their controls, where excluded from the analyses where paired data was required. This also applied to the four plots along the transects since they did not have any paired controls.

Data analyses

To test if there was a difference in visitation rate between impact plots and control plots, a Wilcoxon signed rank test was performed, comparing the average visitation rates for the two treatments for the seven species that were selected. For this test, plots without a paired plot were excluded. To see if elephant impact could have an effect on mammal visitation, total mammal visitation rate was plotted against the proportion of trees with impact. Besides mammal visitation, I also plotted ungulate visitation against the proportion of impacted trees. This was also done separately for the three most common species: red duiker, nyala and buffalo. For this, all plots were included.

Elephant impact on the plots was treated in a binary manner; either a tree was impacted (signs of stripping, broken stems/branches, toppled) or it was not. The number of trees with elephant impact was calculated for each plot, and then divided with the total number of trees for each plot, to obtain the proportion of impacted trees per plot. A t-test was performed to compare the proportions of impact between impact plots and controls, and also to compare the differences in tree density between the two plot treatments. I also tested for a correlation between tree species evenness and the proportion of trees with impact.

For the transect data, I chose to focus on the toppled trees, since this was the only type of impact that, with absolute certainty, could only have been caused by elephants. Using t-tests, comparisons in altitude, slope and aspect were made between 10 m plots with toppled trees and an equal number of random plots without toppled trees. The random plots were chosen by using a random number generator.

Results

Animal visitation in response to elephant impact

A total number of 18 mammal species were photographed on the plots during 4116 events (see Table 1). The most frequent visitor was the red duiker, which was captured during 2162 events. The second most common animal was the nyala (1236 events), followed by buffalo (204 events). No elephants were photographed during the study.

Table 1: All mammal species found on the plots and total number of events for each species respectively

Species	Number of events
Red duiker	2162
Nyala	1236
Buffalo	204
Porcupine	100
Bushbuck	98
Baboon	89
Zebra	69
Samango monkey	46
Bushpig	25
Large spotted genet	24
Blue duiker	18
Leopard	15
Domestic dog	12
Hyena	8
Wild dog	5
Black rhino	3
Cane rat	1
Honey badger	1
Total	4116

One plot, F_C, had considerably more visitations than the other plots. 1781 events had been captured on this plot, compared to plot B_C, which had the second most visitations with 390 events, and plot I, which had the third most captured events with 345. The Wilcoxon signed rank test did not show any significant differences in visitation between impact and control plots for any of the seven selected species (see Table 2, Figure 3). However, exact p-values could not be calculated due to a large number of zeroes in the dataset.

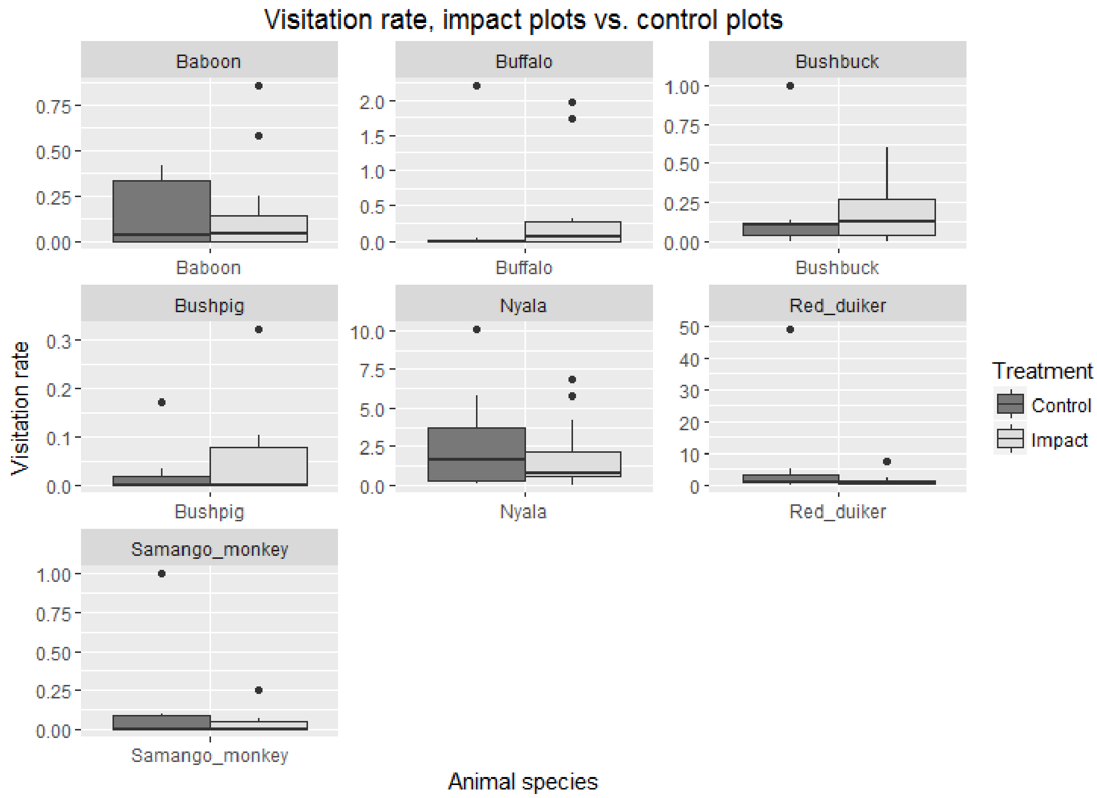

Figure 3: Difference in visitation rate between impact plots and control plots for the seven selected mammal species

Table 2: Results of the Wilcoxon signed rank test

Animal species	W	P
Baboon	7	0.5839
Buffalo	7	0.5839
Bushbuck	15	0.4375
Bushpig	2	0.7893
Nyala	8	0.6875
Red duiker	5	0.5896
Samango monkey	0	0.3711

The total animal visitation rate showed a negative trend to the proportion of trees with impact when plotted against each other, however not significant (estimate = -1.999, SE = 4.913, p = 0.689, t = -0.407; see Figure 4). The same applied for the total ungulate visitation rate (estimate = -3.128, SE = 9.294, t = -0.337, p = 0.741), nyala visitation rate (estimate = -1.261, SE = 2.627, t = -0.480, p = 0.638,) and buffalo visitation rate (estimate = -0.01879, SE = 0.07035, t = -0.267, p = 0.793). For the red duiker, the trend was slightly positive, but not significant (estimate = 0.001235, SE = 0.025937, t = 0.048, p = 0.963).

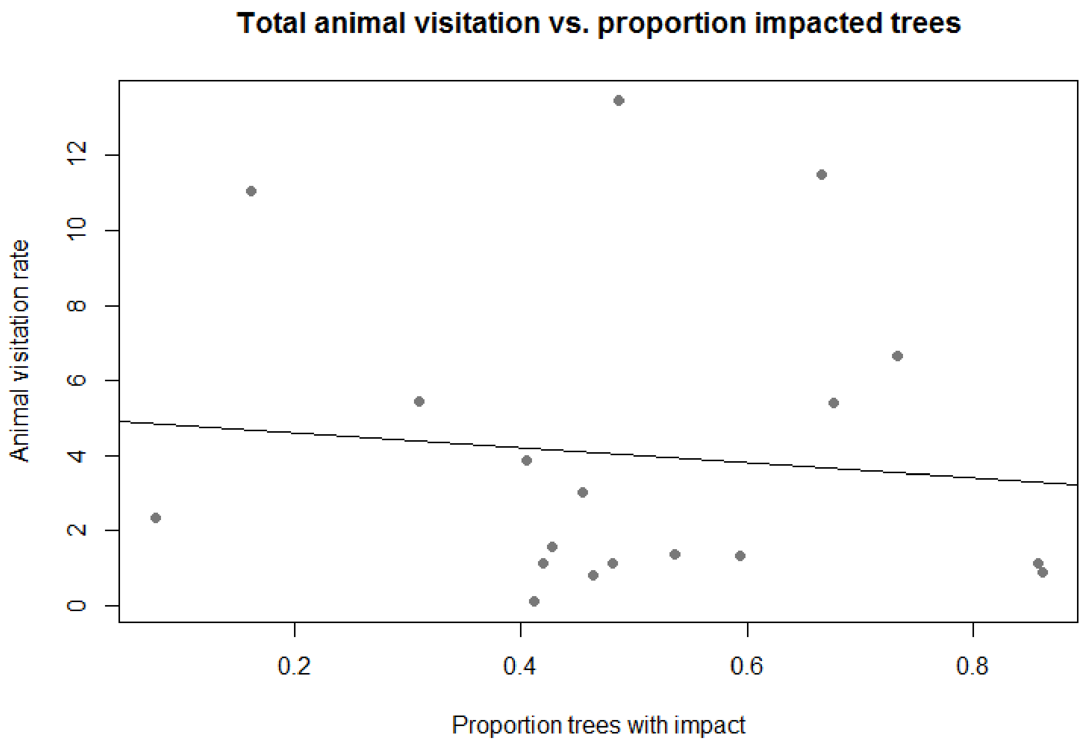

Figure 4: Tree species evenness plotted against the proportion of trees with impact

Tree community response to elephant impact

A total number of 765 trees with 1092 stems were found, divided across 34 species. The number of saplings and small trees found on the plots was very low; only two individuals below the height of 2 m were sampled. Trees between 2 and 4 m in height were 133 in total, and there were 617 trees higher than 4 m. There were 13 trees of unknown height; height could not be measured for these since their stems were broken, and their top parts were missing. Only the ten most numerous species (more than ten individuals) are displayed here (see Table 3). The most abundant tree was *Englerophytum natalense*, which made up 66 % of the trees, followed by *Drypetes gerrardii* (3.8 %) and *Celtis africana* (3.5 %). 55 % of the *E. natalense* trees showed signs of elephant impact. For *D. gerrardii* and *C. africana* it was 41 % and 37 % respectively. However, there was no clear selection for or avoidance of any of the species (see Table 3).

Table 3: The ten most numerous tree species found in the scarp forest

Tree species	Number of trees	Trees with impact	Proportion of trees with impact	Selection index
Englerophytum natalense	505	278	0.5505	0.08687
Drypetes gerrardii	29	12	0.4138	-0.12737
Celtis africana	27	10	0.3704	-0.18278
Combretum kraussii	20	14	0.7000	0.14376
Chaetachme aristata	15	9	0.6000	0.06412
Cola greenwayi	15	2	0.1333	-0.60305
Maytenus mossambicensis	15	9	0.6000	0.06412
Canthium inerme	14	7	0.5000	-0.02908
Protorhus longifolia	14	5	0.3571	-0.19758
Rawsonia lucida	11	6	0.5455	0.01526

The t-test did not show any significant difference in the proportion of impact between impact plots and control plots. ($t = 1.5163$, $p = 0.1679$).

There was a significant correlation between tree species evenness and the proportion of trees with impact, where tree species evenness increased with the amount of impacted trees (estimate = 0.6957, SE = 0.227, $t = 3.069$, $p = 0.0063$; see Figure 5). The difference in tree density between impact and control plots was not significant ($t = 1.4908$, $p = 0.1744$).

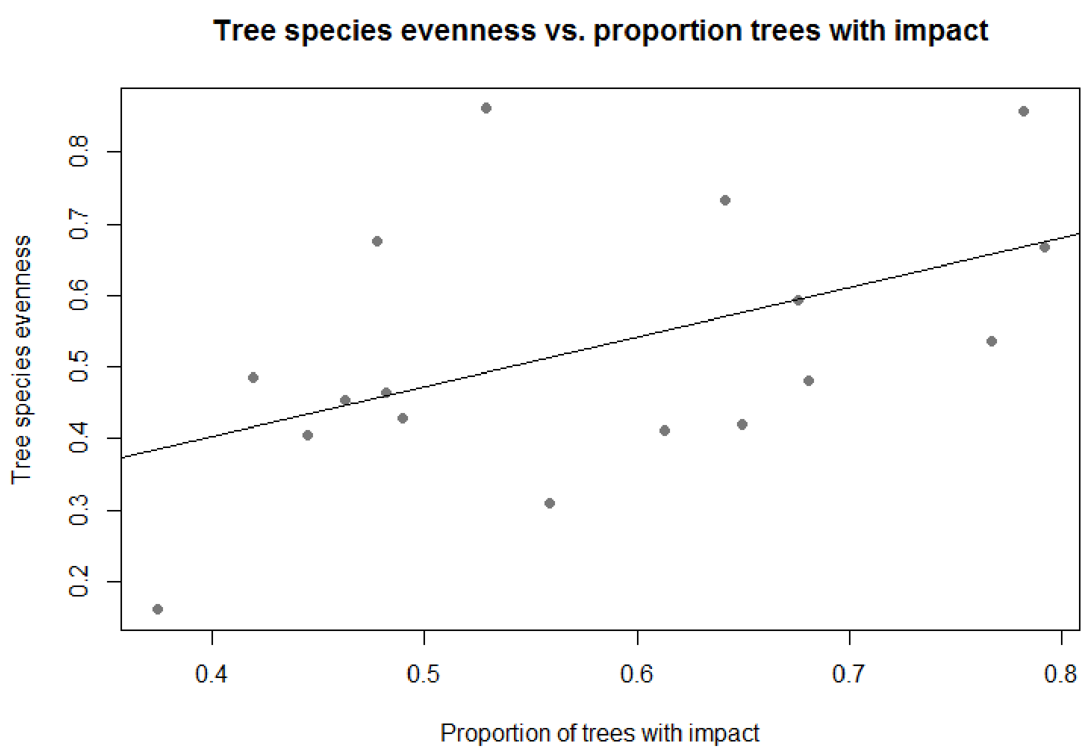

Figure 5: Trees species evenness plotted against the proportion of trees with impact

Transects
In total, there were 95 10 m plots that contained one or more toppled trees. Transect 1 had the largest number of toppled trees per 10 m, while transect 7 had the least (see Figure 6). A t-test showed that there was no significant difference in elevation between plots containing toppled trees and random plots without toppled trees ($t = 1.5245$, $p = 0.1291$). The steepness of the slope did not have any effect on the number of toppled trees either ($t = -1.102$, $p = 0.2719$), neither had aspect ($t = 0.065723$, $p = 0.9477$; see Figure 7).

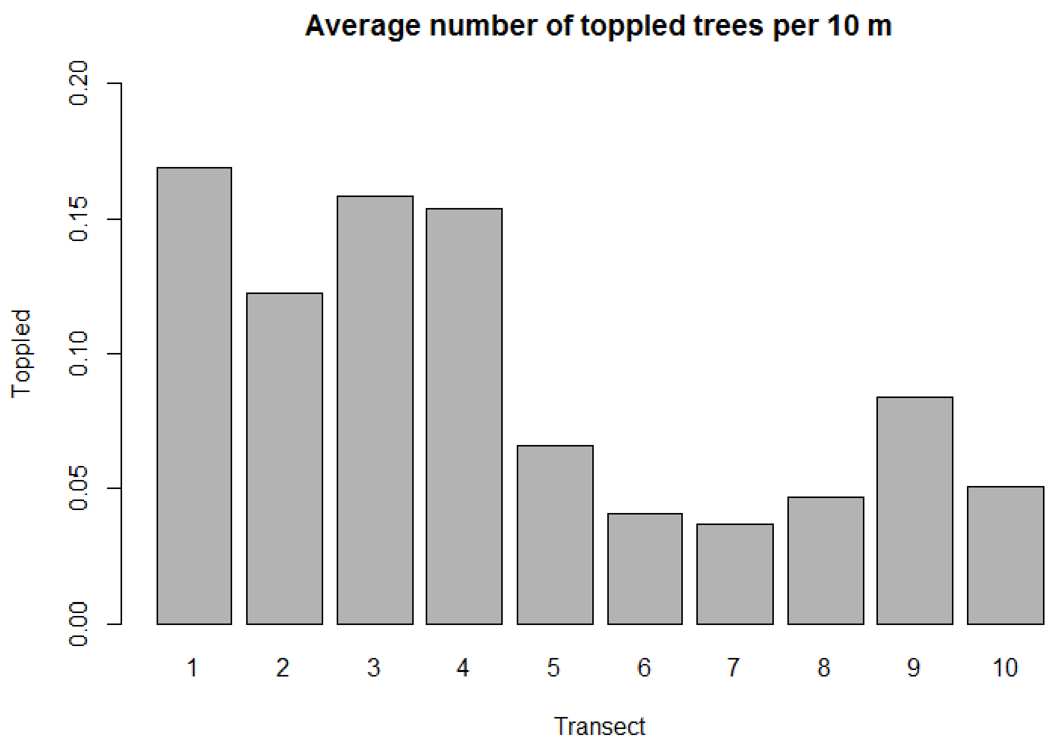

Figure 6: Number of toppled trees per 10 m for each transect

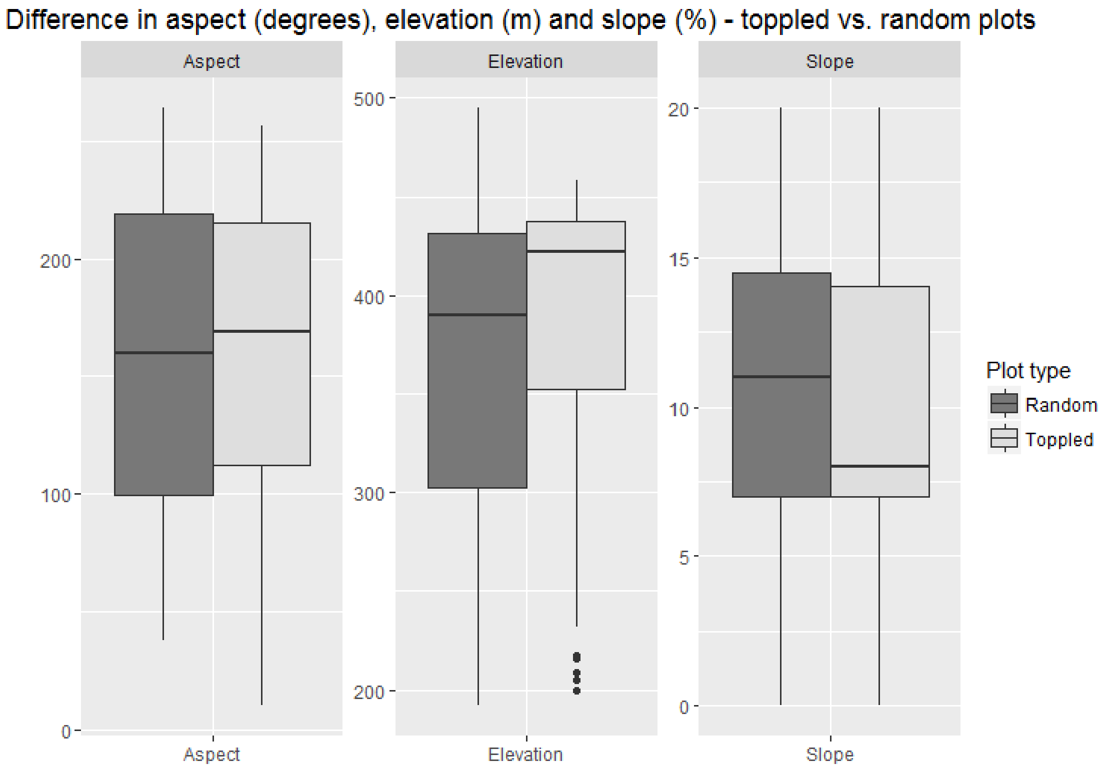

Figure 7: Difference in aspect, elevation and slope for plots with toppled trees and random plots

Discussion

Few studies have investigated elephant impact on animal biodiversity, and the results are varying. (Fritz *et al.*, 2002) found that elephant abundance negatively influence both medium-sized mixed feeders and mesobrowsers , suggesting that they compete for resources, and that elephants also change vegetation communities, making them unattractive for other herbivores, either as food resources or as protection from predators. (Valeix *et al.*, 2008) also found that elephants could have a negative effect on the numbers of other herbivores. On the other hand, there is also evidence that elephants can increase the availability of food for other browsers, both in quantity and quality (Rutina *et al.*, 2005; Makhabu *et al.*, 2006a; Kohi *et al.*, 2011). (de Boer *et al.*, 2015) suggest that where elephants are abundant, they could affect other browsers negatively, while at low to intermediate densities, the effect could potentially be positive. (de Boer *et al.*, 2015) found that buffalo, nyala and bushbuck all showed a positive relation to increased elephant numbers. On the other hand, several other species responded negatively to increased elephant densities (de Boer *et al.*, 2015).

Since I did not have any elephant visitations on my plots during the study, I could not compare elephant visitation directly to that of other browsers. Instead I compared mammal visitation to plots highly impacted by elephants with control plots. In this study, I found no significant difference in visitation rate between plots with high elephant impact and control plots for any of the selected species. This could probably be explained by the fact that the impact plots and control plots were not very distinct from each other. However, when mammal visitation rate was plotted against the proportion of impacted trees, it indicated a decrease in visitations as the impact increased. Though, the relationship was not significant.

Elephant impact on vegetation has been studied rather extensively, at least in savanna environments. In a study made in Mkhuze Game Reserve, South Africa, White & Goodman (2010) did not find any significant differences in elephant browsing level between their high-use and low-use plots, which concurs with the results of my study where no significant difference in elephant impact was found between impact plots and control plots. White & Goodman (2010) found little indication that elephants had an effect on the overall diversity of woody vegetation. The mortality rate of individual species also seemed uninfluenced by elephants (White & Goodman, 2010). The non-significant result of my study could also be explained by the similarities in amount of elephant impact between impact and control plots.

de Boer *et al.* (2015) found that woody plant density decreased with increasing elephant density. I found no significant difference in tree density between my two treatments, which, again, could be explained by the lack of variance in elephant impact between the two.

In general, there were very few saplings growing on the plots as only two were sampled across all plots. Of course, individuals shorter than 2 m were only recorded within an area of 2x2 m, which means that more saplings could have been present within the whole 15x15 m plot, but not recorded. Also, it could mean that smaller trees and saplings are targeted by herbivores, resulting in fewer of them. This is something that was shown in a study by Makhabu *et al.*, (2006b), where browsers preferred shoots with a diameter smaller than 4 mm. In retrospect, it would have been preferable to sample trees below the height of 2 m along the whole middle transect, which would mean an area of 2x15 m.

By altering the availability of resources, elephants can change plant species composition; for instance, White & Goodman (2010) found that sapling recruitment was higher in areas frequented by elephants. Elephant browsing could facilitate the growth of understorey plants by thinning the canopy, which decreases competition with nearby plants for light, water, nutrients etc. (Smith & Goodman, 1986). This could be one reason why the tree species evenness was higher on plots with more elephant impact. Another possibility could be that elephants have dispersed seeds from several different woody species when visiting these areas, resulting in higher species diversity there. Elephants are, as previously mentioned, important seed dispersers. For some forest plants, seed germination even increases considerably after passing through the gut of an elephant (Nchanji & Plumptre, 2003; Babweteera *et al.*, 2007; Campos-Arceiz & Blake, 2011).

I expected to see less elephant impact at higher altitude. Epps *et al.* (2011) found that elephant presence was higher at lower elevations. However, the altitude range (350-2470 m; Epps *et al.*, 2011) at their study site was much higher, than in HiP (60-750 m; Boundja & Midgley, 2010), which might be relevant. On the other hand, in Balule Nature Reserve, South Africa, no difference in elephant browsing intensity was found between footslopes and crests (Lagendijk *et al.*, 2015). Elephants utilise the lower lying areas during the hotter hours of the day, but spend more time on crests at night according to Knegt (2010), which could result in spatially homogenous browsing (Lagendijk *et al.*, 2015). The fact that elevation or slope did not have any effect on the amount of elephant impact, in this case toppled trees, could possibly be explained by the results of Lagendijk *et al.* (2015). If the elephants spend an equal amount of time in both higher and lower areas, the number of toppled trees would be indifferent to slope and elevation.

The non-randomized selection of plots could have influenced the result; for example, most of them were placed near a road frequently used by the park staff, and some of them were also in close vicinity to human settlement. According to a study by Epps *et al.* (2011), elephant presence was negatively correlated with human population density and agriculture. Perhaps, if placed further into the forest, the number of animals visiting the plots would have been even larger. Also, it might have been better to put the control plots further away from the impact plots; many of the control plots also had quite a lot of impact, which might have been due to the proximity to the impact plots. Instead of having clearly defined impact plots and controls, there was more of a gradient of impact between the two treatments. Overall, the elephant impact on plots was fairly old, and there was no fresh dung present (personal observations).

Three of the cameras had malfunctioned completely, and several had failed to take a sequence of three photos. Some had also failed to do a field scan every day, which makes it difficult to determine whether they worked properly or not. It is highly possible that these cameras did not capture all animal visitations; there is quite a big difference in the number of events captured by these cameras compared to the ones that worked. Also, events that are captured immediately after one another often show the same individual(s), which resulted in some double-counting. In this case though, it is not a big problem, as I am not interested in actual densities of mammals, but rather patch use and whether impacted patches are used more or less than controls.

For the plots, it would have been good to include other types of browser impact in addition to elephant impact. As mentioned by (White & Goodman, 2010), it is important to include a control for other herbivores so as not to blame all impact on elephants. White & Goodman (2010) also argue that smaller ungulates, such as nyala, potentially can impact saplings and understorey vegetation, which is why it is so important not to neglect other herbivores when studying browsing impact (see also Lagendijk *et al.*, 2011). As a way to avoid ascribing the impact to the wrong species, I chose not to include impact where I could not make an accurate judgement of its cause. In future impact studies though, I believe other browser impact should be included.

Furthermore, a more thorough protocol for the vegetation mapping would have increased the use of the data. For example, the number of stems was noted, as well as how many of them were broken, but the protocol did not specify which stem was broken. This way, it was not possible to determine which stem diameter class had the most impact. It would have been interesting to know if the elephants target certain size classes, as in the study by Boundja & Midgley (2010), where it was demonstrated that elephants preferred browsing on larger stems.

The transects differed in terrain and vegetation, and also in amount of elephant impact. Some areas were relatively steep and stony, and these parts generally showed fewer signs of elephants. Overall, as seen on the plots, the elephant impact along the transects was fairly old, apart from some fresh bark stripping (personal observations).

A lot of the impact data collected along the transects was not used in the analysis, since it could not with certainty be attributed to elephants. Toppled trees were the only signs of impact that could not have been caused by any other animal, and this was therefore used as a measurement of the impact across the forest. Preferably, other kinds of impact would have been included as well, but for example broken branches and small broken stems were likely to have been broken by other animals. Additionally, other size limits for big and small stems should have been used. Stems with a diameter larger than 5 cm were recorded as big, which was the majority of stems. With a larger diameter, for example 10 cm, fewer trees would have fallen within the big stem category and the data might have been more useful. Since only an elephant would have been able to break a larger stem, this impact could have been attributed to elephants with more certainty, and thus used in the study.

Due to their size, elephants are not often preyed upon, which means that their numbers are mostly dependent on resource availability. This, in combination with the impossibility for the elephants to move between fenced reserves, can result in locally high numbers. Their natural movements are also affected by other factors, such as landscape fragmentation, supplementation of water, and human settlement (van Aarde & Jackson, 2007). van Aarde & Jackson (2007) argue that limiting the locally high abundance of elephants to manage impact is not the answer, an opinion that other researchers share. Reducing the number of elephants solely could lead to unpredictable consequences for biodiversity (Owen-Smith *et al.*, 2006). In Chobe National Park, Botswana, culling of elephants has been proposed as a solution to restore the Chobe riparian woodland to its former state (Moe *et al.*, 2009). However, van Aarde & Jackson (2007) believe that elephants should be allowed to disperse between conservation areas. Culling of animals in source areas might be necessary, even though natural control would be desirable (van Aarde & Jackson, 2007). Developing a network of conservations areas is possible, but it would be a complicated process (van Aarde & Jackson, 2007).

Guldemond & van Aarde (2008) argue that the focus should be on elephant confinement rather than density; fencing had a positive effect even at low elephant densities. However, Owen-Smith *et al.* (2006) mean that fencing is only effective in relatively small areas, and requires an extensive effort, and suggest restriction of water during the dry season is a better option.

Contraception is also used as a means of regulating elephant populations, and researchers argue for this as a good way of controlling the numbers (Fayrer-Hosken *et al.*, 2000; Delsink *et al.*, 2006). This is also the method currently used to regulate the elephant population in HiP. However, the method is only convenient in a known, small to medium-sized population (<500 elephants), and it will only reduce the number of individuals when mortality exceeds birth rates (Delsink *et al.*, 2006). Contraception could also increase the risk of injury to the elephants as the females come into oestrous more frequently than without contraception and thus attracts the attention of males more often (Kerley & Shrader, 2007). The large males are inclined to chase and mount the much smaller females, which increases the risks of injury to females, and also to the males as the male-male aggression over mating opportunities increases (Kerley & Shrader, 2007). Furthermore, contraception could alter the social structures of the elephant family groups and even cause psychological problems, such as depression (Kerley & Shrader, 2007).

The above mentioned methods are just a few examples of how elephant numbers are being managed. I do not believe that there is a correct and general method to manage elephant densities, although some approaches might be more or less ethical. There are also a lot of factors to consider when deciding on how to manage a population. For example, the extent of the elephant impact has to be determined. The consequences of altering the elephant population have to be considered as well. It is likely that the impact of elephants depend on the site (Guldemond & van Aarde, 2008), but also the vegetation composition (Levick & Rogers, 2008), which explains why the effects vary so much.

Conclusions

I cannot with certainty conclude if elephant impact influences the tree community or the animal community in the scarp forest of HiP. Still, the study was short, but with more time and an improved method, more reliable data could be obtained.

However, it is evident that elephants can influence their environment both negatively and positively, depending on the circumstances. I believe further research on elephant impact, specifically in forest communities, is necessary to fully understand the extent of it and to enable the management of elephants.

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