

**Dynamics, Recruitment and structure of *Acacia drepanolobium*
Sjøstedt seedlings at Olpejeta Conservancy, Kenya between 1999 and
2009**

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Summary

This year's report concentrated on the dynamics of *Acacia drepanolobium*, particularly seedling survival. We used monitoring data collected over nine years to determine variability in seedling survival and recruitment. We examined the effect of two management interventions; the elephant translocation of 2001 in which 56 elephants were taken out of Olpejeta and the expansion of the reserve and opening of wildlife corridors in 2007. We further examined browse mediated damage to seedlings, its distribution by height classes of seedlings, factors affecting browse pressure and implications for seedling survival.

We observed that seedling survival varied a lot over the nine years. Seedling survival in tagged *Acacia drepanolobium* over nine years was low, with mortalities being initially high between 2000 and 2001 and then being gradual over the subsequent years to 2007. We recorded a 47% survival with 92 of the 198 seedlings initially tagged being alive nine years later, with 63% having been killed by browsers, drought or other mortality factors. Of the 106 surviving seedlings, only 8 seedlings (0.75%) had grown into trees after nine years of monitoring.

We examined the effect of grass cover on seedling dynamics and determined that *A. drepanolobium* seedlings exhibit a storage effect where most seedlings are found below the grass layer and most exposed or emerged seedlings suffer significantly higher browse damage.

We conclude that survival and recruitment of *A. drepanolobium* seedlings is very low and of concern. The expansion of conservation area has, however resulted in a steady recovery for seedlings of *A. drepanolobium*. Burning and intensive livestock grazing activities at Olpejeta therefore need careful planning in order to allow for healthy *A. drepanolobium* recruitment.

Introduction

Although acacias are ecologically and economically important, their demography is poorly known. In part this is because few field experiments have been undertaken. Also, a bewildering diversity of factors have been suggested to determine their demography. These factors include disease, fire, large and small browsers and grazers, climatic variation, competition with grass, seed predation and anthropogenic impacts (Midgley and Bond, 2001).

In African savannas, large herbivorous mammals such as elephants, giraffes, and various antelopes, are known to kill and damage trees via browsing, uprooting, and trampling (Dublin et al. 1990, Mwalyosi 1990, Sinclair 1995). However, at least three pathways exist by which large herbivores could facilitate growth of tree populations or biomass. One is by dispersing fruits or seeds in dung (Coe and Coe 1987, Miller 1994). A second is by increasing germination via nutrient inputs (Augustine and McNaughton, 1998). The final potential mechanism, which has received only scant attention, is the suppression of other, smaller herbivores, which could have a stronger direct, negative impact than do the large herbivores (Goheen, 2004).

Large mammals indirectly facilitated seedling survival by suppressing populations of other herbivores (rodents and insects). High densities of rodent and insect herbivores caused the increase in mortality on plots without large mammals, killing or severely damaging 75.0% of uncaged seedlings on plots without large mammals as compared to 45.1% on plots to which large mammals had access (Goheen, 2004). There may also be strong temporal variability in the overall effects of different consumers on seedling survival. A recent study of seedling herbivory at a study site (Shaw et al. 2002) failed to detect differences in seedling survival as a function of the presence or absence of large mammalian herbivores, although seedlings exposed only to rodents and insects suffered mortality at a faster rate. Using techniques similar to ours, Shaw et al. (2002) found insects to be the most important agents of *A. drepanolobium* seedling mortality. A major challenge for the future is to assess the importance of seedling mortality, relative to sapling or adult mortality, to the population dynamics of *Acacia* trees in savanna ecosystems. Specifically, we know little about the number of seedlings necessary for successful regeneration of *A. drepanolobium* woodlands, or the size at which seedlings are effectively safe from predation by smaller herbivores (Goheen, 2004). In this paper, we report results of a nine year monitoring study on dynamics and survival of seedlings of *Acacia drepanolobium* in a fenced reserve that is home to a wide range of large mammalian browsers. We relate seedling dynamics to two significant habitat management changes that have taken place at the conservancy within the period of study, with potentially significant implications for *A. drepanolobium*. We examine spatial and temporal variability in distribution and the effect of density on seedling browsing and damage. We also report on a possible seedling strategy where seedlings avoid predation by adopting a stoloniferous stature and a 'storage effect', a strategy to remain cryptic under grass for as longer growing period.

Materials and methods

Olpejeta Conservancy (formerly Sweetwaters Game Reserve) is located in central Kenya, 230 km north of Nairobi, near Nanyuki, on the Laikipia plateau between Mt Kenya and the Aberdare Mountains. It lies at an altitude of 1800m on the equator at longitude 368560. The vegetation is a mosaic of grassland, *Acacia* woodland, *Euclea* scrub woodland and riverine woodland (Birkett, 2002). The Conservancy is on the southern and wettest area of the greater Samburu-Laikipia ecosystem with a mean annual rainfall of 900mm and a bimodal rainfall pattern. The conservancy is currently the largest Black rhino Sanctuary in East Africa with a population of 80 black rhinos (*Diceros bicornis*). Other large mammal herbivores at the study site include elephants (*Loxodonta africana*), giraffes (*Giraffa camelopardalis*), cape buffalos (*Syncerus caffer*), elands (*Taurotragus oryx*), Grevy's zebras (*Equus grevyi*), Burchell's zebras (*Equus burchelli*), Beisa oryx (*Oryx beisa*), Jackson's hartebeests (*Alcelaphus buselaphus jacksoni*), Waterbuck (*Kobus defassa*), Grant's gazelles (*Gazella granti*), steinbucks (*Raphicerus campestris*) and domestic cattle. Predators include Lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), wild dog (*Lycan pictus*), Silver-backed jackal (*Canis mesomelas*), Spotted hyena (*Crocuta crocuta*). Primates include Olive baboon (*Papio anubis*), Patas monkey (*Erythrocebus patas*), Vervet monkey (*Cercopithecus aethiops*) and Lesser bushbaby (*Galago senegalensis*).

A long-term study set up to monitor changes to the *Acacia drepanolobium* woodlands (Birkett, 2002; Birkett & Stevens-Wood, 2005) has now run for ten years.

Tree and seedling measurements

Monitoring of *Acacia drepanolobium* trees and seedlings growth, mortality and survival was carried out in 30 plots set up in 1998 (See Birkett, 2002; Birkett & Stevens-Wood, 2005). The plot locations were recorded by GPS, accurate to 100m and the individual tree locations by bearing and distance (in metres) from the first tree (See Birkett, 2002). Tree and seedling height was measured to an accuracy of 2 cm using a Dynamis Telescopic Measuring Rod (Stanton Hope, 1998) that could be extended to 7m. Measurements were taken of the height, diameter and damage status of all acacia drepanolobium seedlings and trees within one hundred 2m x 2m quadrats in each of the 30 plots. Damage was categorized as browsing, trampling or natural. It was not possible to determine the identity of browsers for seedlings whose diameter was less than 10mm so identity of browser was not determined for analysis. Quadrats were laid in such a way that they started at the first tagged tree of each plot (see Birkett, 2002). From this tree, we laid out a 30m tape that was marked every two metres for twenty metres. This tape was used as the baseline for the quadrats. We then laid out, beginning from the tagged tree, a series of belt transects 2 metres apart along the 30m tape running 20m and 900 from the tape. We counted trees and seedlings of *A. drepanolobium* in 2m x 2m quadrats along these 20m belts. For each seedling, we measured and recorded height, length, diameter and damage. For each belt we counted in ten 2x2 meter quadrats, then moved the tape 2m south and repeated for another ten belts resulting in 100 quadrats. We monitored seedlings and trees in these quadrats annually between 2003 and 2008. In a separate experiment, 198 seedlings were initially tagged using green plastic coated thin wires, their position taken using GPS and monitored for survival and recruitment into adults between 2000 and 2008. Data was recorded in the field using a US Robotics 3ComPalmPilot Professional loaded with software supplied by the University of Kent (Pascoe, Morse & Ryan, 1998). Data was then downloaded from the Palm Pilot into Microsoft Excel 97 spreadsheets and later analyzed using SPSS.

Results

Seedling survival in tagged *Acacia drepanolobium* over nine years was low, with mortalities being initially high between 2000 and 2001 and then being gradual over the subsequent years to 2007 (Figure 1). We recorded a 47% survival with 92 of the 198 seedlings initially tagged being alive nine years later, with 63% having been killed by browsers, drought or other mortality factors. The increase in mortality over time was significantly predictable $R^2 = 0.865$; $F_{(1,7)} = 61.90$; $P = 0.0002$; Figure 1). Of the 106 surviving seedlings, only 8 seedlings (0.75%) had grown into trees after nine years of monitoring (> 1m).

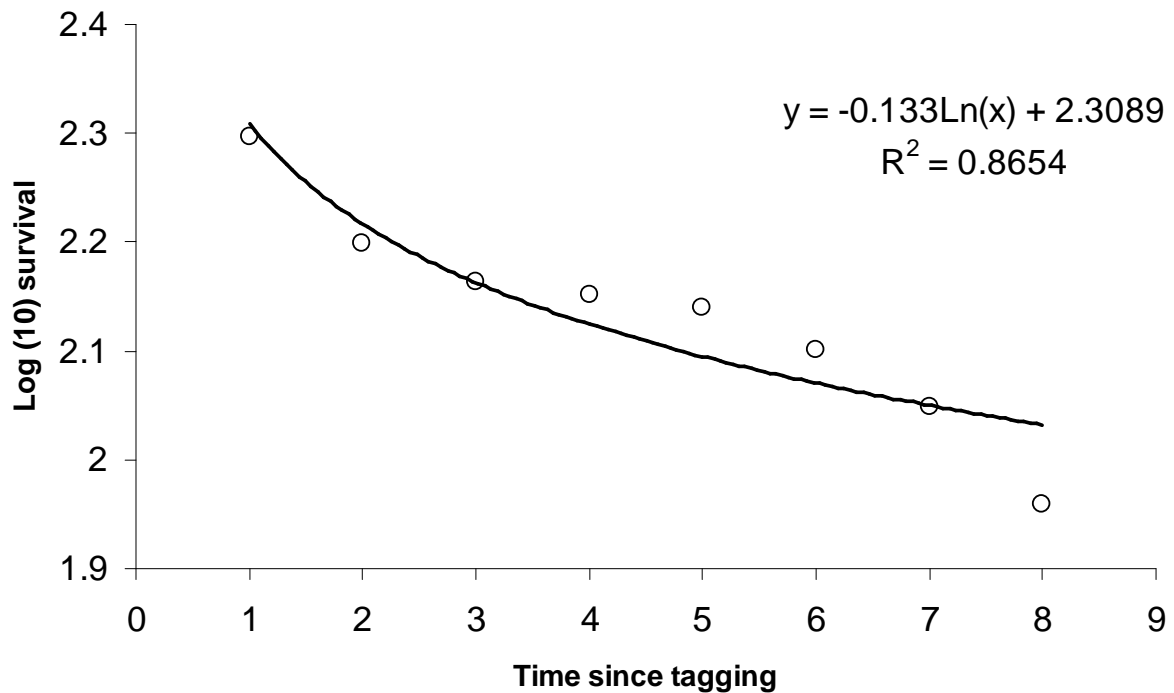


Figure 1: Seedling survival in Acacia drepanolobium at Olpejeta over nine years

We used a mean of 2452 ± 96 seedlings in twenty one $20 \times 20 \text{ m}^2$ quadrants monitored over eight years for density and damage determination. Seedling density (expressed as number of seedlings within a $20 \times 20 \text{ m}^2$ quadrat varied over the years. Density was initially high and then declined to the lowest densities in the period between 2002 and 2005 (Figure 2). Significant events happened in the years 2001 (elephant translocation) and the years 2007 (expansion of the reserve) (Figure 2). We determined that seedling densities rose steadily between 2005 and 2008 with 2008 recording the highest ever seedling density in the eight years.

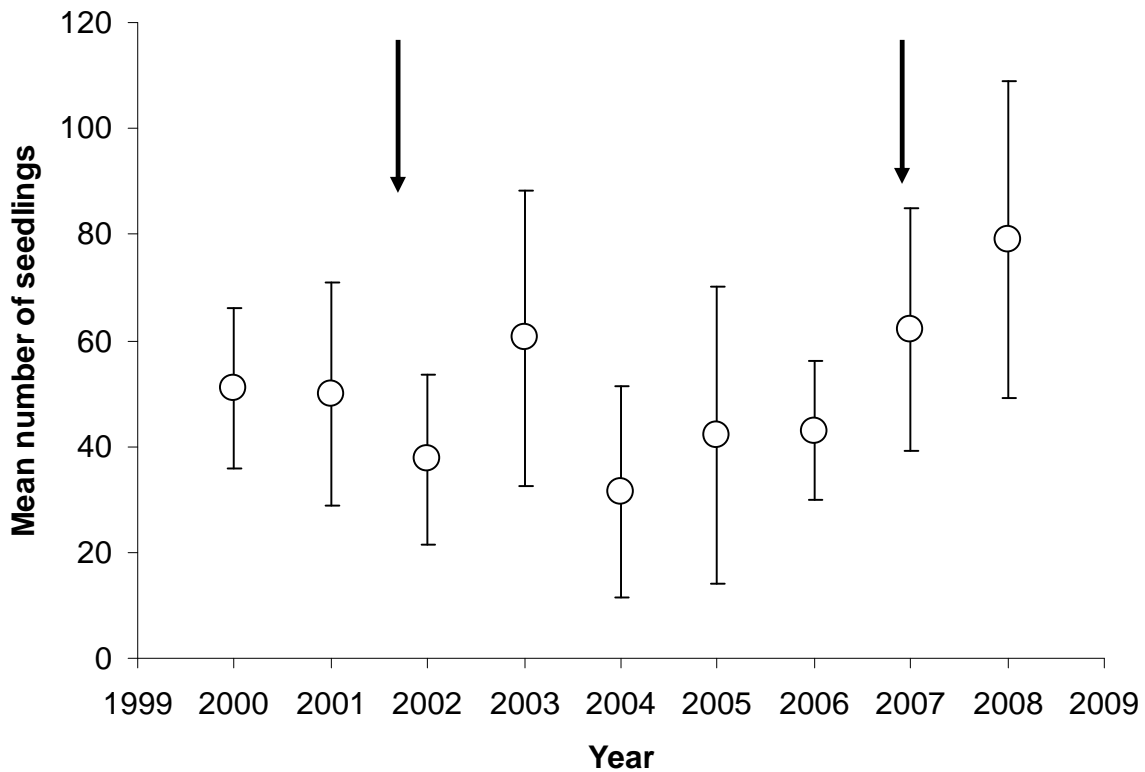


Figure 2: Seedling dynamics of *A. drepanolobium* in Olpejeta over a nine year period. Figure shows significant management changes that have taken place (Shown by arrows) with consequences for seedling survival.

We used Paired sample T-test to examine the relationship between seedling density and the damage frequency. There was a significant relationship ($t = 9.712$, D.F = 54, $P < 0.05$) between density and damage by browsing herbivores as well as other agents. Damage frequency significantly increased with increasing seedling density (Figure 3).

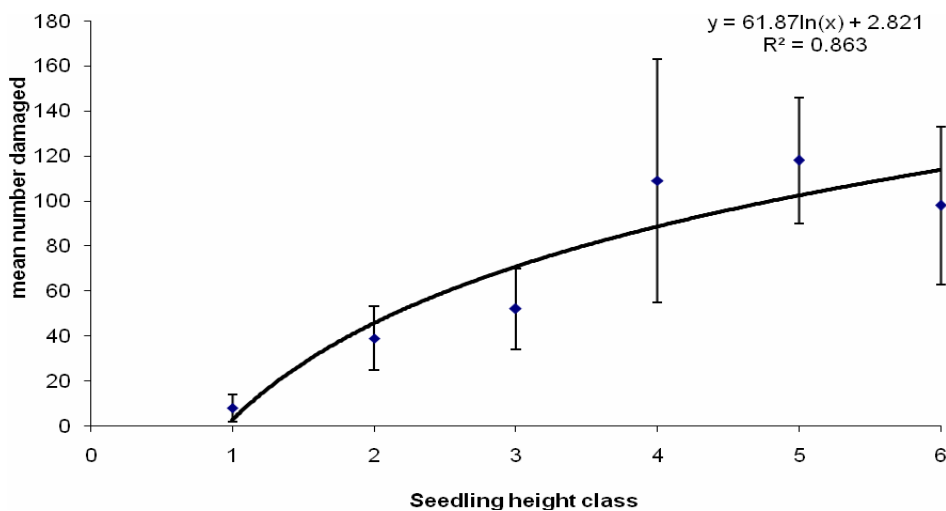


Figure 3: The frequency of damage to *A. drepanolobium* seedlings according to height classes

We hypothesized that seedlings survive well below grass layer where there is enough moisture as well as security from most browsers. We examined the 'seedling storage hypothesis' where *A. drepanolobium* seedlings growth habit is such that seedlings grow like runners under grass and then eventually stand erect at a significantly taller stature. We found that most surviving seedlings were between 15-40 cm tall (Figure 4), coinciding with the mean grass heights during most seasons at Olpejeta (35 cm \pm 20cm), such that seedlings survive well below grass cover. Although we technically defined seedlings as trees < 1m tall, heights between 60 and 100cm were barely represented (Figure 4).

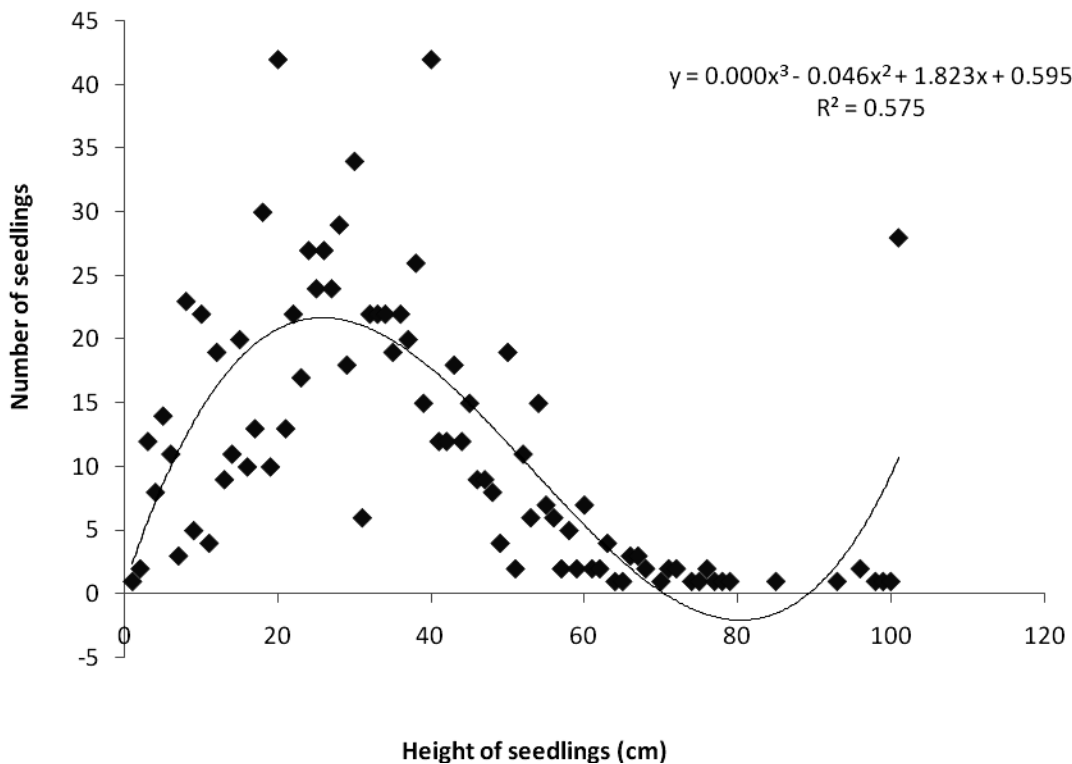


Figure 4: Survival of *A. drepanolobium* seedlings by height classes showing the 'storage effect' where most seedlings are in the 20-40cm height class.

To test the validity of this seedling storage hypothesis, we investigated the relationship between seedling mean heights and mean lengths using paired sample T-test and found a significant relationship ($t = 2.008$, D.F = 54, $P = 0.05$) (Figure 5). As seedlings grew taller, they developed a more cryptic behaviour by adopting a longer length consistent with a stoloniferous stature.

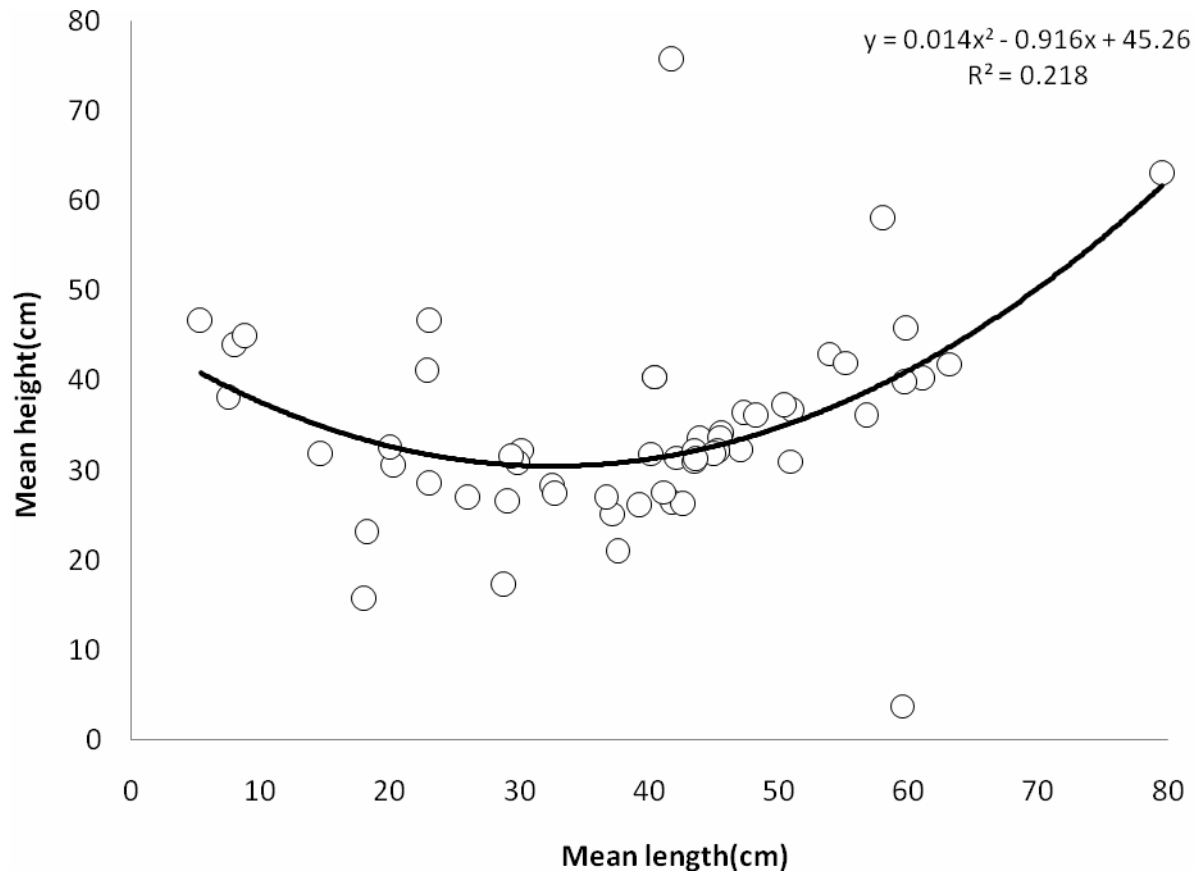


Figure 5: Graph illustrating the relationship between height and length of the seedlings.

We tested the storage effect hypothesis further by comparing heights and lengths of seedlings as seedlings increased in height. Figure 6 shows that the greatest difference between mean lengths and mean heights was for seedlings with heights just below the grass layer, or those keeping within the grass line.

Seedling spatial distribution was not uniform across plots. When we examined the effect of site (plot) on seedling density using ANOVA, we found a significant variation in density across plots ($F_{(21, 33)} = 2.106, P = 0.027$).

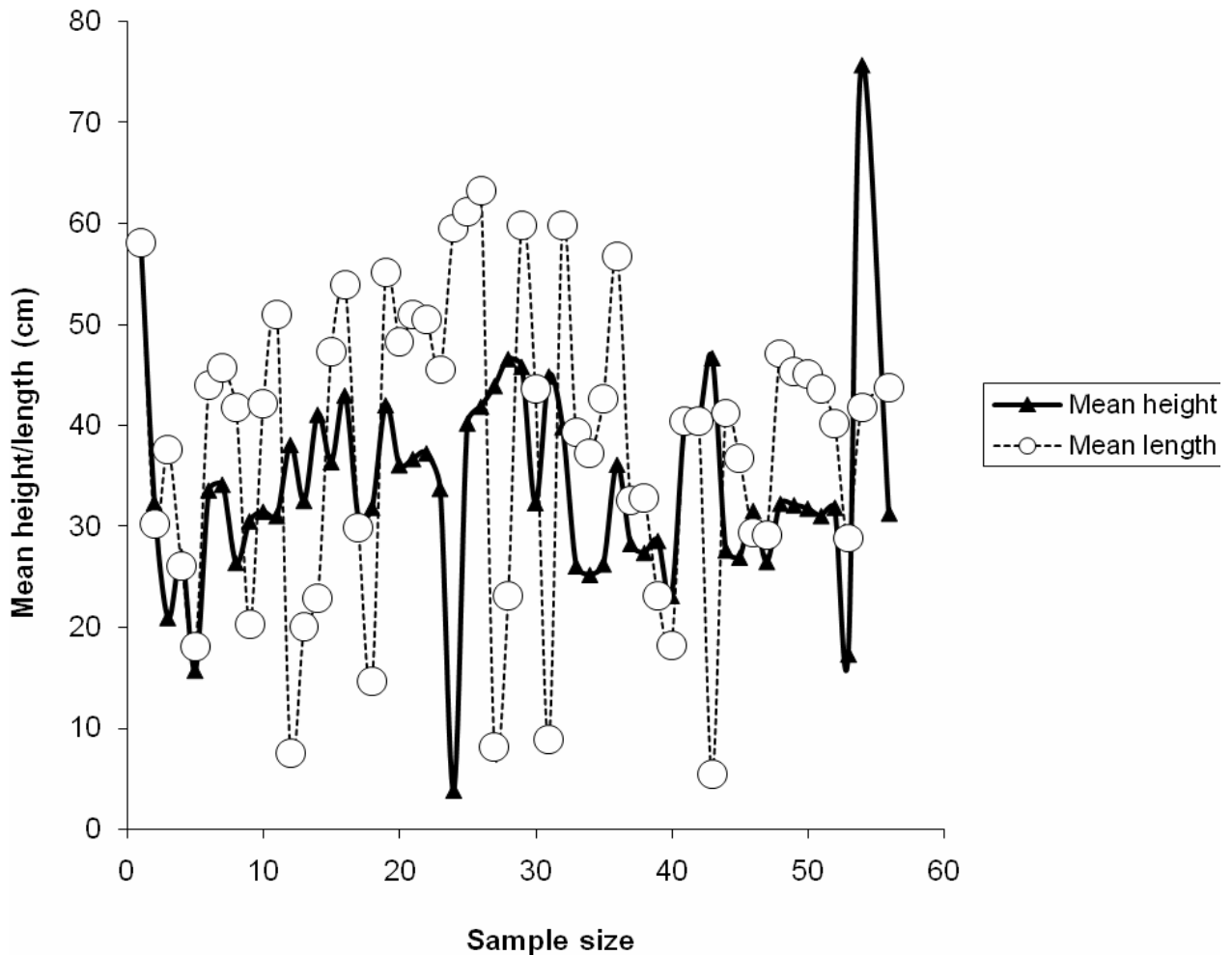


Figure 6: A comparison of heights and lengths of *A. drepanolobium* seedlings at Olpejeta. Figure shows that the greatest difference between mean lengths and mean heights was for seedlings with heights just below the grass layer.

Discussion and Management implications

Recruitment is likely to be limited by survival of tree seedlings, since plants are usually most vulnerable to herbivores at this stage (Crawley 1983). African savannas host a diversity of herbivores, including large native ungulates such as elephants and antelopes, domestic livestock, rodents, and a vast array of invertebrates. The impacts of this array of herbivores on tree seedling survival is not well known. Herbivory by both insects and rodents has been shown to be an important determinant of *A. drepanolobium* seedling survival and large mammalian herbivores have been shown to indirectly assist performance of *A. drepanolobium* seedlings, by limiting the populations of such important seedling herbivores (Goheen 2004). Given the importance of dominant consumer species in driving complex interactions (Jones et al. 1998, Brown et al. 2001), it is likely that future research will demonstrate the cascading effects of the herbivores that influence *A. drepanolobium* dynamics in east African savannas.

Effect of grass on A drepanolobium seedlings

Skarpe (1990) noted an increase in plant size of woody plants, including *Acacia mellifera*, in over-grazed areas, and explained this as being due to increased water availability due to the decline in grasses brought on by over-grazing. In contrast, this could be due to a decline in fire; as Skarpe (1980) previously noted *A. mellifera* can experience mortality in intense fires. For Olpejeta, we found that seedlings emerge above the grass layer (storage effect) after a length of about 50cms. However, exposed or emergent seedlings suffer greatest seedling damage (see 2008 report on effect of fire). Exposure by fire, drought, or through growth exposes seedling to predators as they no longer benefit from the storage effect. Furthermore, this study demonstrated that the greatest difference between mean lengths and mean heights was for seedlings with heights just below the grass layer, or around 40 cm in height, showing that these seedlings tended to grow more horizontally rather than upright. Results of this study therefore show that the critical survival period for *A. drepanolobium* seedlings in relation to herbivore mediated mortality is between 40 and 50 cm. Beyond this height, the seedling is vulnerable to browsing.

Effect of browsers on seedlings

Mwalyosi (1990) focused on the decline of *A. tortilis* in relation to elephants and the compression hypothesis. According to this hypothesis, elephants have been compressed into increasingly smaller areas, which have led to them drastically over-utilizing the vegetation until negative feedback caused the decline of the elephants. This arose because elephant habitats have been reduced over the years and their migration routes too were closed. Among the most significant large mammalian seedling browsers at Olpejeta are elephants and rhinos. It was not possible to establish species specific effects of these two browsers as the seedling diameters were too tiny to be able to differentiate browse marks.

In other studies Goheen, 2004; Van de Koppel and Prins, 1998 suggested that interactions between smaller herbivores such as impala and buffalo and larger herbivores such as giraffe and elephant, due to competition and facilitation, will result in transitions and cycles of the different herbivores. This in turn may explain transitions and cycles between grassland and woodland. They envisage that transitions from coarse-grass feeders (buffalo, zebra) to selective feeders (e.g. impala, gazelles) would cause a change from woodlands to grasslands by preventing regeneration of acacias. We are aware that other mammalian herbivores at Olpejeta such as impala, bushbuck and eland also browse on seedlings of *A. drepanolobium* and it would not be practical to determine species specific herbivore impacts. However, Birkett (2002) observed that the number of missing tagged seedlings reduced with elephant translocation and that the pattern of missed seedlings closely matched that of elephant damage to *A. drepanolobium*. He therefore concluded that elephants had large impacts on seedlings.

Effect of management interventions

We observed a significant relationship between seedling density and management interventions that had an effect on elephant densities (the 2001 translocation and 2007 expansion of the reserve), with immediate rise in seedling densities the year

following each of the activities. However, we can not say with any confidence whether these observations are related to reduced elephant impacts as the density changes for 2003 were followed by a reduction for the following year. However, there is evidence for increased seedling density following opening of corridors with a steady increase since 2007, indicating that the effect of reduced browser density following expansion of the conservation area may be allowing more seedlings to survive, a case of ecological release.

We did not test the effect of changes in rhino densities as most plots we monitored are found in the old reserve section and this section was not much affected by increased rhino densities after the 2007 translocation of 27 rhinos into the conservancy. The effect of fire and drought are discussed in the 2008 report.

We conclude that *Acacia drepanolobium* seedlings are favoured by grass cover and grass cover is critical for their survival. Majority of seedlings are found below grass layer and as they approach the heights of 30-40 cm, they adopt a stoloniferous growth in a bid to delay their emergence and avoid predation. The expansion of the reserve and opening of corridors has resulted in increased survival of *A. drepanolobium* by reducing the browsing density. It is important to maintain grass cover for the successful recruitment of *Acacia drepanolobium* and *Olpejeta*. Good management of fire and grazers including cattle will assist in recruitment of *A. drepanolobium*, which is an important diet for the black rhino.

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