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Recent exposure to African elephants after a century of exclusion: Rapid accumulation of marula tree impact and mortality, and poor regeneration

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ABSTRACT

Concerns exist over the continual decline of marula trees (*Sclerocarya birrea* subsp. *caffra*), a large ecologically and economically important tree species in southern Africa, primarily as a consequence of impact by African elephants (*Loxodonta africana*) and poor regeneration. We assessed changes to marula tree population structure in a protected area that was only recently opened to elephants. Jejane Private Nature Reserve (JPNR) has been subjected to elephants from the Greater Kruger National Park (Greater KNP) since 2013, as it was fenced off beforehand. A previous survey of the marula population in JPNR was done in 2009 and again in 2016. Therefore this study aimed to (i) assess elephant-induced impact and mortality levels on the previously surveyed JPNR marula tree population, (ii) compare these levels with previously recorded impact and mortality levels on marula trees across the Greater KNP, and (iii) assess marula seed predation and seedling recruitment in JPNR. The resurveyed marula population had declined by 23.8% post-elephant movement into JPNR, with the highest annual mortality rates (AMR) and elephant impact scores for trees in the 5–8 m height class. The JPNR marula tree AMR of 8.1% was higher than that of Greater KNP (4.6%). Only two marula seedlings were found across all transects, whilst 84.2% of all endocarps' locules had seeds missing, with bite marks present on 42.3% of all endocarps. This suggests potential high levels of seed predation and a lack of seedling recruitment. The concern over the impact by elephants on adult marula trees is therefore escalated as a consequence of the lack of regeneration, primarily because of seed and seedling predation. Management policies should be focused on protection methods for individual trees, seedlings and seeds, together with a large scale artificial surface water management plan to manipulate herbivore densities and pressures on marula tree populations.
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1. Introduction

African elephants (*Loxodonta africana*) are considered to be one of the major drivers of ecosystem functioning, owing to their ability to alter landscapes and promote habitat heterogeneity (Dublin et al., 1990; White and Goodman, 2010; Coverdale et al., 2016). However, concerns have been raised over the potential negative impacts that can result from high densities of elephants in protected areas (Ben-Shahar, 1998; Gandiwa et al., 2011). This is of particular importance in South Africa's Greater Kruger National Park (Greater KNP), where long-term studies have reported significant declines in the density of large trees (Shannon et al., 2008; Helm and Witkowski, 2013; Asner et al., 2015). Large trees are important for ecosystem services, providing foraging opportunities and habitats for numerous species (Shackleton et al., 2002; Vogel et al., 2014; Mograbi et al., in press), as well as being critical for the cycling of nutrients (Scholes and Archer, 1997). A tree species of particular concern to conservationists is the marula tree (*Sclerocarya birrea* subsp. *caffra*; Anacardiaceae), with elephant impact on marula trees having been extensively studied because of its cultural, ecological and economical importance (Coetzee et al., 1979; Jacobs and Biggs, 2002a; Shackleton et al., 2002; Helm and Witkowski, 2013). Studies suggest that marula trees are actively selected for by elephants and are consequently foraged more intensely in comparison to other large tree species (Shannon et al., 2008; Henley, 2013). Elephants therefore, have been largely recognised as a major factor responsible for the decline of adult

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marula trees within protected areas (Helm et al., 2009; Helm and Witkowski, 2013).

The decline in marula tree numbers is not, however, solely due to elephant impact. A lack of regeneration is a concern in various populations (Helm et al., 2011a; Helm and Witkowski, 2012). Regeneration of trees can be affected by a variety of factors including seed predation (Eriksson and Ehrlén, 1992) and herbivory (Lewis, 1987; Moe et al., 2009). Seed predation is a common seed fate that occurs once either primary or secondary seed dispersal has occurred (Helm et al., 2011a; Midgley et al., 2012), with birds and small mammals being recorded predating marula seeds by manually opening the endocarps to feed on the stored seeds (Manson et al., 2001; Symes and Perrin, 2003). Furthermore, marula seeds which develop into seedlings are highly palatable (Walker et al., 1986), and studies have suggested a negative correlation between seedling survival and herbivore densities, especially those of impala (*Aepyceros melampus*) (Lewis, 1987; Kauffman and Maron, 2006). These recruitment studies indicate that it is necessary to investigate factors that may be influencing marula tree population structure at both the adult and recruitment demographic stages.

In January 2009, Helm and Witkowski (2012) assessed the size class distributions of marula tree populations, both within and bordering the Greater KNP. One of the bordering study sites, Jejane Private Nature Reserve (JPNR), displayed an adult-dominated marula tree population with a lack of seedling recruitment. At the time of the 2009 assessments, JPNR had not had any elephants present within the protected area in over 100 years, and no fires had occurred since the year 2000 (JPNR Management, pers. comm., November 23, 2016). In March 2013, JPNR proceeded to remove the fence-line between itself and the Greater KNP, allowing for elephants to move into JPNR (Thomson, 2013). Subsequent reports have suggested a decline in the number of large trees across JPNR, as well as a growing concern amongst management regarding the impact of elephants on marula trees (Weber, 2014). Therefore, by surveying the JPNR marula trees previously surveyed by Helm and Witkowski (2012), this paper aims to (i) assess elephant-induced impact and mortality levels on the previously surveyed JPNR marula tree population, (ii) compare these levels with previously recorded impact and mortality levels on marula trees across the Greater KNP, as published in Helm et al. (2009), and (iii) assess marula seed predation and seedling recruitment in JPNR. It is predicted that the impact and mortality levels of marula trees in JPNR will exceed those of previously recorded sites in the Greater KNP because of the abundance of marula trees in JPNR as a consequence of having no elephants for so many years. It is further predicted that high levels of seed predation may account for the lack of recruitment in JPNR.

2. Materials and methods

2.1. Study area

JPNR, a 21 km^2 protected area (S24.29045; E30.97664), is situated in the western region of the Greater KNP (Fig. 1). JPNR receives a mean annual rainfall (MAR) of 400–600 mm (JPNR Management, pers. comm., March 16, 2016) and is located in the Granite Lowveld vegetation unit (SVI 3) in the Savanna biome (Mucina and Rutherford, 2006). This vegetation unit is a moderately open savanna that is dominated by tall tree species such as *Sclerocarya birrea*, *Combretum apiculatum* and *Senegalia nigrescens* (Mucina and Rutherford, 2006). The marula trees which were previously surveyed in the Greater KNP by Helm et al. (2009) (Objective ii) were located in the following ecozones: Marula-knobthorn savanna, Delagoa-thorn thickets, Sabie thorn thickets, Mixed bushwillow woodlands, and Gabbro thornveld (Helm et al., 2009). This portion of the Greater KNP receives a MAR of 500–700 mm (Venter and Gertenbach, 1986) and is similarly predominantly located in the Granite Lowveld vegetation unit (SVI 3; Mucina and Rutherford, 2006).

2.2. Study species

The marula tree (Anacardiaceae) is a fast growing dioecious and deciduous tree, reaching heights of 7–17 m (Shackleton et al., 2002). Marula is often a community dominant and is a keystone species with both ecological and economical uses (Shackleton et al., 2002). Marula trees occur on a wide variety of soil-types, but are most commonly found on well-drained soil crests in areas with a MAR of 200–1500 mm (Lewis, 1987). Female trees produce sweet fleshy fruits, which may each contain 0–4 seeds (Leakey et al., 2005). Marula trees have been listed as a protected species in South Africa since 1962 (Shackleton and Shackleton, 2005).

2.3. Elephant impact and mortality levels

During 29 April–01 May 2016, 202 previously surveyed marula trees by Helm and Witkowski (2012) were resurveyed for elephant impact. These trees had not been previously assessed for elephant impact. The surveys had been done along eight transects which were all 40 m in width and ranged from 203 to 289 m in length. All trees had been previously georeferenced using a Global Positioning System (GPS). Upon arrival at the GPS location of each tree, methodology followed Helm et al. (2009) and Helm and Witkowski (2012, 2013). The located tree was classed into the following three tree fates: ‘Surviving’, ‘Missing’ and ‘Dead’. Trees classified as ‘Dead’ were further categorised into the cause of the death, being ‘Stem snapping’, ‘Uprooting’ or ‘Bark stripping’. Trees that were classified as ‘Surviving’ were further categorised into the following tree fate categories: ‘Mature’ (tree alive and >2 m in height), ‘Stem snapped’ (main stem broken but tree coppicing), or ‘Toppled’ (tree has been pushed over but coppicing). Each surviving tree had its height measured to a level of accuracy of 1 cm using the *VolCalc* digital photography method for estimating tree dimensions (Barrett and Brown, 2012). To compare height class distributions to those previously measured by Helm and Witkowski (2012), surviving trees were placed into the same 12 height classes (Table 1). The basal stem diameter (BSD) of each tree was measured 30 cm from the ground. To compare BSD class distributions to those previously measured by Helm and Witkowski (2012), surviving trees were placed into the same ten BSD size classes (Table 1). Elephant impact scores (Table 2), as previously used by Jacobs and Biggs (2002a), Helm et al. (2009) and Helm and Witkowski (2013), were assessed on all ‘Surviving’ trees that were categorised as ‘Standing’ and ‘Stem snapped’. As these impact scores would be compared to impact scores on marula trees in the Greater KNP, the trees were separated into an additional arrangement of height classes (Table 1) to correspond with the previously assessed trees by Helm et al. (2009) in 2001 and 2008. Impact score comparisons were only carried out on trees >5 m, as only one tree from the 2009 survey by Helm and Witkowski (2012) was <5 m. Additional notes were recorded on the presence or absence of bracket fungus (class Basidiomycetes), termites (*Coptotermes* species) and woodborer activity. The age of any elephant impact was estimated into the following age classes using parameters established by Henley (2013): 1 (within the past month); 2 (1–6 months); 3 (6–12 months); and 4 (more than a year old). Previous research has indicated that elephants may have a preference for female trees because of the fruit they bear (Hemborg and Bond, 2007), and therefore the sex of each tree was determined by searching for fruit endocarps beneath the tree’s canopy (Helm et al., 2009, 2011a).

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