



University of Venda

The Population Biology of *Sclerocarya birrea* at Nylsvley Nature Reserve, Limpopo
Province, South Africa.

By

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DECLARATION

I, Tshifhiwa Tshimomola MSc student at the University of Venda, hereby declare that this dissertation is an original work done and prepared by me under the guidance and supervision of Mr MH Ligavha-Mbelengwa and Mrs Georgina Mokganya. This work has not been previously done at this University or any other University in the world. The materials from other sources included in my dissertation have been properly referenced and acknowledged

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Date.....

ABSTRACT

The overall aim of this study was to determine the population biology of *Sclerocarya birrea* (A Rich) Hochst., subspecies *caffra* (Sond) at Nylsvley Nature Reserve, Limpopo, South Africa. *Sclerocarya birrea* is a keystone plant species which is rated as one of the most highly valued indigenous trees because of its multiple uses. It is identified as a key species to support the livelihood of rural communities and it is central to various commercial activities. *Sclerocarya birrea* is also widely used by game in protected areas and by humans in communal areas for its fruit, wood and medicinal properties. Understanding the population biology for this key stone species is important as there are many environmental factors that are affecting its population structure. The study found that the population of *S. birrea* at Nylsvley Nature Reserve is fairly healthy and is mainly comprised of seedling and adult trees. Evidence of predators feeding on the seeds of *Sclerocarya birrea* was also recorded in this study. Additionally, disturbance, such as fire and cutting do not have negative impact on *S. birrea*.

Keywords: *Sclerocarya birrea*, population biology, key species, predators

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1 INTRODUCTION

African savanna trees are heavily utilised by both humans and wildlife, resulting in unstable population structures for certain species (Helm *et al.*, 2011). Currently there is insufficient information on the impacts of these unstable populations' structures on the reproduction of savanna species. There are a number of factors that influence the population dynamics and distribution pattern of plants. These factors include differences in environmental conditions, resources, predators, neighbours and disturbance (Tshisikhawe *et al.*, 2012). According to Barbour *et al.*, 1987 the distribution, survival, and patterns of growth and reproduction reflect the plant's adaptations to a particular environment which is a critical part of plant ecology

Sclerocarya birrea (A Rich) Hochst., subspecies *caffra* (Sond) (Leal *et al.*, 2015) is a keystone plant species which is rated as one of the most highly valued indigenous trees as they provide valuable food and shade and is a favourite food plant of the elephant. Their leaves are browsed by game, the bark stripped by elephants and the abundant crops of fruit which are high in vitamin C, are eaten by game animals, monkeys and baboons.

Various studies showed *Sclerocarya birrea tree* populations to be highly clumped (Walker *et al.*, 1986; Lewis 1987). Lewis (1987) studied a population of *Sclerocarya birrea* trees in the Luangwa Valley, Zambia, and correlated the spatial distribution and highly aggregated pattern of this sample population with physical soil characteristics. The majority of this population (75%) was found on well-drained sandy soils (Lewis 1987). In the Kruger National Park, *Sclerocarya birrea* occurs widely but clumped on

sandy granitic soils, mostly on the crests, midslopes and dolerite intrusions where the soils are shallow.

Previous studies on the population characteristics of *Sclerocarya birrea* in other nature reserves suggested that the population structure of this species is not different from that of Southern African trees (Jacobs *et al.*, 2002). Walker *et al.* (1986) concluded that the successful regeneration of the *Sclerocarya birrea* is highly episodic, while Lewis (1987) suggested that population regulation of the *Sclerocarya birrea* may be controlled by seedling browsers other than elephants

1.1 The problem statement.

It has been established that *S. birrea* is a widely utilised species in terms of browsing by game in protected areas and utilisation by humans in communal areas for fruit, wood carving, shade and beer. This motivated most of the reviews of *S. birrea* research including those by Shone (1979), Von Teichman (1982; 1983), Hall *et al.* (2002); Shackleton *et al.* (2002), and Wynberg *et al.* (2002). These reviews concluded that much is known about the fruit and its uses, as well as growing *S. birrea* under artificial conditions. However, the available information on natural *S. birrea* populations is incomplete, based on a collection of observations which have not been integrated (Shackleton *et al.* 2002). There is therefore a need for a reliable interpretation of the population biology of this extremely important indigenous savanna tree. According to Shackleton *et al.*, (2002) little is known about the regeneration ecology of this species in its natural habitat.

According to Helm *et al*, (2002), there is a gap in terms of understanding the reproductive biology of *S. birrea* which is hampering the efforts to predict the future dynamics of the populations under threat and also to explain the diverse population structures observed in private reserves, national parks and communal areas in South Africa. The most important factors to be considered in trying to understand the reproductive biology and the population structures of the *S. birrea* trees are the factors limiting seeds dispersal, germination rate and seedling survivorship.

With no available information on the germination of *S. birrea*, it important to study the population biology of this species considering that most of the threats to biodiversity such as fire, livestock, tree removal and soil disturbance affect the regeneration and population structure of *S. birrea*. There have been references to intervals of 6 – 10 months between seed dispersal and germination in the field, which allows a period of dormancy (Von Teichman, 1982; Lewis, 1987).

Shackleton *et al*, (2002) indicated that there has been no systematic appraisal of the densities and productive capacity of *S. birrea* throughout its range. They furthermore reported that existing data is largely a coincidental result from other work recording densities of all woody species for vegetation mapping or characterisation purposes.

1.2 Aim

The aim of the study is to determine the population biology of *Sclerocarya birrea* at Nylsvley Nature Reserve, Limpopo Province, South Africa.

1.3 Objectives

1. To assess the impact of disturbance on the regeneration of *S. birrea*
2. To identify factors affecting the dispersal of *S. birrea* seeds at Nylsvley Nature Reserve
3. To determine the population size and distribution of *S. birrea* at Nylsvley Nature Reserve
4. To determine the primary mechanism which favours the germination of *S. birrea*
5. To determine the dispersal and predation rates of *S. birrea* populations

1.4 Research questions

1. How is *S. birrea* reproduction limited by disturbance agents?
2. What are the factors affecting the reproduction of *S. birrea* at Nylsvley Nature Reserve
3. What is the population size of *S. birrea* at Nylsvley Nature Reserve
4. What are the primary mechanism which favours germination of *S. birrea*?
5. What are the dispersal and predation rates for *S. birrea* populations?

2 LITERATURE REVIEW

2.1 Description of *Sclerocarya birrea*

Sclerocarya birrea commonly known as marula is a widespread species throughout the semi-arid, deciduous savannas of much of sub-Saharan Africa. *Sclerocarya birrea* is a member of the Anacardiaceae, along with 650 species and 70 genera or subtropical evergreen or deciduous trees (Chirwa *and* Akinnifesi, 2008). There are three subspecies of *S. birrea* in sub Saharan Africa. *Sclerocarya birrea* subsp. *caffra*, occurs across a very broad area within southern Africa, including the southern to large tree, usually grows up to 9 - 12 m tall and it is single stemmed with short bole, up to 120 cm in diameter, dense, spreading crown and deciduous foliage . The bark is grey and usually peels off in flat, round disks, exposing the underlying light yellow tissues.

Sclerocarya birrea has a well-developed root system which is one of its characteristics and can withstand fairly prolonged drought. According to Petje (2008) and Hall *et al* 2008, the longest lateral root recorded from *S. birrea* is 58 m, with a maximum depth for tap root of 2.4 m. It is associated with seasonal rainfall patterns, with a mean annual rainfall of 500 - 1250 mm (Chirwa *et al.*, 2008). Hall *et al.* (2002) provide the most detailed distribution maps with respect to environmental factors such as elevation and rainfall.

It is primarily dioecious, which is a mechanism that ensures no selfing, although male and female flowers occasionally occur on the same trees. In some cases there has been a rare occurrence of bisexual flowers. Male flowers are borne in groups of three

on racemes below new leaves. The female flowers occur below the leaves on long peduncles and consist of four curling petals. They have numerous infertile stamens and a long, shiny ovary (Hall *et al.*, 2002). Male and female flowers are borne on separate trees, the flowers of male plants producing pollen and the female flowers producing the fruit for which the tree is so well known. Flowering takes place from September to November (Van Wyk and Van Wyk, 2007). The flowers are bright red when in bud but then open into small pinkish-white flowers; which are frequented by insects during the flowering season (Palmer and Pitman 1972; Hall *et al.* 2002). Morphological evidence and observations suggest that *S. birrea* is an entomophilous species that produces sticky pollen and secretes nectar, and that the honeybee is a major pollinator (Hall *et al.*, 2002). In southern Africa flowering is in September-November and fruiting in February - June (Petje, 2008).



Figure 1: *Sclerocarya birrea* male flowers (Hall, 2002)



Figure 2: *Sclerocarya birrea* female flowers (Hall, 2002)

Sclerocarya birrea fruits consist of a specialised stone consisting of 2 - 5 carpels and fruiting occurs from March to June. The fruits are up to 3,5 cm in diameter and approximately 42 g in weight when they fall to the ground (Jacobs and Biggs 2000). The fruits are green and turn yellow after falling between February and June. The fruits drop from tree when they are fully developed but still green and ripen on the ground, making harvesting relatively easy (Hall *et al.*, 2000; Shackleton *et al.*, 2002). The kernels consist of seed coat and an embryo without endosperm. The seeds are enclosed in a hard, light brown, smooth oval-shaped stone (endocarp) and each contains 1- 4 seeds and are 1 to 1.5 cm in length (Hall *et al.*, 2000, Petje 2008). Each seed cavity is covered by an operculum that needs to be removed during seed extraction.

The seeds do not germinate readily when the fruit is dropped from the tree, but may remain dormant for more than six months in a temporary seed bank in the soil and may only germinate after sufficient rain in the following growing season. *Sclerocarya birrea* fruits have a strongly lignified endocarp or stone which contains several seeds,

each of which is within its own locule that is sealed by an individual operculum. The strong casing prevents germination, not by preventing the passage of water to the seeds, but by preventing oxygen from reaching the seeds (Von Teichman *et al.*, 1985). Elephants seem to be the main dispersal agents of *S. birrea* seeds. Animals such as, parrots, rodents and other small mammals, like the ground squirrels also target the seeds of *S. birrea* and targeting the uneaten endocarp. Further investigation on the effects of mammal dispersers on the germination rates as well as the dispersal and predation rates is required. (Helm *et al.*, 2011).



Figure 3: *Sclerocarya birrea* kernels and seeds (Jacobs and Gibbs, 2000)

Vertebrates play a vital role in seed dispersal, especially the frugivores (Setlalekgomo *et al.*, 2013). Frugivores may thus help in the restoration of degraded land areas as well as in the resurrection of some endangered plant species. Seed dispersal by vertebrates especially mammals may occur in several ways such as epizoochory, which is a mode of seed dispersal whereby seeds stick to the fur of the animal or by endozoochory, which occurs via seed ingestion. The seeds may be ingested by an animal in an intact fruits then egested in faeces (gut passed seeds). *Sclerocarya birrea* fruits are eaten by some vertebrate frugivores and their seeds passed out in faeces. The ingestion of *S. birrea* fruits and the egestion of the seeds by elephants (*Loxodonta africana*) are reported to have a positive effect on the germination of the seeds (Lewis, 1987; Dudley, 2000; Helm *et al.*, 2011; Midgley *et al.*, 2012). There are other vertebrate frugivores which feed on the *S. birrea* fruits and information on the effects of their gut passage on the germination of the seeds is scarce

It is also well known that *S. birrea* fruits taken from the dung of the African elephant (*Loxodonta africana* Blumenbach) have more rapid germination than those that have not been eaten by elephants (Lewis, 1987, Dudley, 2000). This positive impact of elephants on *S. birrea* germination continues to be considered to be through acid treatment in the digestion system of the elephant (Helm *et al.*, 2011). There is no work done on what proportion of the diet or nutrient intake *S. birrea* contributes to these animal species. *Sclerocarya birrea* also appear to have short term persistent seed banks (Witkowski, unpublished). Seed dispersal occurs largely through fruit consumption by mammalian herbivores, which disperse the nuts during eating and defaecation. Dispersal distances vary greatly and may be as far as several kilometres (Shackleton, 2003).



Figure 4: *Loxodonta africana* feeding on *S. birrea*

Fire, livestock, tree removal and soil disturbance affect the regeneration and/or population character of *S. birrea*. Despite their positive effect on the regeneration and/or population characteristics of *S. birrea* fires remain the most regular and often destructive annual event (Lamprey *et al.*, 1967).

2.2 Uses of *Sclerocarya birrea*

Sclerocarya birrea forms an integral part of the diet, tradition and culture of rural communities in southern Africa and also is central to various commercial initiatives (Wynberg *et al.*, 2002). It is also widely used by rural populations in most countries in which it is found (Wynberg *et al.*, 2002). It has multiple uses, including the fruits, kernels, oil, bark, wood and leaves. Maroyi (2013) discovered that *S. birrea* is regarded

as an important source of livelihood needs such as aesthetic value, fodder, food, fuelwood, medicine, and shade and utility timber used for making crafts. The main product harvested are the fruit. The seeds are eaten raw and the fruit juice is fermented to produce beverage or traditional beer. The marula beer contribute to sustainable livelihood to poor families.

2.2.1 Seed oil

The seeds are rich in protein and oil, magnesium, phosphorus and potassium, which are important to an African diet. The seeds are eaten, dried or ground and added to soups, stews and vegetables, to which they are reputed to give a delicious flavour (Petje, 2008). Fresh seeds are also added to newly-boiled meat, which is then eaten immediately (Shackleton *et al.*, 2002). The oil from the nuts is also used as a skin moisturiser, medicine and insecticide by the cosmetic industry.

2.2.2 Medicinal uses

Sclerocarya birrea is also used as a medicinal plant throughout its distribution range. The parts that are used includes the barks, leaves and roots. The bark has medicinal properties that are used in treating dysentery, and diarrhoea, rheumatism, gangrenous rectitis, insect bites, burns and a variety of other ailments (Shackleton *et al.*, 2000; Hall *et al.*, 2000). Essence from the leaves provides a remedy for abscesses, spider bites and burns. The leaves are also used as a sedative (Petje, 2008).

Because of these multiple uses, and its significance in the landscape, several African cultures have specific beliefs and ceremonies associated with this species, and it is

often maintained in homestead and arable plots. (Shackleton *et al.*, 2002; Ngorima, 2006). Because of the widespread occurrence, potentially high fruit production and use of *S. birrea* has frequently been identified as a key species to support the development of rural enterprises based on the fruit, beer, oil or nuts and therefore as a species for potential domestication. Localised breeding and cultivation initiatives commenced in the 1970s. Interest in this species was renewed after the development of a highly successful liquor using extracts from the fruits (Shackleton *et al.*, 2002, Ngorima, 2006).

2.2.3 Ecological uses

Sclerocarya birrea is important in the ecology of other plants and animals as it grows into a large tree. They are also rated as one of the most highly valued indigenous trees as they provide valuable food and shade and they are favourite food plants of the elephants. The leaves are browsed by game, the bark stripped by elephants and the abundant crops of fruit, which are high in vitamin C, are eaten by game animals, monkeys and baboons. The elephant in particular being a major consumer. Because of the large canopy *Sclerocarya birrea* produces a large area of improved micro-environment within the subcanopy, which is said to be a key resource area. These conditions are important to the development of different sub-canopy woody plants, grasses and other microorganisms. The dominance and large size of *S. birrea* also make the crown of the tree an important habitat for small vertebrates and invertebrates, as well as parasitic plants. Furthermore, *Panicum maximum* grows under *S. birrea* and it is one of the most valuable fodder grasses in the tropical and subtropical regions (Shone, 1979).

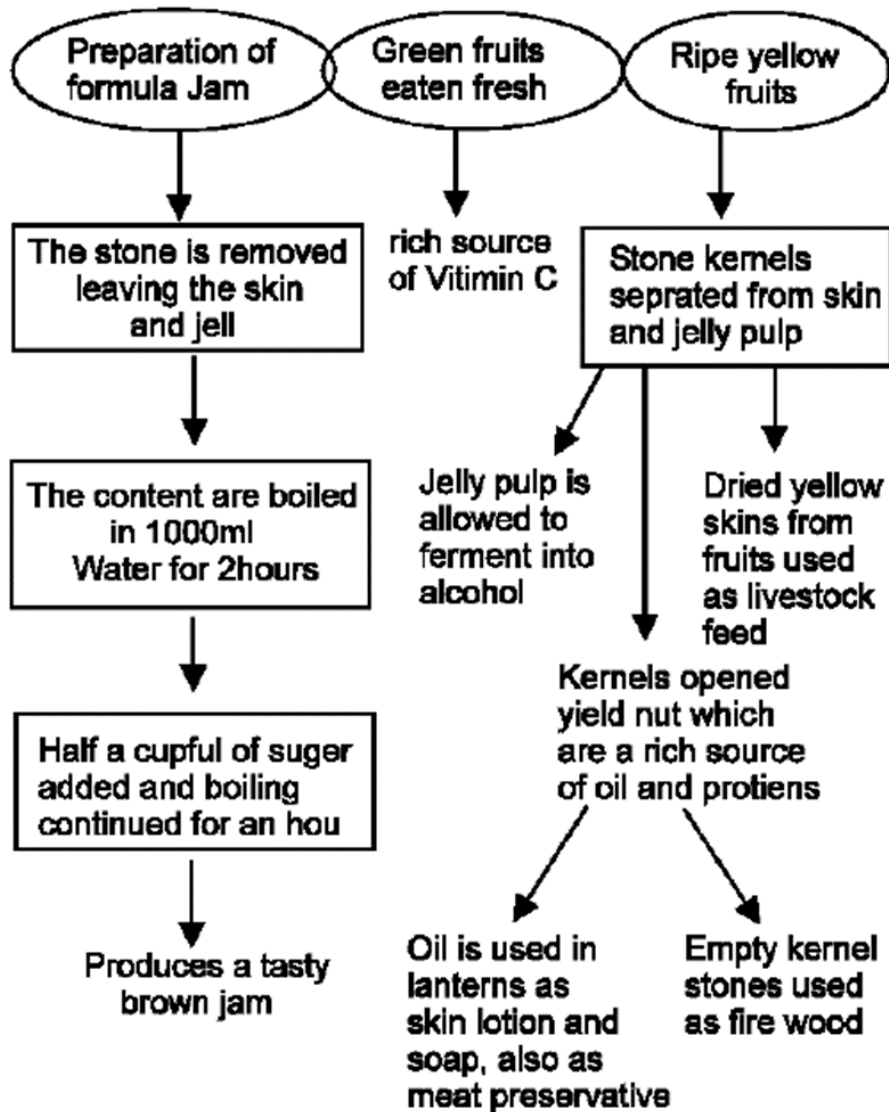


Figure 5: Schematic representation of uses of *Sclerocarya birrea* (adapted from Motlhanka *et al.*, 2008)

2.3 Distribution of *Sclerocarya birrea*.

Sclerocarya birrea is widely distributed across the sub-Saharan Africa as well as the miombo woodlands. Occasionally it may grow in high-lying areas, which experience very short sub-zero spells in winter (Petje, 2008). *Sclerocarya birrea* occurs in 29 countries, from the west to the east and north to south in countries such as, Mauritania, Mali, Burkina faso, Ghana, Togo, Benin, Niger, Nigeria, Chad and Sudan, and in low Africa; Eritrea, Kenya, and Tanzania, whilst in eastern High Africa; it occurs in countries like: Angola, southern Congo, Zambia, Malawi, Mozambique, Namibia, Botswana, Zimbabwe, South Africa, Lesotho and Swaziland in southern Africa (Figure. 1, Hall *et al.*, 2000). In South Africa the distribution of *S. birrea* is clearly controlled by climatic conditions (Petje, 2008). The species is abundant in warmer parts and where conditions are suitable, almost pure stands of *S. birrea* may be found. The main or critical controlling factor concerning its distribution is frost (Shone, 1979).

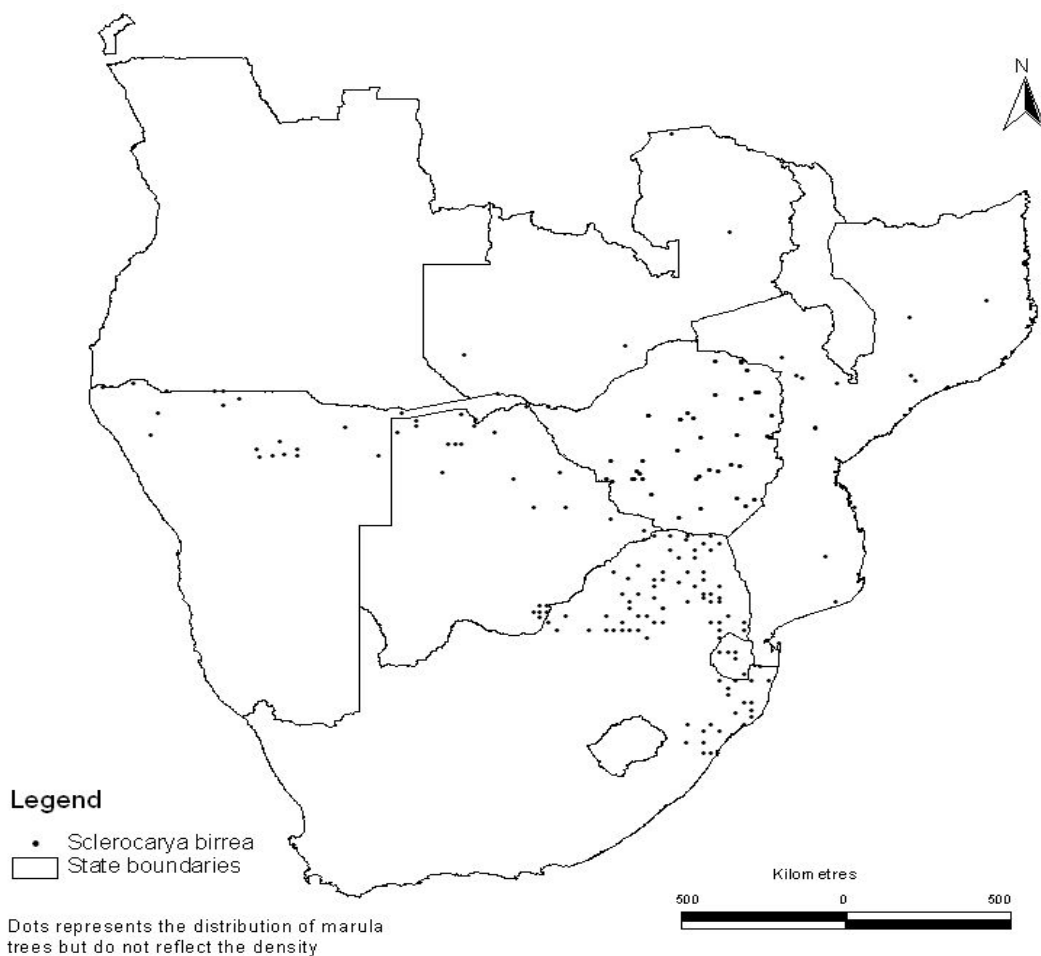


Figure 6: The distribution of *Sclerocarya birrea* in southern African countries

(Source: PhytoTrade Africa, 2005).

According to Jacobs and Biggs, 2000 *S. birrea* tree populations are usually highly clumped wherever they occur. In Kruger National Park, studies show that *S. birrea* occurs widely but clumped on sandy granitic soils on the crest, midslope and dolerite intrusions where the soils are shallow. On the drier clayey basaltic soils, the tree populations decrease as soils forms with high clay contents become more dominant and are largely restricted to crest and midslope of moister climates with an annual rainfall exceeding 500 mm (Jacobs and Biggs, 2000). This is supported by a study conducted by Lewis (1987) which found that the tree population was decreased with

clay content. The study therefore concluded that the granitic landscapes in the Kruger National Park are therefore more suitable for the establishment of the *S. birrea* tree population (Lewis, 1987).

Studies on the population characteristics of *S. birrea* in other nature reserves suggested that the population structure of this tree species is not different from that of southern African trees (Weber, 2014). Furthermore, some studies have reported unstable *S. birrea* populations as well as locally extinct populations and discussed causes such as elephant impact, herbivory, fire and episodic recruitment events (Weber, 2014). Walker *et al.*, (1986) found unstable population structures with no immature trees and little evidence of successful regeneration and recruitment.

2.4 Factors affecting the distribution of *Sclerocarya birrea*

2.4.1 Seed dispersal

According to Wall *et al.* (2012), seed dispersal is a critical and important step in a plant's life cycle. It has an effect on the demography, spatial distribution, colonization, gene flow, population genetics, and evolution of species. There is a number of seed dispersal syndromes of which two of them involves vertebrates that consume seeds even as they disperse them. These two syndromes are frugivory and scatter hoarding and both of them are associated with a distinct animal guild. Frugivory is wherein the animals ingest fruits and then defecate or vomit the seeds across the landscape whereas in scatter-hoarding involves storing of seeds in well-spaced caches in the ground, returning later to eat many but not all of them (Wall *et al.*, 2012).

2.4.2 Fire

Even though there is very little scientific studies done of the effect of fire intensity on tree mortality, it was determined that mortality rate of 7400 trees subjected to head fires ranging from 110 kJ/s/m to 6704 kJ/s/m was only 1.3%; it was therefore concluded that fires alone in the savanna contribute very little to the mortality of the trees irrespective of the intensity. The dominant effects of fires is to kill the top part of trees (Trollope *et al.*, 1995). Furthermore a study by Jacobs (2001) to investigate the response of *Sclerocarya birrea* to fire, concluded that the structure of the *Sclerocarya birrea* seedlings were affected and not the density. The study further determined that fire enhances the change in the structure of *Sclerocarya birrea* seedlings to a multi-stemmed morphology, where increasing fire intensities resulted in increased proportions of multi-stemmed individuals.

2.4.3 Temperature

Sclerocarya birrea prefers a warm, frost-free climate but is also found at high altitudes where temperatures may drop to below freezing point for a very short period in winter. The tree is frost sensitive and moderately drought resistant (Net Database, 2003). Lewis 1987 indicated that *sclereoncarya birrea* has a high optimum germination temperature between 27 °C and 37 °C. *Sclerocarya birrea* in general occurs in areas with temperatures ranging from as little as 10 °C (at high elevations) to over 40 °C at low elevations with average temperature of 20.6 to 27.4 °C (Petje, 2008, Hall *et al.*, 2000). According to Shone 1979 the distribution of *Sclerocarya birrea* in South Africa is clearly controlled by climatic conditions and is abundant in warmer parts and where conditions are suitable, almost pure stands may be found (Shone, 1979).

2.4.4 Rainfall

Sclerocarya birrea is found in rainfall regimes typical of sub humid to semi-humid conditions (Shone, 1979). Rain and humidity during the growing season have a number of adverse effects. Rain and cool weather during bloom can reduce bee activity and cross-pollination and thus diminish the crop load. According to Jaynes (1969) humidity and rain increase the potential for fungus and bacterial diseases that can decrease the species. Shone (1979) indicated that *S. birrea* is best suited to the drier areas receiving an annual rainfall of between 250 mm and 800 mm per annum.

2.4.5 Frugivores

The role and importance of vertebrates in seed dispersal, especially the frugivores have been emphasized (Setlalekgomo, 2013). Frugivores are important in the restoration of degraded land areas as well as in the resurrection of some endangered plant species. Seed dispersal by vertebrates especially mammals is in the form of epizoochory and endozoochory. Epizoochory is a seed dispersal mode wherein the seeds stick to the fur of the animals and dispersed far away from the mother plants and by endozoochory, which wherein the seed are ingested by the animal and egested in faeces and referred to as gut passes seeds (Setlalekgomo, 2013). *Sclerocarya birrea* fruits are eaten by some vertebrate frugivores and their seeds passed out in faeces. The ingestion of *S. birrea* fruits and the egestion of the seeds by elephants (*Loxodonta africana*) are reported to have a positive effect on the germination of the seeds (Lewis, 1987; Helm *et al.*, 2011; Midgley *et al.*, 2012). There are other vertebrate frugivores which feed on the *S. birrea* fruits and there is lack of information on the effects germination after gut passage. It is well known though that

S. birrea fruits taken from the dung of the African elephant (*Loxodonta africana*) have more rapid germination than those that have not been eaten by elephants (Midgley *et al.*, 2012).

2.5 Conservation Status of *Sclerocarya birrea*

The Red List of South African plants classified *S. birrea* as a species of least concern, South Africa uses the internationally endorsed IUCN Red List Categories and Criteria. This scientific system is designed to measure species' risk of extinction. The purpose of this system is to highlight those species that are most urgently in need of conservation action. Species classified as Least Concern are considered at low risk of extinction.

3. METHODOLOGY AND STUDY AREA

3.1 Description of the Study area

The research project was conducted at the Nylsvley Nature Reserve (NNR), Limpopo Province, South Africa. Nylsvley Nature Reserve is located in the Waterberg Region and situated approximately 12 km to the south of Mookgophong and 50 km to the North-East of Bela Bela in Limpopo Province, South Africa (LEDET, 2013). Nylsvley Nature Reserve is located between the latitudes of 24°35'S and 24°40'S, and longitudes of 28°35'E and 28°45'E in Limpopo Province, South Africa (Figure 7). According to Dippenaar-Schoeman *et al.* (2009), the altitude of Nylsvley Nature Reserve ranges between 1080 m and 1154 m above sea level with an average altitude of 1100 m. The reserve comprises 3965.251 ha (LEDET, 2013). The Waterberg foothills rise to almost 1600 m in the Nyl River catchment and contribute most of the runoff that supplies the floodplain with water. According to Noble and Hermens, 1978, the Nyl River floodplain is the largest inland wetland in South Africa.

The NNR provides protection to a portion of approximately 800 ha of the larger Nyl River floodplain wetland system, which extends from Middelfontein to the west of Nylstroom in a north-westerly direction to Moorddrift. It covers a total area of 24 250 ha. Nylsvley was designated as a Ramsar site which are wetlands of international importance in July 1998, following South Africa's accession to the Ramsar Convention. Nylsvley is regarded as one of the premier bird watching spots in South Africa, boasting one of the highest diversities in avifaunal species in the country.

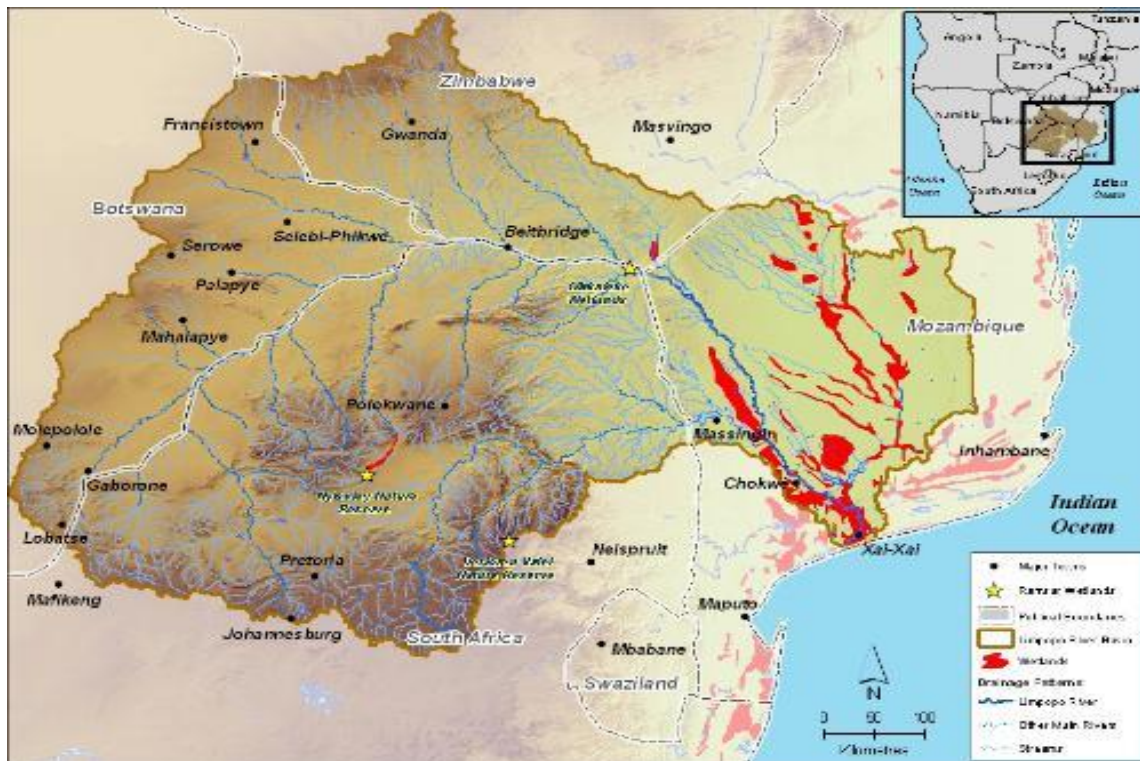


Figure 7: Location of the study site in Mookgophong, South Africa (Lehner and Döll 2004)

3.2 Climate and weather patterns

The Nylsvley Nature Reserve lies in the bushveld, which has a warm climate with a mean annual temperature of 18.6°C (Frost, 1987). According to Frost (1987), maximum daily temperatures at the NNR range from a mean of 29°C in December/January to 21°C in June/July while minimum daily temperatures vary between approximately 17°C in December/January and 4°C in June/July. The average annual rainfall for the NNR is approximately 648 mm and is highly variable: annual rainfall can vary between 250 mm and 1100mm within a 15 to 21 year cycle (Tooth *et al.*, 2002).

Nylsvley Nature Reserve has a typical savanna climate which is a hot wet season and a warm dry season; the climate in the reserve has a high degree of short and medium term unpredictability which permits coexistence of closely related species (Scholes and Walker, 1993). The atmosphere at NNR is relatively dry throughout the years, but is especially dry in winter. The mean monthly atmospheric water content varies from 5.2 g/m^3 in July to 13.5 g/m^3 in January (Scholes and Walker, 1993). The high radiation and the consequent high temperatures and saturation deficits in NNR lead to high potential rates of evaporation (Scholes and Walker, 1993). Nylsvley Nature Reserve is a drought prone environment and rainfall is in the hot summer months (Scholes and Walker, 1993). Nylsvley Nature Reserve is situated in the summer rainfall region, receives rainfall during the hot summer months and experiences cool dry winter (Dippenaar-Schoeman *et al.*, 2009). The NNR receives least amount of rainfall during July with an average monthly rainfall of 3 mm per month and the most in November with an average monthly rainfall of 150 mm per month (LEDET, 2013).

3.3 Flora and fauna

The Nylsvley Nature Reserve falls within the Savanna Biome in South Africa. The savanna biome covers about 20% of the global land surface, and about half of the area of Africa and about 35% of South Africa (Scholes and Walker, 1993). Savanna is characterized by an herbaceous layer usually dominated by grasses with a woody component and most typically an overstorey of trees (LEDET, 2013). In southern Africa, bushveld is an apt description of the vegetation structure, as the vegetation most often does not comprise distinct shrub and tree layers and the shrubs and trees occur in a matrix with a grass dominated herb layer. The vegetation of the reserve comprises Central Bushveld vegetation units of the Savanna Biome and a Freshwater

Wetland Vegetation unit of Inland Azonal Vegetation (LEDET, 2013). Savanna are fire prone ecosystems and therefore fire is essential in maintaining both its structure and floristic compositions. The exclusion of fire results in bush encroachment and a diminishing grass and herbaceous layer.

Approximately 600 plant species have been recorded in the NNR (Dippenaar-Schoeman *et al.*, 2009). There are nine distinguished vegetation types which are : *Burkea africana* savanna; *Diplorhynchus condylocarpon* savanna; *Combretum* savanna; *Acacia tortilis* savanna; Old village sites; *Acacia karoo* savanna; Floodplain grasslands; Grasslands on vertic soils; Seepline grassland (Dippenaar-Schoeman *et al.* 2009 and Scholes and Walker, 1993). These vegetation types may be further grouped into two broad categories (Low and Rebelo, 1998): Mixed Bushveld; Clay Thorn Bushveld. Nylsvley Nature Reserve provides a suitable habitat to a wide variety of bird, mammal, reptile, fish and insect species. Seventy-nine mammal species have been recorded in the reserve, as well as 382 bird, 22 fish, 23 lizard, 1 worm lizard, 17 frog and 29 snake species (Dippenaar-Schoeman *et al.*, 2009).

3.4 Geology and soils

Nylsvley Nature Reserve has a variety of geological formations which can be grouped according to the vegetation unit it supports. The geological sub-strata of the Central Sandy Bushveld are mostly sandstone, siltstone, shale and conglomerate (Mucina and Rutherford, 2006). The soils which are found in the Central Sandy Bushveld are either well drained deep Hutton or Clovelly soils but Glenrosa soils are also present in this vegetation unit (Mucina and Rutherford, 2006). Springbok flats Thornveld soils are predominantly deep vertic clays but freely drained with high base status and self-mulching (LEDET, 2013).

3.5 Vegetation types

The reserve comprises of Central Bushveld vegetation units of the Savanna Biome and a Freshwater Wetland vegetation unit (Alluvium vegetation) of Inland Azonal Vegetation. It is characterized by a herbaceous layer (usually dominated by grasses) with a woody component most typically an overstorey of trees. In southern Africa, bushveld is an apt description of the vegetation structure, as the vegetation most often does not comprise distinct shrub and tree layers and the shrubs and trees occur in a matrix with a grass-dominated herb layer. Savannas are fire prone ecosystems and therefore fire is essential to maintaining both its structure and floristic composition. Fire is also important in the prevention of bush encroachment and diminishing grass as well as the herbaceous layer. Mid-dry season burns favour scrubby and coppiced savannah (i.e. an increase in browse capacity at the expense of grazing), while early wet season burns favour grass production (LEDET, 2013)

4. METHODS OF DATA COLLECTION

4.1 Sampling of Individual trees

When determining the population biology of a single tree species, such as the *S. birrea*, it is necessary to record as many trees as possible in the study area that will be representative of the population in the reserve. Data was collected during the year 2015 and 2016. A random sampling method was used to sample the population of *S. birrea*. A five meter height rod was used to measure the height of individual trees. Estimates were done where individuals were taller than the five meter height rod using the four finger rule. All trees counted were sprayed using a marking spray to avoid duplication or counting of *S. birrea* trees more than once. In this study, seedlings were considered as individuals ≤ 1 m in height, juveniles as individuals between 1 and 3 m in height, and mature trees as individuals ≥ 3 m in height.

4.1.1 Adults

When sampling adult *S. birrea* trees, the following parameters were recorded: Basal stem circumference (cm), Plant heights (m), Crown health (m) and damage estimates on a sliding scale of 0 - 5 and the distance between trees. Stem circumference measurements (cm) were taken on each basal area of the individuals. Basal area measurements were used instead of diameter at breast height (DBH) because most plants were multi-stemmed at breast height. Plant height measurements were recorded in meters (m). For each tree, the basal diameter measured was used to classify the species into size classes (Munondo, 2005). Estimates were done where individuals were taller than the five meter height rod using the four finger rule. The

canopy cover was measured in meters on both sides of the trees. Furthermore the distance between individual trees was also measured using 100 meters tape measure.

The assessment of crown health was made using a sliding scale of 0 to 5 as follows:

- 0 - 100% crown mortality,
- 1 - Severe crown damage,
- 2 - Moderate crown damage,
- 2 - Light crown damage,
- 3 - Traces of crown damage,
- 4 - No damage

The disturbance intensity was also estimated using a slide scale of 0 to 5 as follows:

- 0 - No damage,
- 1 - Traces of damage,
- 2 - Light damage,
- 3 - Moderate damage,
- 4 - Severe damage,
- 5 - 100% damage.

4.1.2 Juveniles and seedlings

When sampling juvenile and seedling trees, the same parameter recorded on adult trees were also recorded, they are: Basal stem circumference (cm), Plant heights (m), Canopy cover (m), damage estimates on a sliding scale of 0 - 5 and the distance between trees. A five meter height rod was used to measure the height of juvenile trees and 50 meter tapes were used to measure the heights of seedlings.

4.2 Collection and observation of kernels and seeds

According to Knight *et al.*, 2009 seed timing collection is correctly as important as having a good technique for gathering the seeds. Seeds should be collected when they are physiologically mature, at which point they have the greatest ability to survive. It is necessary to observe the internal structures of the seed to decide if the seed is mature and healthy enough to be collected. During the site visit *S. birrea* kernels which were under the mother trees were also collected. A camera was used to take pictures of the fruits. The distribution of seedlings around their parent plants were used to estimate seed dispersal patterns. This approach was applied effectively by Houle, (1982) in studies on seed dispersal of tree species.

5. RESULTS AND DISCUSSION

5.1 Population structure and status. *Size-class distribution.*

Stem circumference size-class 0 cm - 40 cm showed high number of individuals (n = 47), and a significant decrease in the number was observed in the size-class of 40.1 cm - 120 cm (n = 3) (see Table 1, Figure 8). According to Siaga (2006 unpublished), a healthy plant population is able to produce a large number of seedlings which proceed to become older individuals. In contrary this study showed a high number of individuals within small circumference size-class of 0 – 40 cm. Figure 8 below also shows a decrease in individuals with a larger stem circumference showing a low number of juvenile trees.

There were difficulties in the recruitment of individuals with large circumference size-classes, this was manifested by a low number of mature trees. This might be due to certain growth limiting factors such as interspecific and intraspecific competition between seedlings for space and resources such as sunlight, nutrients, and moisture amongst others as well as the effects of herbivory and frugivory on the species. There are reports on the caching of seeds and such tendency might result in the production of aggregated seedlings which would naturally compete for resources as they continue to establish and grow. (Schupp *et al*, 2010)

It was found during the survey that there are animals that collect and gather the seeds under the trees which can also be a factor that is limiting the dispersal and distribution of seeds. In addition, the kernels that were found during the survey were opened and void of the seeds. The few number of individuals of *S. birrea* found in the reserve is

therefore sign of the devastation caused by predators on the population of *S. birrea* species. Huge numbers of marula fruits were found produced by some marula trees in the reserve and there is report of them collected for human consumption or any other human use (personal communication); it is therefore valid to advance the theory/vindication that predators in the name of mammals and humans are responsible for the scantiness in population of *S. birrea* in the Nylsvley Nature Reserve. The narrow distribution of *S. birrea* of in the Nylsvley Nature Reserve is thus ascribable to the patterns of seed dispersal by predators which tended to generally gather seeds under the *S. birrea* parent plants.

Figure 8 also showed a positively skewed population structure with seedlings and small plants dominating while larger sized individuals were few. Furthermore *S. birrea* species seem to have a good capacity to regenerate naturally under protection. The absence of juveniles individuals raises a concern, however it is necessary to prevent cutting of adults and juveniles trees and also to regulate grazing and browsing, which most likely have a negative effect on seedling establishment and survival in this and other woody species.

Table 1: Stem circumference size-class distribution of *S. birrea* in the Nylsvley Nature Reserve. Frequency is taken as the number of individuals in any given size-class from the total population number.

Stem circumference size classes (cm)	Frequency (n)
0-40	47
40.1-80	0
80.1-120	3
120.1-160	10
160.1-200	8
200.1-240	10
240.1-280	3
280.1-320	2
360.1-400	0
400.1-440	2

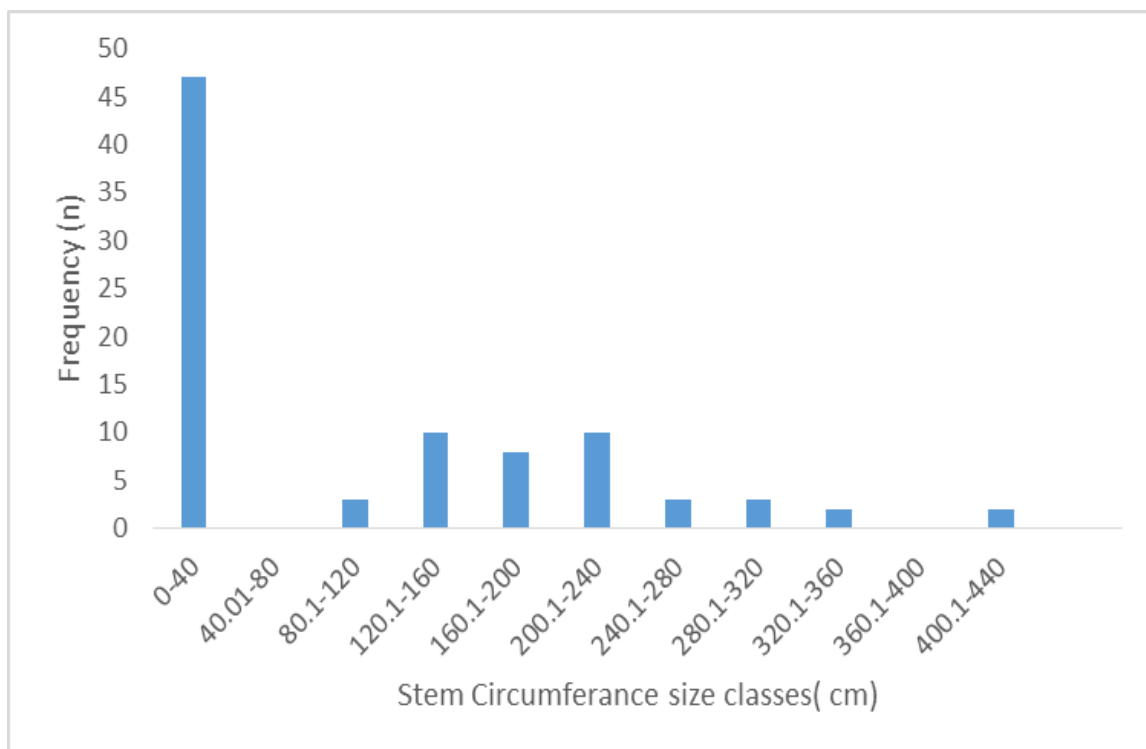


Figure 8: Stem circumference size-class distribution of *S. birrea* in the Nylsvley Nature Reserve. Frequency is taken as the number of individuals in any given size-class from the total population number. Data was collected in September 2015 and April 2016

5.2 Plant height measurements.

Table 2 shows Eighty eight individuals that were categorized into five plant height size-classes (see Figure 9). Figure 9 shows an irregular shape, but from this pattern it is clear that the height class of 0 m – 4 m showed the highest number of individuals, and there was a decrease in the number of individuals from this size-class to the remaining size-classes. Figure 9 also showed that there were very few individuals that were falling into large-scale plant-height classes (see Figure 9). Figure 9 also showed that the individuals with a height class of 4.1 - 8 meters were very few. There is also a gap between species that are falling between individual that are falling in height class of 0 m – 4 m and 4.1 - 8 meters. This may be due to competition of resources within individual species or the effects of browsing and fire on the species. Walker *et al.* (1986), Lewis (1987) and Gadd (1997) found markedly unstable population structures with no immature trees and little or no evidence of successful regeneration and recruitment. Walker *et al.* (1986) concluded that the successful regeneration of the marula is highly episodic, while Lewis (1987) suggested that population regulation of the marula may be controlled by seedling browsers other than elephants. Jacobs and Biggs (2001) found marula seedlings up to a height of 1.5 m to be highly susceptible to fire and suggested that the fixed triennial winter burns in the Kruger National Park between 1954 and 1992 have hampered the establishment and development of marula seedlings into the upper canopy. According to Ryneker *et al.*, 2006 if seedlings do not grow into adult tree population, it means that the population of that species may be locally extinct. Within populations, larger individuals often have a disproportionate advantage in competition with smaller individuals and suppress the growth of the latter. (Xiao *et al* 2006). Tshisikhawe *et al.*, (2012) suggest that the practice of fire has to be regular, and an increase in browsers play an important role in opening spaces which

allows plants the availability of resources which were not previously available. In order to prevent the extinct of this key stone species, it is important for the nature reserve managers to optimise these Nature Reserve management strategies and make sure that the *S. birrea* seedlings are protected and monitored.

Table 2: Height of *S. birrea* in the Nylsvley Nature Reserve. Frequency is taken as the number of individuals in any given size-class from the total population number.

Height (m)	Frequency (n)
0-4	47
4.1-8	1
8.1-12	10
12.1-16	22
16.1-20	8

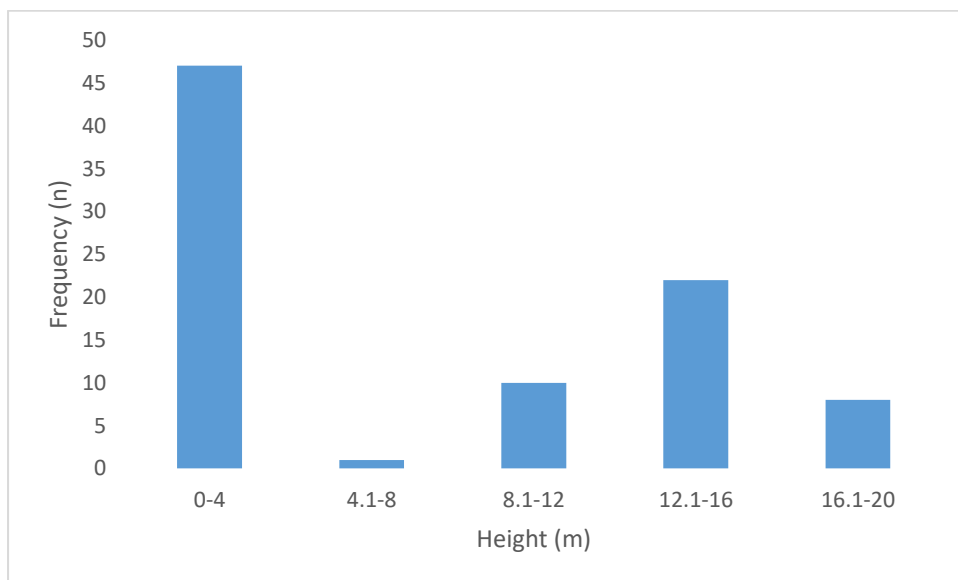


Figure 9: Height size-class distribution of *S. birrea* in the Nylsvley Nature Reserve. Frequency is taken as the number of individuals in any given size-class from the total population number. Data was collected in September 2015 and April 2016.

5.3 The distance between *Sclerocarya birrea* trees

Individuals of a population can be distributed in one of three basic patterns: which are uniform, where they can be more or less equally spaced apart; random which is when they are dispersed randomly with no predictable pattern, or clustered in groups. Figure 10 below shows that *S. birrea* species at Nylsvley Nature Reserve are more or less closer to each other. The individual trees are clumped together. There are only few individuals that are more than 500 meters away from the population. In this way, the clumped dispersion pattern of the individuals within a population provides more information about how they interact with each other and their environment. Furthermore there are several factors that can affect the distribution of species which are (i) predators which can exert direct or indirect effects on the species, (ii) disturbances, which are defined as all types perturbations that are affecting environment and (iii) resources which are assimilated by organisms (e.g. energy and water) (Guisan and Wilfried, 2005). In this case predators played a critical role in the distribution of *S. birrea*, because there were numerous seeds that were found gathered together by predators under the parent trees which can be a factor that is limiting seed dispersal. The relationships between species and their overall environment can cause different spatial patterns to be observed at different scales (Guisan and Wilfried, 2005). Furthermore the study found that most of the adults trees were clumped together and seedlings also clumped together.

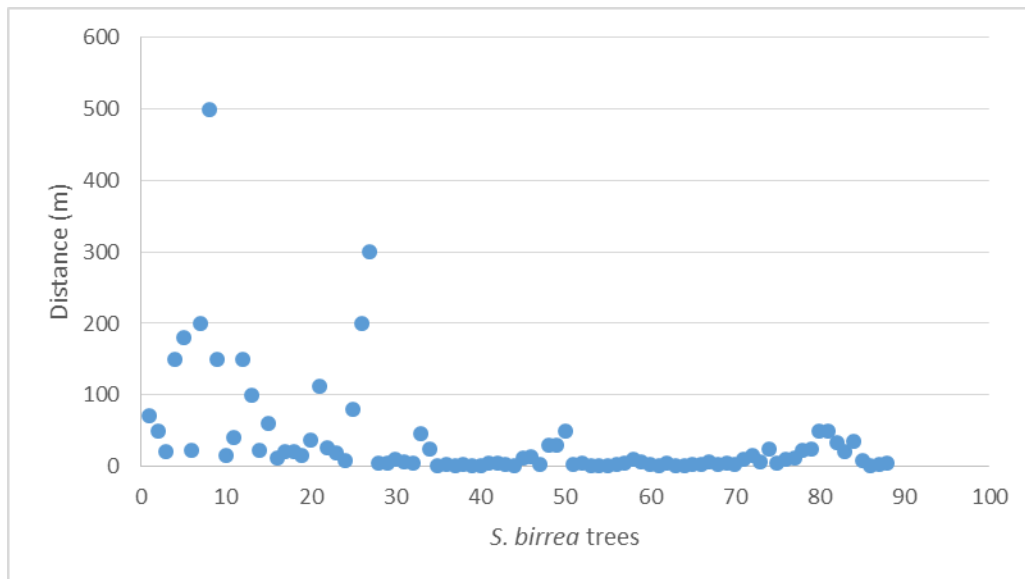


Figure 10: The distance between *S. birrea* trees in the Nylsvley Nature Reserve.

5.4 Canopy cover and crown health

According to Avsar (2004), tree basal diameter (BD), tree height and canopy cover are important tree characteristics. There is also a close relationship between parameters such as diameter, height and canopy cover, as shown in the results. The bigger the basal diameter the bigger the canopy as well as the height. Most of the individual trees that had a big basal diameter were tall in height and they also had huge healthy canopies. Figure 11 shows that 53% of the canopy cover is dominated by individual classes between 0 - 4 meters. This was followed by individuals with a size class distribution between 12.1 -16 and 16.1-20. Figure 11 also indicated that *S. birrea* species with a large canopies were very few only contributing 5 % of the canopy cover. Furthermore the study also found that there were no seedlings that were found under the parent plants. Conversely, Scott *et al*, 2013 indicated that trees with more

established crowns may reduce seedling survival by preventing understorey species from establishment, or by producing allelopathic chemicals through the leaf litter.

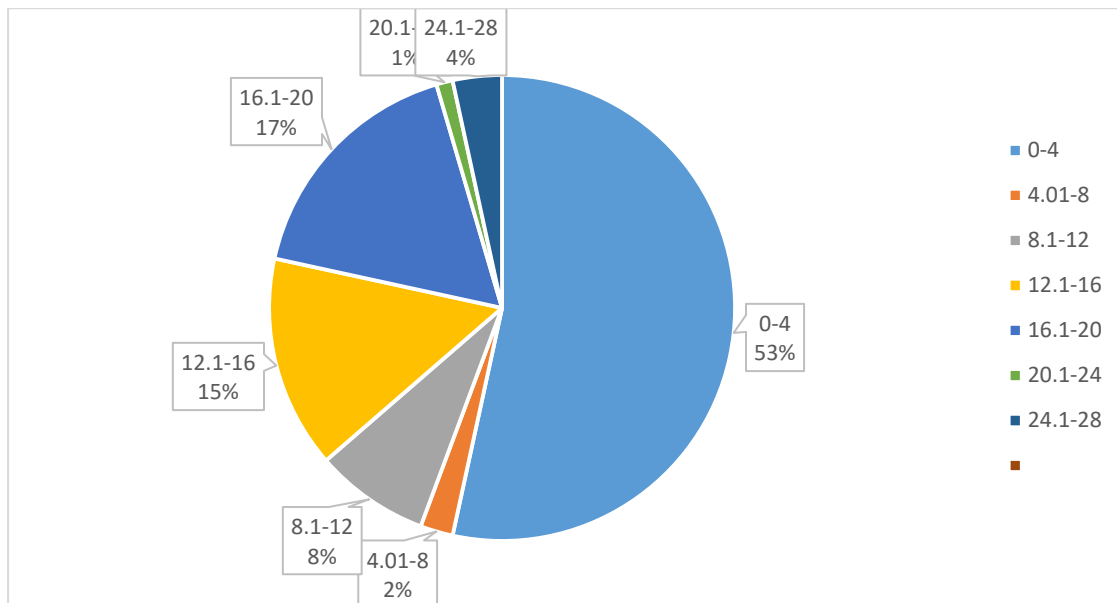


Figure 11: Crown cover class-size distribution of *S. birrea* in the Nylsvley Nature Reserve. Frequency is the percentage in any given size-class with respect to the total population. Data was collected in September 2015 and April 2016

5.5 Crown health

Most individuals of the population of *S. birrea* have either healthy or just traces of crown damage (Figure 12). Seven percent of the population showed lightly damaged crowns, and there were no individuals with a severe crown damage. The low damage of the crown was found on seedlings. The low damage to crown health might have been due to the fire regime that is in practice in the Reserve and browsing. A study

conducted by Jacobs, 2001 concluded that fire affects the structure of *S. birrea* seedlings. Fire enhanced the change in the structure of *S. birrea* seedlings to multi-stemmed morphology. This proved to be true because of the seedlings that were found during the data collection were multiple stemmed.

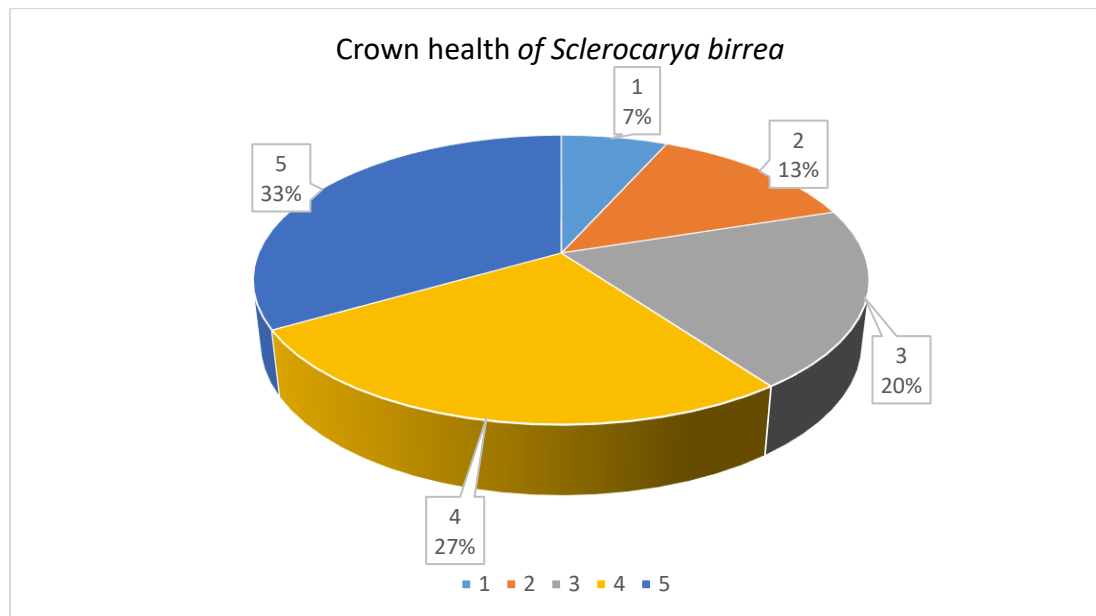


Figure 12: Crown health class-size distribution (see the methods section for details of classes from 0 to 5 of *S. birrea* in the Nylsvley Nature Reserve. Frequency is the percentage in any given size-class (0 to 5) with respect to the total population.

5.6 Collection and observation of kernels and seeds

During data collection, it was discovered that few adults of *S. birrea* individuals produced fruits during the years 2015 and 2016 and as such individuals had few fruits. This may be due to the drought that affected South Africa during the years 2015 - 2016. During drought seasons, water stress causes the flowers to go into a sterile phase causing them to skip fruit production. Drought can also cause the plant to shed older leaves and the fruits stay unripe on the trees for a longer period (Jain *et al.*,

2009). According to Singh and Kushwaha, 2006, climate change may force variation in timing, duration and synchronization of phenological events in tropical trees. Tropical trees are expected to respond variously to changes in rainfall and temperature because they differ widely with respect to adaptations to seasonal drought and cues for bud break of vegetative and flower buds (Singh and Kushwaha, 2006). The kernels that were found under the parent trees were gathered together next to the trunk of the trees and they were void of the seeds (see figure 13). Some of such kernels were collected and taken to the University of Venda for closer observation. Besides the kernels that were found under *S. birrea* parent plants, there were others that were found about 20 away meters from the parent plant. Those found gathered together under the parent plants were probably gathered by squirrels and other animals that eat *S. birrea* fruits.

Tree squirrels in the savanna biome favours feeding on large seeds of species such as *Acacia spp* and the kernels of *Sclerocarya birrea* and destroying them in the process (Crowling *et al.*, 1997). Daldoum *et al.*, 2012 found that ruminants only eat and swallow the fruits but do not damage the seeds whereas animals like rodents, squirrels, warthogs, monkeys, termites amongst others cause serious damage to seeds by breaking the hard kernel. This affected the distribution of *S. birrea* population at Nylsvlei Nature Reserve. Witkowski *et al.*, (2011) indicated that because *S. birrea* fruits are large and fairly heavy, the species relies mainly on mammalian dispersal agents such as the African elephant, which have also been shown to increase the germination rate. It is well known that marula fruits taken from the dung of the African elephant (*Loxodonta Africana*) have more rapid germination than those that have not been eaten by elephants. However, rodents also appear to play a significant role in

seed dispersal. Seed predation rates tend to be highest in areas of low disturbance with no fire and no large browsers.



Figure 13: *Sclerocarya birrea* kernels devoid of seeds found gathered under the tree



Figure 14: *Sclerocarya birrea* kernels found gathered under the tree and destroyed

6 CONCLUSION

The overall aim of this study was to determine the population biology of *Sclerocarya birrea* at Nylsvley Nature Reserve, Limpopo, South Africa. *Sclerocarya birrea* is a keystone plant species which is rated as one of the most highly valued indigenous trees. The study showed that the population of *S. birrea* at Nylsvley Nature Reserve is fairly healthy. However the absence of individuals within the size-class of 40.1 cm -80 cm, followed by the presence of the subsequent size-class for e.g. 120.1 cm -160 cm, 160.1 cm - 200 cm, 200.1 cm - 240 cm and so on is somehow puzzling and could not be explained by this study. This does not necessarily predict population extinction because subsequent size-class were found available and fairly healthier.

The study found that the population of *S. birrea* at Nylsvley Nature Reserve is comprised of seedlings and adult individuals. On the other hand, this might mean that the population of *S. birrea* may not be self-sustaining and would decline if serious management decisions as burning of the reserve when the fuel load is low and monitoring of the species are not implemented. Although it is recognised that protected areas are under land pressure from grazing and other pressures such as fire and logging, the findings of this study found that protected areas are an important means of biodiversity conservation and are very important in providing ecosystem services and supporting habitat conservation. Furthermore, the study found that most of the adult trees were not damaged by fire mainly because they are well adapted to the effects of fire. They possess a thick bark and they resprout extensively followed by fast growth rates following fire. Furthermore the study found that fire has an effect on the germination of *S. birrea* seeds. This is because in 2014 there were no *S. birrea*

seedlings that were found during data collection and after that there was fire that broke out in the reserve and the seedlings were found in areas that were burnt.

During data collection in 2015 and 2016, all the adults *Sclerocarya birrea* trees observed in the Nyilsvley Nature Reserve had no fruits. This indicates that the population may be under threat. South Africa was hit by drought during the years 2015 and 2016 and Limpopo Province was declared as one of the drought disaster risk area. Jain and Priyadarshan (2009) indicated that during drought seasons, water stress causes flowers to go into a sterile phase resulting in non-productive skips in fruit production. He also indicated that drought also leads to the rapid shedding of older leaves and the fruits stay unripe on the trees for longer. However there is a need for research on the impacts of climate change on indigenous species especially *Sclerocarya birrea* since it is a key stone species. In addition, the reserve managers should also take into consideration climate change adaptation measures during the management of nature reserves. The number of kernels that were found under *S. birrea* trees persuaded us to consider predators as an important role player in the dispersal of *S. birrea* seeds.

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