ANALYZING THE ANTHROPOGENIC ALLEE EFFECT IN CYCAD (*ENCEPHALARTOS* SPECIES) POPULATIONS IN SOUTH AFRICA: AN EVALUATION OF ILLEGAL TRADE AND CONSERVATION POLICY

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ABSTRACT

South Africa is a country known for rich biodiversity and ecosystems across the land and seascape. South Africa is one of the global hotspots for cycad diversity. Cycads are known to be the world's most threatened plant species; declining in South Africa at a rapid pace, with threat of extinction in the wild. The main factor being harvesting from the wild for private collections.

Rare cycad species' are especially sought after by collectors. Economic theory assumes that the exploitation of a species is unlikely to result in extinction due to the increasing costs of finding the last few individuals of a species. However, the theory of the Anthropogenic Allee Effect (AAE) suggests that if consumers place a disproportionate value on a rare species', a cycle may result whereby increased exploitation decreases population size, increasing the value of the species and, consequently, leading to its extinction in the wild.

This hypothesis was tested for 37 *Encephalartos* species using data collected on wild populations, auction prices and the IUCN Red List status for the year 2010. It was hypothesised that an AAE was present within *Encephalartos* species, as three species have already gone extinct in the wild. The price per centimetre was positively correlated to the rarity of the species and the price per centimetre was negatively correlated to the wild population size. The results suggest a trend of an AAE for the year 2010.

Adequate conservation policies are needed to reduce the effects of demand on illegal harvesting and prevent extinction in the wild. The effect of rarity needs to be taken into account to ensure successfulness of such policies. The most recent conservation policy implemented to protect cycads in South Africa is the Strategy and Action for the Management of Cycads in South Africa, which was introduced in 2016. The successfulness of this policy cannot, however, be analysed due to a lack of census data following its implementation.

DECLARATION

This thesis has not been submitted to a university other than Rhodes University, Grahamstown, South Africa. The work presented here is that of the author, unless otherwise stated and all references have been accurately recorded.

Signed___ ______________ Date___22 March 2019______________________

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LIST OF ABBREVIATIONS

AAE	Anthropogenic Allee Effect
BMP	Biodiversity Management Plan
CITES	The Convention on International Trade in Endangered Species of Wild Fauna and Flora
DEAT	Department of Environment Affairs and Tourism
DEA	Department of Environmental Affairs
IUCN	The International Union for Conservation of Nature
NEMBA	National Environmental Management Biodiversity Act 2004
OECD	The Organisation for Economic Co-operation and Development
SOS	Save Our Species
SANBI	South African National Biodiversity Institute
TRAFFIC	Trade Records Analysis of Flora and Fauna in Commerce
TESA	TRAFFIC East and Southern Africa
TOPS	Threatened or Protected Species Regulations of 2007
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
WWF	World Wide Fund for Nature

CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

Illegal markets constitute the sale or exchange of goods and services by a person or party, which infringes authorised legal trade specifications (Beckert and Wehinger, 2012). Such markets arise when either the cost of a good sold legally is greater than that of a good sold illegally (the Organisation for Economic Co-operation and Development (OECD), 2012) or when a legal market for a good is non-existent (Beckert and Wehinger, 2012). According to Beckert and Wehinger (2012), illegal markets can be broken up into four parts. These include: (1) the production or distribution of illegal goods and services; (2) goods and services that are legal but whose distribution is illegal; (3) trade of stolen goods or counterfeit products and (4) the violation of regulatory trade requisites along the production chain (Beckert and Wehinger, 2012). Examples of such include, amongst others, the illegal trade of drugs and child pornography, organ harvesting and trafficking, trade of counterfeit designer clothing and the trade of protected species without the required documentation (Beckert and Wehinger, 2012). The illegal trade of goods and services is difficult to document and quantify essentially because it is a secret activity and due to a lack of data available (Trade Records Analysis of Flora and Fauna in Commerce (TRAFFIC), 2010; Beckert and Wehinger, 2012). It has evolved to evade law enforcement and taxation, which often damages a country's domestic and national economy (TRAFFIC, 2010).

Illegal markets have great consequences politically, socially, economically (Beckert and Wehinger, 2012) and environmentally (OECD, 2012). Politically, the illegal trade of goods and services creates a challenge for government and law enforcement agencies to control and implement the policies needed (Beckert and Wehinger, 2012). Socially, the illegal trade of goods and services presents an array of moral and ethical challenges to societies; such as impacts on corruption, organised crime, health (OECD, 2012) and the impact on food security (Czudek, 2013). Environmentally, the illegal trade of natural resources or wildlife, for example, undermines environmentally sustainable activities, leads to a loss of the natural resource base, loss of biodiversity, damaged ecosystems, pollution (OECD, 2012) and the deterioration of the environment (United Nations Environment Programme (UNEP), 2014). The illegal trade of goods and services have an annual revenue estimated to exceed US$1 trillion (Beckert and Wehinger, 2012). On an economic level, this has a detrimental impact on the loss of government revenue, the undermining of legitimate industries, loss of income, tax and employment in the related industries (OECD, 2012), loss of tourism (Criticos, 2014), amongst others.

According to Wyler and Sheikh (2008), one of the largest illegitimate markets globally, after illegal drugs, contributing largely to the above impacts, is the illegal trade of wildlife. The illegal trade of wildlife is classified as any monetary transaction or exchange of fauna and flora by a person or party; reasons for wildlife trade include food, healthcare, trophies, pets, ornamental use and private collections (TRAFFIC, 2008a). Examples of illegal wildlife trade include, amongst others, trade of live tortoises, birds and tigers (Burgener, 2002), rhinoceros horns, tiger bones, bear paws, animal skins, cycads, orchids (Hewson, 1998), abalone, shark fins and beluga caviar (Redpath, 2001). There has not been a large amount of research conducted on the illegal trade of endangered wildlife and protected species (Schneider, 2008; Lawson and Vines, 2014), and therefore the value of illegal trade in endangered wildlife and protected species is unknown (Hansen *et al.* 2012; OECD, 2012).

South Africa is argued to be one of the most active hubs for illegal wildlife trade because of its central geographic location, road systems, international harbours and airports (Warchol *et al.,* 2003). In addition, South Africa is claimed to be one of the most environmentally diverse countries in the world (Driver, 2014) due to its large endemic populations of endangered and exotic wildlife making it a thriving illegal wildlife trade hotspot (Warchol *et al.* 2003). As such, South Africa has faced serious poaching problems, in connection to illegal trade, of elephant tusks, rhinoceros horns, abalone and cycads (Warchol *et al.,* 2003). The over-exploitation of wildlife due to illegal trade in South Africa not only threatens the conservation of endangered and protected species but is also argued to be incentivized by offering high rewards and low risks to all parties involved in the harvesting, selling and buying of wildlife due to poor enforcement (Cook *et al.,* 2002). Cycads are believed to be one of the world's most threatened plant species (Department of Environmental Affairs (DEA), 2016).

Cycads are one of the oldest living plant species in existence (Lochen, 2011). Thus, the species is of great scientific importance as they are unrelated to any other living plant species. Therefore, they are believed to represent a link in the evolution from ferns to flowering plants and have unique characteristics, such as chemicals not found in other plant species (Rutherford *et al.,* 2013). Globally, cycads are the most highly threatened group of plant species (Rutherford *et al.,* 2013). The reasons for the decrease of cycad populations can be attributed to habitat destruction, harvesting for traditional practices, use as food in times of famine and the removal from the wild for landscaping and ornamental use (Donaldson, 2003). According to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (2003), the two largest threats to cycad populations are habitat destruction and trade of wild collected plants.

1.2. GOALS AND IMPORTANCE OF THIS RESEARCH

In an attempt to determine the impact of overexploitation on wildlife species, not only does the market for illegal trade (supply-side and demand-side factors) need to be addressed, but the outcomes of trade policies being implemented and the effect on the perceived rarity of the species (Chen, 2015). The extinction of a species is unlikely to occur from exploitation alone (in theory), as finding wildlife from a decreasing population results in escalating harvesting and poaching costs (Gault *et al*., 2008). Conservation efforts often classify species' by threat status as a means to protect that species; however, such efforts can often have a negative effect by implying that such a species is rare and thus valuable, resulting in increased consumer demand (Hall *et al*., 2008). If consumers place a disproportionate value on rare species', a cycle may result whereby increased exploitation decreases population size, increasing the perceived rarity of that species, and therefore its value, and, consequently, leading to its extinction in the wild. This is known as the Anthropogenic Allee Effect (AAE) (Lyons and Natusch, 2013). Exploring the behaviour of consumers and suppliers of cycads to perceived rarity is vital for predicting the impacts of illegal trade and conservation strategies aimed to minimize extinction risk (Hall *et al.*, 2008).

The primary research goal is to determine the economic effect of illegal cycad (*Encephalartos* species) trade in South Africa. More specifically to explore whether or not illegal cycad trade has induced an AAE in *Encephalartos* cycad populations in South Africa and why such effects (i.e. deterioration of wild populations with threat of extinction) are existing with the present conservation and trade policies in place. Secondary research goals include:

- To describe current conservation and trade policies of cycads, in South Africa and internationally, and to discuss institutional barriers affecting the illegal cycad trade within the policy analysis. Secondly, to compare such policies, to determine why they have not eradicated illegal cycad trade in South Africa, with possible recommendations.
- To investigate the relationship between: the price and rarity of cycads; the price and frequency of trade of cycad plants; and the rarity and frequency of trade of cycad plants to determine the possible effects of consumer preferences for perceived rarity.

According to CITES reports, only a small amount of trade in wild collected plants is shown; however, experts consider trade a significant threat to cycad populations as populations are declining (TRAFFIC East and Southern Africa (TESA), 2003). TESA (2003) suggests that this implies that a large portion of cycad trade is either not controlled by CITES, does not pass through any formal borders (international trade) or is illegal. In South Africa, the large amount of poaching and trade is believed to be largely driven by collectors (Torgersen, 2017). Wildlife is an essential component of biodiversity (Save Our Species (SOS), 2016), and although the market for illegal wildlife trade has been described, very little research has been done on the culture and criminal initiatives (Torgersen, 2017). According to Lawson and Vines (2014), the majority of research into the effect of illegal wildlife trade is concentrated on the biodiversity and conservation issues of an endangered species. This approach is highly relevant due to many endangered species facing challenges of habitat loss and illegal trade (Lawson and Vines, 2014). With the increasing threat of poaching and illegal trade, research and the work done by various organisations is therefore of the utmost importance in order to prevent further loss (SOS, 2016).

1.3. OUTLINE OF THE THESIS

The literature review (Chapter 2) will cover the following topics in the thesis. Firstly, an overview of the effects of overexploitation on rare species' populations and factors influencing the market (demand and supply) of illegal wildlife trade. Secondly, an explanation of the theoretical framework of the AAE. Thirdly, an illustration of the application of illegal wildlife trade activities to the AAE. Finally, an overview of the effects of conservation and trade policies on reducing illicit wildlife trade and the importance of biodiversity conservation in developing countries.

The third Chapter of this thesis will provide an overview of cycads, their geographic location, uses, value, threats, trade of and conservation management.

Chapter Four (methods) provides an overview of the methodological approach followed to analyse conservation and trade policies in place to protect cycads. Previous studies on the AAE are discussed to determine which method to use in order to determine whether an AAE exists within the *Encephalartos* species. The analytical approach to determining an AAE is discussed thereafter. Then the type of data collected, sources of data, adaptions and limitations experienced is discussed. Lastly, this chapter will address how to measure the effectiveness of conservation policies.

Chapter Five illustrates the results of research conducted; this is broken up into two sections, (1) the presence of an AAE and (2) the effectiveness of conservation policies in place for cycads in South Africa.

Chapter Six will discuss the research limitations faced, provide policy recommendations for improved protection of endangered cycad species and conclude this thesis.

CHAPTER 2
LITERATURE REVIEW

2.1. INTRODUCTION

Ecosystems and wildlife conservation are argued to be increasingly threatened by human behaviour through illegal trade (Sodhi *et al.,* 2009). Such threats caused by illegal wildlife trade can partially be attributed to the overexploitation of wildlife for the use of medication (traditional and modern), sustenance, clothing, pets, luxury items and ornamental use (Lyons and Natusch, 2013). This may result in the spread of pathogens (Gómez and Aguirre, 2008), the growth of organised crime syndicates (Hinsley *et al.,* 2015), the introduction of alien invasive species and genetic pollution (Festa-Bianchet, 2012).

These potential threats resulting from illegal wildlife trade, can initiate irreversible consequences such as species extinction (Gault *et al.,* 2008). However, economic theory predicts that economic 'extinction' would precede species extinction as it becomes increasingly more expensive to exploit a declining population (Courchamp *et al.,* 2006). This may decrease the species' population to an extent whereby a natural Allee effect will arise. This effect being a scenario where a small population of a species will be negatively affected by a positive relationship between the population growth rate and density (Courchamp *et al.,* 1999). By extending the theory of intrinsic Allee effects to include such threats driven by human actions and behaviour, one can further understand the effects of overexploitation of wildlife.

2.2. EFFECTS OF OVEREXPLOITATION ON RARE SPECIES' POPULATIONS AND FACTORS INFLUENCING THE MARKET OF ILLEGAL WILDLIFE TRADE

The international market for illegal wildlife trade is argued to be one of the largest threats to wildlife species (Lyons and Natusch, 2013). These potential threats relate to irreversible consequences such as species extinction, amongst others (Gault *et al.,* 2008). "Standard economic theory predicts that exploitation alone is unlikely to result in species extinction because of the escalating costs of finding the last individuals of a declining species" (Courchamp *et al.,* 2006: 2405). Chen (2015) suggests that consumers attach a higher value to wildlife and wildlife derivatives if they are considered to be rare. Past empirical studies have shown that if consumers attach an exaggerated value to a rare species, a cycle may result in which the exploitation of the species is fuelled by the increase in its value. Thus, further increasing its value and desirability, allowing extinction to become profitable, and ultimately forming an extinction vortex. Such a hypothesis is known as the AAE (Courchamp *et al.,* 1999; Stephens and Sutherland, 1999; Gault *et al.,* 2008; Hall *et al.,* 2008; Prescott *et al.,* 2011; Tournant *et al.,* 2012; Lyons and Natusch, 2013; Harris *et al.,* 2013; Branch *et al.,* 2013; Hinsley *et al.,* 2015). In 1931, Warder Clyde Allee proposed a scenario where "populations at low numbers are affected by a positive relationship between population growth rate and density, which increases their likelihood of extinction" (Courchamp *et al.,* 1999: 1). This natural scenario is then known as the AAE when combined with threats driven by human behaviour (Courchamp *et al.,* 1999).

The AAE model has been applied to many areas of conservation, such as trophy hunting, collections, ecotourism, pets, luxury items and traditional medicine (Courchamp *et al.,* 2006). To prevent extinction caused by the AAE, conservation efforts often classify a species by threat status as a means to protect a species (Hall *et al*., 2008). However, such efforts can often have a negative effect by implying that such a species is rare and thus valuable, resulting in increased consumer demand (Hall *et al*., 2008). Therefore, further understanding of supply-side and demand-side factors in the illegal wildlife trade market is vital to conserving endangered wildlife species and the implementation of effective trade policies (Chen, 2015).

2.2.1. Impacts of Rarity on the Exploitation of Wild Populations

Harris *et al.* (2013: 946) defined the AAE model as "a scenario in which rarity itself enhances the perceived value of the species or population to users and thus encourages additional exploitation". According to Stephens and Sutherland (1999), the importance of the AAE has been highlighted in areas of ecology and conservation. The increasing interest in conserving wildlife has emphasized the need to protect dwindling species populations thus placing a value of rarity on such species (Stephens and Sutherland, 1999). Studies have shown that a species' actual or perceived rarity has had a negative effect on the species' populations due to unsustainable exploitation (Hall *et al.,* 2008; Lyons and Natusch, 2011; Tournant *et al.* 2012). For instance, hobby collectors aim to acquire a large variety or a complete set of a specific wildlife species with the rarest species being most valued; for example, orchids, butterflies, beetles and bird eggs (Tournant *et al.,* 2012). Tournant *et al.* (2012) argued that considering rare species' as a luxury good is a worrying issue as, if the average level of world wealth continues to increase, the risk of extinction for rare species already faced with unsustainable overexploitation and the AAE will increase.

The concept of rarity in conservation ecology is based on the distribution and abundance of the species; as such the rarity of a species is a relative concept rather than absolute (Flather and Sieg, 2007). The price or value of a species rises due to the species' actual rarity (decreasing population size); this is influenced by factors such as, increasing search costs and conservation methods aimed at reducing legal availability (Prescott *et al.,* 2011). However, perceived rarity of a species can further increase desirability and lead to an exaggerated value of the species to a point where overexploitation becomes profitable (Gault *et al.,* 2008). Courchamp *et al.* (2006) proved how the AAE model, in theory, is present in the trade of wildlife in a variety of situations when rarity attains value.

2.2.2. Theoretical Framework: The Anthropogenic Allee Effect

The AAE model is based on two assumptions: (1) the correlation between species rarity and its value must be positive, and (2) this positive relationship between species rarity and its value increases demand to the extent where the market price exceeds the increasing costs of harvesting a diminishing population (Courchamp *et al.,* 2006). If these assumptions are met, exploitation of the species reduces the population growth rate and thus population numbers, leading to an increase in the rarity and value of the species (Stephens and Sutherland, 1999). This further stimulates exploitation of the species, resulting in the species' extinction (Courchamp *et al.,* 2006). The model is applied to open-access (unregulated) exploitation (Courchamp *et al.,* 2006) where supply and demand are determined by market forces and where existing conservation methods in place do not affect the harvest rate of the species (Harris *et al.,* 2013) or government and private land owners are unable to protect rare species from third party poachers (Bulte, 2002).

Courchamp *et al.* (2006) demonstrates the AAE through a mathematical model based on an adaptation of the Gordon-Schaefer model of resource exploitation. The Gordon-Schaefer model assumes that when the price of a harvested species is greater than the harvesting costs, the harvesting effort will rise, and will decline otherwise; the price that poachers receive and the market price are proportional to one another and attention is restricted to a single species fuelled by the collection, exotic pet and luxury goods markets (Hall *et al.,* 2008). The above two AAE model assumptions are added as a simple modification to the Gordon-Schaefer model of resource exploitation to evaluate their effect on the species population density equilibrium (Courchamp *et al.,* 2006). A particular species' population growth in the absence of exploitation can be expressed mathematically by the following quadratic function (Bulte, 2002):

$$G(x) = rx(k - x) \tag{1}$$

where x measures the population size growing at rate r and carrying capacity k (Courchamp *et al.*, 2006). When poaching is present (open access exploitation) the harvesting function is:

$$h = qEx \tag{2}$$

where q is the species catchability coefficient and E the aggregate harvesting effort. The harvesting function is subtracted from the population growth function to determine the equation of motion of the species' population (Schaefer, 1957):

$$\frac{dx}{dt} = G(x) - h = rx\left(1 - \frac{x}{k}\right) - qEx \tag{3}$$

Supplementing equation (3) by including the effect of poachers' behaviour, one can determine an equation to solve for population size and effort level of exploitation (Bulte, 2002). It is assumed that poachers will exploit a species until it is no longer profitable to do so (Hall *et al.,* 2008). Economic profit can be defined by the following equation:

$$\pi = E(pqx - c) \tag{4}$$

Where p is the price obtained per unit harvested and c the cost per unit effort (Bulte, 2002). Economic profit is assumed to be proportional to the change of poaching effort (Courchamp *et al.,* 2006) and this adjustment is not immediate (Bulte, 2002). We can mathematically define the poaching development over time as:

$$\frac{dE}{dt} = \alpha(pqEx - cE) \tag{5}$$

where α is the adjustment coefficient (Courchamp *et al.,* 2006). Figure 1 illustrates the AAE of an exploited population.

The price and cost per unit harvest in unit time is represented as a function of population x.

When the price is independent of x (Figure 1A) and when the price is assumed to increase with rarity (Figure 1B) (Courchamp *et al.,* 2006). On condition that a poacher would make a profit when exploiting a population at carrying capacity (k), pqk>c, a stable equilibrium would exist in the system (Figure 1A) (Courchamp *et al.,* 2006).

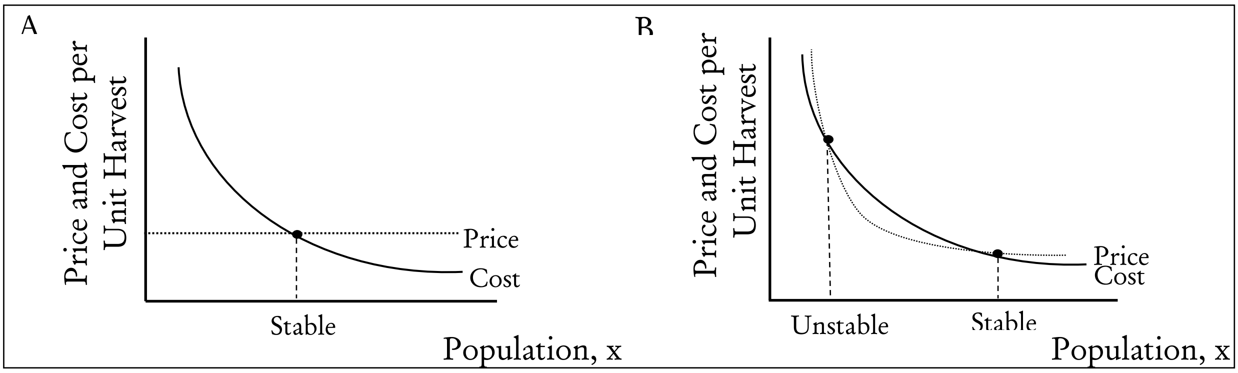

Figure 1. Illustration of an Anthropogenic Allee Effect of an Exploited Species.
Source: Courchamp et al. (2006)

At population levels greater than the stable equilibrium, poachers have the incentive to increase exploitation as profit returns per unit harvest exceed cost per unit harvest; whereas at population levels lower than the stable equilibrium, poachers (with the assumption of rational behaviour) would reduce exploitation as the cost per unit harvest exceeds profit returns per unit harvest (Harris *et al.,* 2013). Therefore, as x tends to zero, the species population will not be exploited to extinction (no AAE) as cost per unit harvest in unit time ($\frac{c}{qx}$) becomes very large (Courchamp *et al.,* 2006). However, in the scenario where the price per unit harvest is an increasing function of species rarity ($p = p(x), \frac{dp}{dx} < 0$), an unstable equilibrium will exist in the system (Figure 1B) (Courchamp *et al*., 2006). Such a scenario producing an unstable equilibrium point is a necessary condition to create an AAE (Harris *et al*., 2013). Exploiting a species' population below this unstable equilibrium point leads to a further decline in population numbers and ultimately risk of extinction. This occurs as the price per unit harvest will increase with a decline in population numbers, which creates a further incentive to increase exploitation for poachers (Courchamp *et al.,* 2006). As well as verifying that the price per unit harvest of a species increases with rarity, Harris *et al.* (2013) advises that demonstrating an unstable equilibrium would thus be a sufficient condition to induce an AAE.

2.2.3. Application of Illegal Wildlife Trade Activities to the Anthropogenic Allee Effect

The advancement in the research of the AAE of rare species has shown that, directly or indirectly, the consequences of such an effect induced by humans is now effectively seen in almost every area of conservation and ecology (Branch *et al.,* 2013). Courchamp *et al.* (2006) established five human activities that have been claimed to induce an AAE: collecting, trophy hunting, luxury items, exotic pets and ecotourism. A selection of activities will be explained and the necessary circumstances needed by humans to induce an AAE will be analysed further with regards to empirical evidence.

a. Collections

According to Courchamp *et al.* (2006), one of the most common examples of a nature-related activity where rarity determines the value of the species, is hobby collections; the rarer the species, the more highly valued it is. The hobby collections market contributes to the overexploitation of wildlife worldwide both legally and illegally (Brook and Sodhi, 2006). As the value of a rare species increases, more effort and resources are needed to find and acquire it. This therefore increases the value of the species and decreases population numbers as the species becomes rarer to induce an AAE (Courchamp *et al.,* 2006). Collections of wildlife species are often unsustainable, leading to the species' depletion and extinction in the wild; through the process of the AAE, rare species that are highly valued by collectors are paradoxically driven to extinction by the collectors (Tournant *et al.,* 2012). Thus, rarity is an important factor to consider in the growth of hobbyist trade (Hinsley *et al.,* 2015). Hall *et al*. (2008) and Gault *et al.* (2008) illustrated that the desire to collect rare species could theoretically result in the extinction of the species. This can be supported by several studies completed on orchids (Hinsley *et al.,* 2015), stag beetles (Tournant *et al.,* 2012) and butterflies (Slone *et al.,* 1997), amongst others.

It was concluded in the findings of a study, conducted on consumer preferences in the global orchid trade, that species rarity played a significant role in driving hobbyist trade (Hinsley *et al*., 2015). A similar result was seen in a study conducted on the hobby of collecting stag beetles; it was discovered that the main choice of acquisition was based on species rarity (Tournant *et al.,* 2012). Due to the size and growth of such a lucrative market, the attraction of collecting stag beetles creates a potential extinction threat for such rare species (Tournant *et al.,* 2012). Not only does rarity influence the growth of the market, but the price of species in the market. Often the objective of collections is to obtain a diversified set of specimens, with the highest valued being the rarest (Tournant *et al.,* 2012). This can be seen in a study conducted by Slone *et al.* (1997) where the price of butterflies sold for hobbyist collection was positively correlated to species rarity.

According to Hinsley *et al.* (2015), there are two main motives as to why rarity plays an important role in hobbyist trade: (1) the difficulty of propagating the species quickly and in large numbers; and (2) the recent discovery of a species. Hobbyist collection for scientific intentions have also been seen to trigger an AAE. This was the case for three rare species of freshwater fish endemic to Mexico, which were collected to extinction within a few years of their discovery (Rodriguez-Estrella *et al.,* 2006). The great auk is another example of a possible AAE (Courchamp *et al.,* 2006). The great auk became rare due to overexploitation for food and feathers, thus becoming extremely valuable to collectors wanting to acquire the eggs or skin of an almost extinct bird; because of further exploitation from collectors and a decrease in natural breeding sites, the bird became extinct (Fuller, 1999).

The threat of an AAE due to hobby collection, may recommend a trade ban on all cases of overexploitation (Tournant *et al.,* 2012). However, trade bans have been seen to stimulate illegal trade by attaching a higher value of perceived rarity to the species, yet alternative measures of withholding rarity information hinder conservation programmes (Rivalan *et al.,* 2007). By conducting market research methods, conservationists can discover which species are threatened by the hobbyist collections market and can implement more effective conservation policies aimed at reducing demand or behavioural change, thus decreasing the risk of an AAE (Hinsley *et al.,* 2015).

b. Luxury Items

According to Courchamp *et al.* (2006: 2408), "The consumption of rare species as luxury food items is another way of displaying wealth and/or social status. The rarer the item, the more expensive it is, and the more prestige is gained by its acquisition." The AAE exists in commercial markets when poaching is driven by rare and valuable wildlife derivatives regardless of trade restrictions and controls (Stephens and Sutherland, 1999). In situations where demand for luxury wildlife derivatives continues to grow despite species populations declining, prices for such goods are expected to rise as supply is reduced. This results in increasing incentives to poach rare species, further lowering population numbers (Harris *et al.,* 2013). Examples of wildlife and wildlife derivatives for delicacies, clothes and accessories in the luxury market vulnerable to an AAE, include, *inter alia,* exotic wood, turtle shells (Courchamp *et al.,* 2006), abalone (Hobday *et al.*, 2001), reptile skins, caviar, leather hides (Gault *et al.,* 2008), Tibetan antelope wool (Khan, 2014) and tiger skins (Nowell and Ling, 2007).

Caviar is argued to be one of the most popular delicacies in the market for luxury goods (Gault *et al.,* 2008). All 27 species of sturgeons are threatened with extinction due to overexploitation for caviar (Pala, 2005). In a caviar tasting experiment conducted by Gault *et al.* (2008), it was established that the perceived rarity of caviar was high regardless of the continuous price increases and extinction threat of these species. Sturgeon exploitation is a highly profitable market (Pikitch *et al.,* 2005), with prices increasing as population numbers decline. It is suggested that an exaggerated value of perceived rarity drives the commercial market for wildlife derivatives (Gault *et al.,* 2008). Abalone is another example of a marine delicacy overexploited for the luxury market (Courchamp *et al.,* 2006). White abalone is the rarest of the six species due to continuous overfishing (Davis *et al.,* 1998). This resulted from failure to recognise that fishing was unsustainable (Hobday *et al.*, 2001) and abalone is on the verge of extinction unless successful recovery measures are put in place (California Department of Fish and Game, 2005).

The population of Tibetan antelope has declined by more than 50% in the past two decades (Khan, 2014) due to the high demand for its wool to make Shahtoosh shawls (Mallon, 2013). As they became rarer, they were further exploited (Gault *et al.,* 2008); and due to slow breeding, the Tibetan antelope is now endangered and extinct in some countries, such as Nepal (Khan, 2014). The World Wide Fund for Nature (WWF), in conjunction with TRAFFIC, has been raising awareness regarding the threat status of the antelope, assisting in improving poaching controls and implementing conservation policies with local communities to further decrease poaching and illegal trade (WWF, 2015a). The illegal trade in tiger and leopard skins for clothing has become a growing threat due to an improvement in the economy and popularity of traditional clothing in fashion industries (Tsering, 2006). The global population of adult tigers in the wild is fewer than 2500, thus increasing the demand for other big cat species, such as leopard (Nowell and Ling, 2007). Captive-bred tigers have become an increasingly popular conservation method in China with the captive-bred population exceeding 4000 animals (Government of China, 2006). However, it is argued that this method only further encourages the demand for tiger products, conflicting with China's existing policy, which has been vital to reducing the illegal trade of tiger products (Nowell and Ling, 2007).

c. Exotic Pets

Courchamp *et al.* (2006) argued that exotic pet ownership, for example reptiles, birds, fish and monkeys, is becoming an increasingly significant component of the illegal wildlife trade market; with a main driver being the popularity of owning exotic and rare species as pets in some areas of the world. In the past decade, the exotic pet market has expanded immensely, contributing greatly to the endangerment of many animal and plant species (Sollund, 2011). Unfortunately, the capture, treatment and transportation of targeted species is often poor, resulting in high levels of mortality and decreasing population numbers (Courchamp *et al.,* 2006). Due to the advancement of international travel and transportation of goods, the legal and illegal trade of wildlife has become a popular market (Dutton *et al.,* 2013). To reduce rare species exploitation detrimental to conservation, the popular method of publicizing the potential negative consequences of overexploitation and the availability of substitute goods has been used (Festa-Bianchet, 2012). However, this is overshadowed by digital media driving demand through improved access to information and internet companies sourcing and selling exotic pets (Bush *et al*., 2014). Broadcasting of wildlife films have been seen to correspond with increased demand for featured species, such as clownfish in *Finding Nemo* (Yong *et al.,* 2011).

Overexploitation of wildlife for the exotic pet trade has already led to a decrease in species populations and population collapses; for example, the radiated tortoise (*Astrochelys radiata*), which is now critically endangered (Leuritz and Paquette, 2008). At the start of 2006, Courchamp *et al.* (2006) conducted a study comparing the market prices, from the biggest herpetologist retailer in France, of amphibian and reptile species sold as pets. It was found that species listed on the CITES appendices were significantly more expensive than species that were not. A probable reason being that the perceived rarity of such species was higher, thus increasing their value (Courchamp *et al.,* 2006). Furthermore, Courchamp *et al.* (2006) analysed the effect on the illegal trade of 133 animal and plant species, resulting from a change from CITES Appendix II to CITES Appendix I over the last 30 years. Of the 133 species, 44 had no evidence of being traded illegally and 23 showed an increase in illegal trade over the period of the status change (Courchamp *et al*., 2006). This scenario illustrates how policy aimed at protecting species and controlling trade, contradicts itself by making the species more desirable to poachers and buyers of exotic pets (Sollund, 2011).

A successful method used to decrease the pressure on wild populations from poaching and maintain biodiversity conservation is the use of wildlife breeding farms. However, in the case of slow breeding animals, there has been concern that such farms are being used to launder illegally caught wildlife from the wild (Lyons and Natusch, 2011). They confirmed that such wildlife laundering was occurring for many Indonesian reptiles, such as green pythons. Surveys conducted revealed that, to remain competitive and meet demand, farm owners participated in laundering, as snakes could not be bred fast enough (Lyons and Natusch, 2011), and needed to compete with large exports from other South East Asian nations, such as Indonesia (Nijman and Shepherd, 2009). Regardless of being illegal, the poaching and sale of wild green pythons is continuing, undermining conservation efforts and further threatening wild populations (Lyons and Natusch, 2011).

According to Pires (2012), a key factor leading to the endangerment of many parrot species around the world, is the demand for parrots as pets. Although argued to increase the illegal trade of a species, the trade ban on parrots by the United States of America and Europe has decreased the volume of illegal trade in parrots (Tella and Hiraldo, 2014). However, many parrot species that are routinely poached due to abundance, are expected to become extinct in future if nothing further is done to prevent exploitation and falling parrot populations in other areas of the world, such as South America (Pires, 2012).

2.2.4. Effects of Wildlife Trade and Conservation Policies on Supply and Demand of Illegal Wildlife Trade

Many developing countries have poor environmental conservation monitoring, enforcement and policies, which are vital indicators used to distinguish what species are more highly valued and becoming popular in trade (Lyons and Natusch, 2013). Conservationists should consider indicators of a potential AAE, such as price and population numbers (Lyons and Natusch, 2013), as well as encouraging factoring in the effect of changes in consumers' perceived rarity of a species in response to newly implemented conservation and trade policies aimed at minimizing extinction risk (Hall *et al.,* 2008). The effect of well-regulated trade policies in some circumstances can have a positive impact on the conservation of threatened species (International Union for Conservation of Nature (IUCN), 2011). In addition to trade policies, supply-side and demand-side methods are used to target producers and consumers by attempting to reduce market prices and consumer demand for wildlife (Hinsley *et al.,* 2015). To decrease consumer demand of threatened wildlife species, it is vital to understand the consumer behaviour that drives it. Without this understanding, policies have the potential to be ineffective or have a negative effect (Courchamp and Angulo, 2009). However, there still exists a poor understanding of factors influencing the demand side of wildlife trade, such as consumer preference for different species, amongst others, which hinders effective policy implementation (Hinsley *et al.,* 2015). By using supply and demand theory to further understand how policy implementation would affect consumers and producers, factors affecting perceived rarity and poaching are applied to establish possible outcomes. This is illustrated in figure 2.

Figure 2 illustrates a market for a wildlife species; with initial equilibrium point 0 and Q_0 representing the level of poaching in the market at price P_0 (Chen, 2015). By implementing a sterner anti-poaching policy, policy makers increase the risk of participating in poaching. As such, the supply curve shifts to the left (S_1). This leads to a rise in the price (P_0 to P_1) of wildlife in the market due to the restriction on supply and at the new equilibrium point (1) a decrease in poaching is observed (Q_1) (Chen, 2015). The same effect can be seen, *inter alia,* by flooding the market with confiscated wildlife derivatives (public auctions) or cultivated alternatives (Bulte and Damania, 2005), increasing the protection of wildlife, strengthening trade enforcement and increasing poaching penalties (Hinsley *et al.,* 2015). Chen (2015) argues that in countries rife with poverty, compensating local communities for good conservation practices, implementing policies that reduce poverty in these communities and increasing employment opportunities will reduce the inclination to poach.

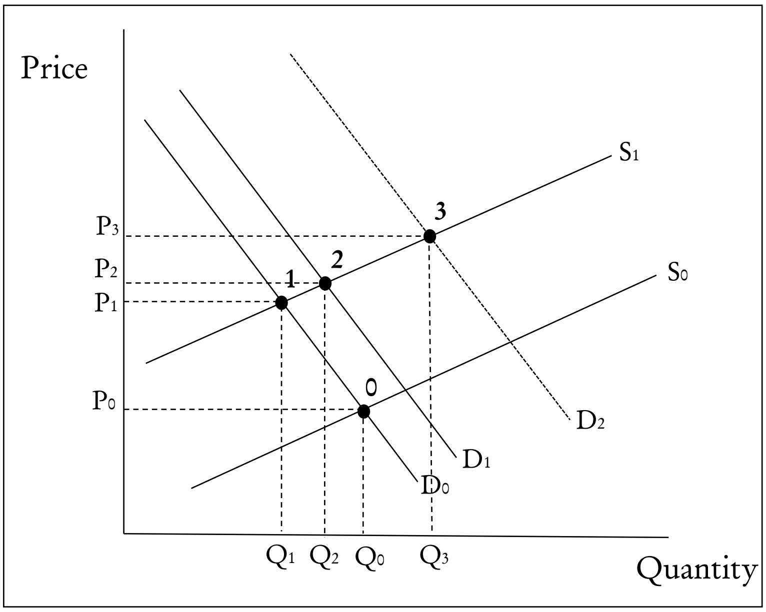

Figure 2. Illustration of the market for a Wildlife Species.
Source: Chen (2015)

However, in a market where consumers value rarity, the increase in price and decrease in quantity will result in an increase in the demand curve as consumers are willing to pay more for the good (D_1). At this new equilibrium point 2, the price and quantity of wildlife has further increased (P_2 and Q_2). In this case, the effect of the trade policy has been partially offset by the consumers' response to a change in perceived rarity (Chen, 2015). In the case where the policy would have a negative effect, such as an IUCN red listing increasing a species' perceived rarity, as argued by Prescott *et al.* (2011), there is a potential outcome in which there is more poaching than before the policy is implemented (demand shifting to D_2); rendering the policy useless. Chen (2015) argues that this would not occur, as the quantity would increase to the extent where the perceived rarity of the species would decline. Other ways to influence the market would be to reduce consumer demand through conservation education and high profile media and publicity campaigns (Oldfield, 2003). Thus, the influence of a consumers' perceived rarity of a species is vital when implementing supply-side trade policies, as the potential impact of such policies can be greatly diminished (Chen, 2015).

2.3. EFFECT OF CONSERVATION AND TRADE POLICIES ON REDUCING ILLICIT WILDLIFE TRADE AND IMPORTANCE OF BIODIVERSITY CONSERVATION IN DEVELOPING COUNTRIES

The illegal trafficking of wild fauna and flora is argued to be a major concern for biodiversity, thus creating the need for effective legal protection of traded species (Flores-Palacios and Valencia-Díaz, 2007). The illegal trade of wildlife is argued to be a threat to the conservation of biodiversity in two ways: directly, through over-collection of wildlife species (Li and Li, 1998; Wilcove *et al.,* 1998), and indirectly, by disrupting ecosystems in importing nations by introducing pathogens (Daszak *et al.,* 2000; Karesh *et al.,* 2005), invasive alien species (Vitousek *et al.,* 1996; Oldfield, 2003), pollution and habitat destruction (Cunningham and Cunningham, 2008). Methods have been adopted to stop unsustainable levels of wildlife exploitation by creating policies to restrict harvesting of protected and endangered species (Flores-Palacios and Valencia-Díaz, 2007). Many countries have adopted such policies in order stop the illegal trade of wildlife at local, national and international levels (Flores-Palacios and Valencia-Díaz, 2007). The importance of assessing conservation policies is built upon the need to evaluate biodiversity and ecosystem services; such valuations are essential tools to inform policy-makers who are often unaware of their value and importance (Gutman, 2003). Economic assessments of biodiversity and ecosystems play an important role in ensuring that conservation efforts are financially sustainable as they encourage further investment by creating a perceived need for conservation (Mertz *et al.,* 2007). For example, the use of ecotourism is an important aspect in the conservation of biodiversity and ecosystems in developing nations, as revenue received from tourism is a valuable incentive for protection (Gössling, 1999).

2.3.1. Importance of Biodiversity: Costs and Benefits for Developing Countries

Impacts of wildlife trade on the security of natural resources have been argued to be mostly negative, however, the value of wildlife and their derivatives are said to make an important contribution to the fulfilment of human needs (Oldfield, 2003). Biodiversity offers a variety of cultural, aesthetic and recreational values (Bulte *et al.,* 2005) that motivate the protection of wildlife and their natural habitats and systems (Oldfield, 2003). Costs and benefits of biodiversity and ecosystem conservation include, *inter alia*, foregone income from potential development projects; cost to maintain protected areas (Myers, 1997); sustainable use of timber for fuel; soil conservation and productivity; flood control; sustainable harvesting of plants for medicinal use; fishing and hunting (Gössling, 1999). According to Shukor *et al.* (2008), biodiversity is a vital element in agricultural development of developing countries, as it provides an array of food for consumption (food security) and commodities for trade. Biodiversity is crucial for ecosystem functions and agricultural ecosystems such as nutrient cycling, soil rehabilitation, water quality, pollination and pest regulation (Shukor *et al.,* 2008). Maintaining biodiversity leads to a decrease in costs of agricultural inputs by increasing soil fertility, improving water usage and soil structure and by acting as a natural control for pests (Shukor *et al.,* 2008).

High levels of biodiversity are seen with decreasing latitude (Gössling, 1999); thus, the highest proportion of biodiversity rich land is found in highly populated developing countries in the southern hemisphere (Alam and Van Quyen, 2007). This is argued to be a major threat to biodiversity, as many developing nations are faced with issues such as high population growth rates, workforce pressure, foreign debt, lack of capital and high levels of poverty (Gössling, 1999). Poverty stricken areas increase pressure on biodiversity resources (Alam and Van Quyen, 2007) and are argued to result in the overexploitation of biodiversity due to expansion of land for agriculture and forestry and exploitation of living and marine resources (Gössling, 1999). Thus, the loss of biodiversity of coastal and marine wildlife due to unsustainable use, is a major challenge to developing countries, as legislation, enforcement and education is inadequate and further worsened by poverty and disease (UNEP, 2006). According to the United Nations Development Programme (UNDP) (2012), the loss of biodiversity and ecosystems in the past few decades has had a detrimental impact on the world's poor, as those living in poverty are often dependent on goods and services provided by nature. According to Adams *et al.* (2004), biodiversity loss and poverty are believed to be linked issues that ought to be addressed together, yet the success of strategies addressing both issues is highly debated. Strategies addressing poverty alleviation are believed to conflict with strategies aimed at preventing biodiversity loss (Adams *et al*., 2004). The UNDP has identified poverty alleviation as a focus in their mission. Thus, by conserving biodiversity and ecosystems, they hope to alleviate poverty and promote sustainable development in developing countries (UNDP, 2012).

Due to a poor understanding of the relationships between biodiversity and ecosystems, the goods and services they provide, and the role they play in the economy, biodiversity and ecosystems are inadequately managed and protected (UNDP, 2012). This is seen in developing countries where a large percentage of wildlife is not found in protected areas. Therefore, Government and enforcement agencies have limited to no power to protect and manage wildlife (Abensperg-Traun, 2009). Biodiversity conservation includes major costs that are borne by developing nations, yet benefits are often experienced by the global community (Gössling, 1999). Additionally, most developing nations have limited funds and are unable to finance environmental governance, thus needing funding and support to implement successful biodiversity and ecosystem conservation management (UNDP, 2012). Pearce and Moran (1994) suggested that funding for biodiversity conservation must come from developed countries, as biodiversity conservation is not a priority or unaffordable for developing countries. For example, many developing nations, particularly in Africa, have poor governance, high levels of corruption and political instability resulting in the ineffective implementation of policies (Abensperg-Traun, 2009).

2.3.2. Organisations Involved with Preventing Illegal Trade of Wildlife and Promoting Biodiversity Conservation

Environmental organisations have, since the early 1960’s, aimed to identify environmental issues and bring such issues to the attention of politicians and the public; as many countries are unable to address environmental issues, such environmental organisations contribute in policy-making (Boström, 2003). This highlights the importance of such organisations for environmental sustainability, research and data collection. Organisations such as CITES, IUCN and TRAFFIC, aim to protect wildlife species from overexploitation for wildlife trade and aid affected countries by contributing policy guidelines as the illegal trade of goods such as weapons and drugs, may be of a low priority for such countries (Schneider, 2008). As information regarding the true scale of illegal wildlife trade is unknown, Rosen and Smith (2010) argue that such organisations provide the most accurate data.

The IUCN is the largest environmental organisation globally with nearly 1300 government and NGO members and more than 15000 volunteers from 185 different countries. The organisation works towards finding solutions for environmental and developmental challenges (IUCN, 2015). In 1949, The Species Survival Commission was created by the IUCN to determine what species are endangered (Schneider, 2008). With help from scientists and government agencies (Schneider, 2008), the IUCN Red List of Threatened Species was created and is the world's most complete source of information on the global conservation status of fauna and flora where more than 76 000 species have been assessed (IUCN, 2015). CITES was established in 1973 (Santos *et al.,* 2011) because of a decision made by IUCN members to regulate international wildlife trade (Driver, 2014). CITES consists of 181 parties who enforce an international environmental agreement (Santos *et al.,* 2011) to protect rare and threatened species through regulating the international trade of these species (Driver, 2014). Countries associated with CITES have been encouraged to implement policies to decrease the illegal trade of endangered species (Schneider, 2008). CITES covers 34 000 animal and plant species (Driver, 2014), which are negatively affected by international trade or at risk of becoming so (Abensperg-Traun, 2009).

CITES classifies plant and animal species on three appendices. Firstly, species in danger of extinction (Driver, 2014) and thus international trade is illegal (Abensperg-Traun, 2009). Secondly, species not yet endangered but may become so with unregulated trade listed on appendix II (Driver, 2014). Thirdly, species that can be traded without restriction (Driver, 2014), but international trade is regulated to prevent unsustainable exploitation listed on appendix III (Abensperg-Traun, 2009).

"TRAFFIC, the wildlife trade monitoring network, is the leading non-governmental organization working globally on trade in wild animals and plants in the context of both biodiversity conservation and sustainable development" (TRAFFIC, 2008b: 1). TRAFFIC is a combined project of the World Wide Fund for Nature and the World Conservation Union, and works together with CITES to conduct studies on the trade of fauna and flora, help investigate illegal wildlife trade networks and to discover ways to help manage wildlife trade sustainably (Rosen and Smith, 2010).

2.3.3. Defining and Evaluating Policies, Methods and Penalties Used to Prevent the Illegal Trade of Wildlife and Promote Biodiversity Conservation

The effect of trade policies implemented for a large number of CITES-listed plant and animal species is unknown; this is largely due to a lack of accurate trade data (Abensperg-Traun, 2009). However, it has been noted that illegal wildlife trade has a severe effect on biodiversity, species survival and habitat protection (Lowther *et al.,* 2002). Lowther *et al.* (2002) highlighted the importance of effective trade legislation in developing countries as they maintain markets comprising of most the legal and illegal wildlife trade.

The original design of the policies implemented by CITES intended to decrease the detrimental impact of international trade which was regarded as a threat to many wildlife species (Abensperg-Traun, 2009). This section addresses the most common policies, methods and penalties; this includes wildlife trade bans (Santos *et al.,* 2011), breeding programmes (The Economist, 2008), media/campaigns (Rosen and Smith, 2010), penalties (Warchol *et al.,* 2003) and incentives (Keane *et al*., 2008).

a. Wildlife Trade Ban

A wildlife trade ban prohibits the trade of wildlife individuals, parts and/or derivatives (Santos *et al.,* 2011). The aim of a wildlife trade ban is to decrease the commercial trade of a species to maintain or support population recovery of an endangered species (Santos *et al.,* 2011). For example, the United States of America passed the Wild Bird Conservation Act on October 23, 1992 (Santos *et al.,* 2011). This Act prohibits the importation of exotic bird species to prevent the negative effect on exotic bird populations because of international trade (United States Fish and Wildlife Service, 2009).

The success of a wildlife trade ban is dependent on three factors. In the first instance, the ban must be accompanied by a decrease in demand for the banned products. Secondly, the ban must not decrease incentives to conserve endangered species. Finally, government and residents must support the ban in the countries where the specific species are found (The Economist, 2008). If these three conditions are not met, the wildlife trade ban is unlikely to reduce trade or support population recovery of the species (The Economist, 2008). Wildlife species, such as timber, orchids and medicinal plants, are examples where trade bans are difficult to enforce as they disrupt cultural practices (Cooney and Jepson, 2006). Trade in cat skins, sealskins and parrots, decreased because of movements against such trade occurring at the same time as trade bans decreased supply (The Economist, 2008).

Bans may also lead to more sustainable legal wildlife trade; however, some argue that this may undermine conservation efforts (The Economist, 2008). A wildlife trade ban may also cause a species to seem rarer, thus more valuable having an adverse effect (Hutton and Dickson, 2000; Abensperg-Traun, 2009; The Economist, 2008; Nijman, 2010; Nijman *et al.,* 2009; Rivalan *et al*., 2007).

b. Wildlife Breeding Farms

An alternative to banning wildlife trade is wildlife breeding farms; CITES sometimes allows breeding programmes as a legal source of animal products (The Economist, 2008). A wildlife-breeding farm aims at promoting and aiding biodiversity conservation by decreasing the harvest of wild populations (Lyons and Natusch, 2011). Such a method has been seen to be successful in reducing exploitation; for example, in the case of crocodilians (The Economist, 2008). Crocodilians are largely harvested for their skin (Revol, 1995). Approximately 75% of trade in crocodilian skin is supplied from alligators, caimans and crocodiles bred in captivity (The Economist, 2008).

For wildlife breeding farms to be a successful conservation policy, they need to supply an alternative to wild-harvested individuals, which are cheaper and more ethical (Bulte and Damania, 2005). For example, the cost of raising a tiger in captivity can cost thousands of dollars; whereas killing a tiger in the wild is far cheaper (The Economist, 2008). Breeding animals in captivity may save wild populations but may leave the species being undervalued; as such this decreases the incentive to conserve the species in the wild (The Economist, 2008).

According to TRAFFIC (2008a), there is uncertainty around whether wildlife-breeding farms really decrease the demand for wild harvested individuals. This is due to issues such as laundering of wildlife through breeding farms, the inability to compete with prices of wild harvested individuals and inadequate monitoring of law enforcement agencies (Lyons and Natusch, 2011). Lyons and Natusch (2011) believe that effective monitoring and stern disincentives for illegal activity by farm owners should go together to ensure the effectiveness of using wildlife-breeding farms as a conservation measure.

c. Campaigns, Awareness and Education

Campaigns can be used as an effective method to educate consumers on the effect of illegal wildlife trade in an attempt to reduce demand (Rosen and Smith, 2010). Examples include, amongst others, videos, posters, leaflets, souvenirs, social media campaigns and outreach programs with partners (TRAFFIC, 2017). Programs should be created to encourage consumers to invest in natural resources, which will benefit conservation efforts (Rosen and Smith, 2010). To be successful, campaigns for awareness or educational purposes need to attempt to influence the underlying factors that motivate people to partake in wildlife trade and should include a monitoring and evaluation element (TRAFFIC, 2008a). The IUCN (2009) suggests the most efficient conservation method to address illegal wildlife trade is a combination of education, awareness and enforcement.

Decreases in the acquisition and demand of cat skins (1970s) and ivory (late 1980s and early 1990s) were associated with large public awareness campaigns and advertising campaigns in importing countries (IUCN, 2009). A large campaign being run on a global scale to create awareness, to influence opposing views and behaviour is “Save the Rhino” (Save the Rhino, 2012). The WWF and TRAFFIC are two organisations, out of at least 150 actively involved organisations, who are working closely together to address the illegal trade of rhinoceros’ horn (WWF, 2017a). “Save the Rhino” aims to create awareness as well as encourage people to donate, fundraise and volunteer for rhinoceros’ projects to clamp down on supply and demand of horn and has been seen to be a relatively successful drive (Save the Rhino, 2012).

d. Penalties

Contemporary solutions to poaching and illegal trade in wildlife include strict penalties (Warchol *et al.,* 2003). However, wildlife trade penalties are substantially less severe in comparison to other trafficking fines (Wyler and Sheikh, 2008). Many countries lack the needed legislation and/or appropriate penalties for illegal wildlife trade (WWF, 2017b). Rosen and Smith (2010) believe that more resources need to be allocated to investigating and regulating illegal wildlife trade at national and international levels. Political stability and having the appropriate legislation in place are crucial for the effective implementation of CITES policies (Abensperg-Traun, 2009).

The fear of a severe penalty alone is not sufficient to prevent illegal wildlife trade. The potential offender of the crime must comprehend that detection, arrest and prosecution is a certainty (Lowther *et al.,* 2002). For example, in the United Kingdom, the risk that a wildlife offender takes is minimal, yet the rewards are extremely high; when comparing this with the possibility of being caught, the penalty would not have the desired effect (Lowther *et al.,* 2002).

2.4. SYNOPSIS

Ecosystems and wildlife conservation are becoming increasingly threatened by human behaviour through illegal trade (Sodhi *et al.,* 2009). As highlighted in Section 1.1, Chapter 1, there is not sufficient research conducted on the illegal trade of endangered wildlife and protected species (Schneider, 2008; Lawson and Vines, 2014), thus the value of this illegal trade is unknown (Hansen *et al.,* 2012; OECD, 2012). This highlights the importance of research in this area.

As an environmentally diverse country and a thriving hotspot for illegal wildlife trade, South Africa needs to ensure that successful conservation measures are enforced to tackle the market for illegal wildlife trade (Driver, 2014). In measuring the successfulness of conservation measures, supply and demand factors of the market need to be considered, as well as the effect of perceived rarity (Chen, 2015). Exploring the behaviour of consumers and suppliers in the market to perceived rarity is vital when evaluating conservation strategies (Hall *et al.,* 2008). This thesis will consider the conservation efforts put in place to protect cycads in South Africa and determine the possibility of an AAE in the *Encephalartos* genus.

Cycads are an iconic plant species in South Africa and are highly threatened (Rutherford *et al.,* 2013). Chapter 3 explores the geographic distribution of cycads, the various uses of the plant, conservation measures in place and the impact of illegal trade.

CHAPTER 3
GEOGRAPHICAL DISTRIBUTION, THREATS, CONSERVATION MANAGEMENT AND ILLEGAL TRADE OF CYCADS

3.1. INTRODUCTION

Cycads are a collection of evergreen, dioecious plants (Golding and Hurter, 2003); described as having thick trunks ranging from 30 centimetres to 13 metres tall with large, stiff green leaves (Donaldson *et al.,* 2013). Cycad species differ through various characteristics, which affect their population size, geographic location, geographic distribution and response to harvesting (CITES, 2003). Such characteristics include, *inter alia*, growth arrangement, coning behaviour, size of cone(s), number of cones, size of seeds, pollination biology, dispersal agents, drought tolerance, shade tolerance and fire resistance (CITES, 2003). They are believed to be one of the oldest living plant species in existence (Lochen, 2011); it is assumed that cycads originated on earth approximately 300 million years ago (Donaldson *et al.,* 2013; CITES, 2003). Cycads are often referred to as 'living fossils', implying the plants have not changed greatly over their existence, however, they are in fact a largely diverse group of plants (CITES, 2003). The species is therefore of great scientific importance as they are unrelated to any other living plant species. Rutherford *et al*. (2013) believe the plants represent a link in the evolution from ferns to flowering plants and have unique characteristics, such as chemicals not found in other plant species. This has resulted in them being useful for research and education in plant evolution (Kay *et al.,* 2011). Cycads were believed to be at their greatest diversity during the Triassic and Jurassic age; fossils showing the plants being distributed from Siberia to Antarctica, accounting for roughly 20% of earth's plant life (Donaldson *et al.,* 2013).

Globally, cycads are the most highly threatened group of plant species (Walter and Gillett, 1998; South African National Biodiversity Institute (SANBI), 2010; Rutherford *et al.,* 2013). The reasons for the decrease of cycad populations can be attributed to habitat destruction, harvesting for traditional practices, use as food in times of famine and the removal from the wild for landscaping and ornamental use (Donaldson, 2003).

This chapter aims to educate the reader on the geographical distribution of cycads, the value of cycads, the threats facing wild populations and conservation management. Obtaining an in-depth understanding of the geographic distribution of cycads, the uses, threats and conservation methods in place is important to understand the severity and impacts of illegal trade (through the AAE) on cycad populations and thus the importance of protecting such a species. Chapter 2 reviewed the theoretical framework of the AAE and provided empirical evidence of the effects of trade for collections, luxury goods and exotic pets; the results of which were detrimental to species' populations. Price and population numbers are important indicators of an AAE and thus should be considered carefully by conservationists and law enforcement agencies when implementing cycad conservation policy (Lyons and Natusch, 2013). By comparing successful conservation methods from various species to that of cycads, law enforcement can provide more effective solutions to illegal wildlife trade going forward.

3.2. GEOGRAPHICAL DISTRIBUTION

Figure 3 shows the current world cycad distribution. Cycad populations today are believed to be remnants of a once much larger distribution (Donaldson *et al.,* 2013). Today's populations consist of relatively small populations distributed across several continents (Donaldson *et al.,* 2013).

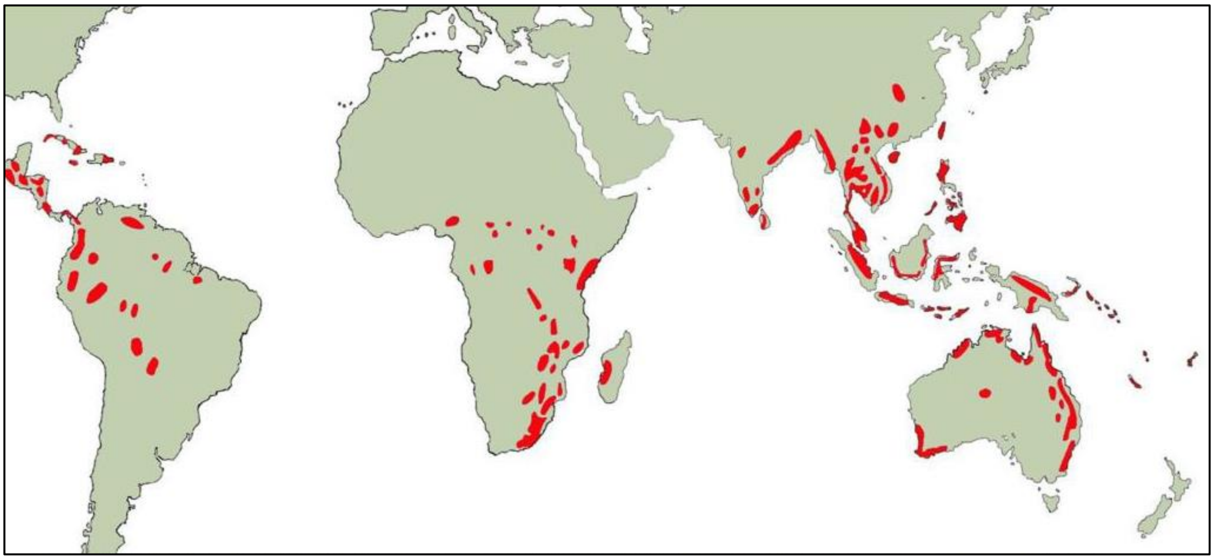

Figure 3. Illustration of cycad population distribution.

Source: Donaldson et al. 2003

Cycads are part of the plant group Cycadophytina, which comprises of 330 species (Donaldson *et al.,* 2013). They are classified into three families: Cycadaceae, Stangeriaceae and Zamiaceae (CITES, 2003).

Table 1. Distribution of cycad families and genera globally.

Source: CITES, 2003

Continent	**Family**	**Genera**
Africa	Cycadaceae Stangeriaceae Zamiaceae	*Cycas* *Stangeria* *Encephalartos*
Asia	Cycadaceae	*Cycas*
Oceania	Cycadaceae Stangeriaceae Zamiaceae	*Cycas* *Bowenia* *Mocrozamia* *Lepidozamia*
Central and South America	Zamiaceae	*Ceratozamia* *Dioon* *Microcycas* *Zamia*

Cycads can be found in different ecosystems, such as rainforests, seasonal dry forests, grasslands and occasionally can be found in the forest canopy (Golding and Hurter, 2003). According to Donaldson *et al.* (2013), South Africa, Australia, Mexico, China and Vietnam account for 65% of the world's cycads. South Africa is home to the highest variety of cycad taxa on the African continent (Golding and Hurter, 2003). This is in part, due to the country's climate and landscape which provides protection for the plants from the elements (Cowling and Hilton-Taylor, 1997). Cycads are found in relatively small population groups and most species are restricted to particular geographical areas, which increases the risk of extinction through a number of threats, including distribution and specialisation for example (Donaldson *et al.,* 2013). The wide distribution of some species sees a large distance between male and female plants thus increasing the risk of decline due to pollination issues (Donaldson *et al.,* 2013). Some cycad species display niche specialisation within the habitats they grow; this is also a threat that increases extinction risk (Golding and Hurter, 2003). During the evolutionary process, a number of insects have evolved with cycads and thus are dependent on them for survival (Retief, 2013). With the decline of cycad populations in the wild, such species of insects dependent on cycads are decreasing concurrently (Retief, 2013). This further contributes to biodiversity loss following the extinction of cycads in the wild.

3.3. VALUE, THREATS AND ILLEGAL TRADE OF CYCADS

There are a number of factors which effect the value of cycads: (1) the value of cycads is often exaggerated due to the rarity of the plant, thus increasing its desirability to collectors (Retief, 2013); (2) cycads have an unusual form and sense of antiquity about them, as they are associated with the dinosaurs (Kay *et al*., 2011); and (3) cycads grow slowly and take many years to reach reproductive size or the size desired for ornamental use (Retief, 2013). Therefore, the number of offspring produced is also low coupled with a slow reproductive cycle (Vorster, 1993).

According to Retief (2013), prices of cycads can range from R8 to R5000 per centimetre (measured by the length of the stem). This large monetary value placed on cycads increases the inclination to poach cycads from the wild (Retief, 2013). Consequently, there are not enough large plants cultivated to satisfy the current demand, which perpetuates the illegal harvesting and trade cycle (Donaldson *et al.,* 2013). Cycads can be considered as K-strategists; plants with high survivorship and resistance to disturbances, but low reproductive output and little chance of recovery once disturbed (Golding and Hurter, 2003). These two factors thus promote the removal of already established plants out of the wild (Retief, 2013) for reasons such as landscaping, amongst others; resulting in illegal trade (Donaldson *et al.,* 2013).

3.3.1. Threats to Cycad Populations

Anthropogenic acivities such as habitat destruction and illegal harvesting and trade, pose the greatest threat to cycads. Mankind has used cycads over the centuries for a number of uses including, *inter alia*, harvesting for traditional practices, use as food in times of famine and the removal from the wild for landscaping and ornamental use (TESA, 2003). More recently, in modern times, the harvesting cycads from the wild is said to be the most significant threat to wild cycad populations. In some parts of the world, however, there is evidence to suggest that habitat destruction could be an equally significant threat to cycad populations (Donaldson *et al.,* 2003). According to Donaldson *et al.* (2003), there is much evidence to suggest that human activities have had a significant detrimental impact on cycad populations; such impacts are influencing the future survival, or perhaps, extinction of wild cycads, far more than natural processes.

Habitat destruction, according to CITES (2003), is the biggest threat in Asia, South America, Central America and the Caribbean. Habitat destruction can occur through road construction, dam construction, clearing of vegetation for agricultural use and invasion of alien species (Cousins *et al.,* 2011). Habitat destruction could also have a potential indirect effect on cycad populations by making plants more visible and accessible to poachers and collectors (Donaldson *et al.,* 2003). As cycad populations are restricted to particular areas, this increases the risk of population depletion from habitat destruction (Golding and Hurter, 2003).

Cycad leaves have been seen to be harvested for use in cultural ceremonies and floral arrangements (Donaldson *et al.,* 2013). A large demand, for example, exists for festivals and ceremonies in Mexico (Vovides *et al.,* 2010). Cycad leaves, for the use of floral arrangements and basketwork, has been a substantial market (TESA, 2003). However, this has not been seen to have a detrimental effect on wild populations (Donaldson *et al.,* 2013), as sources of leaves often come from artificially propagated plants (TESA, 2003).

The use of cycads for medicine and magic occurs in a number of regions, such as in South Africa, for example (Donaldson *et al.,* 2013). Here, bark strips and stem sections from cycads are sold in traditional medicine markets (Cousins *et al.,* 2011). While this is regarded as only internal trade, it is having a detrimental effect on wild populations (Donaldson *et al.,* 2013). Although the use of cycads for medicinal purposes has occurred for many years, an increase in human populations has resulted in unsustainable harvesting in comparison to historic use (Cousins *et al.,* 2011).

In times of famine, cycad stems and cones are used as a food source for local communities in Africa (Donaldson, 2003). Consumption of cycad stems and cones may affect wild populations (Whitelock, 2002), however, available data does not show any indication of on-going trade in cycads for food (TESA, 2003).

Trade in cycads for ornamental use accounts for the greatest volume of all threats (TESA, 2003); nearly 50 million plants were traded between 2002 and 2011 (Donaldson *et al.,* 2013). It is assumed that there are only a few thousand cycad collectors across the globe; each seeking a diversified range of species across each taxon (TESA, 2003). Plant collectors, according to Red List Assessments, are believed to be responsible for the decline of cycad populations in South Africa (Golding and Hurter, 2003); with this possibly resulting in two species becoming extinct in the wild (SANBI, 2010). It is believed that the large number of cycads found in gardens today were a result of harvesting from the wild; over one million cycads are estimated to be found in private collections in South Africa (Donaldson *et al.,* 2003). The lack of many cycad species in cultivation further stimulates the market for plants collected from the wild, thus, fuelling illegal harvesting and negatively impacting rare species (TESA, 2003).

3.3.2. Illegal Trade of Cycads

Documented international trade in wild harvested cycads is negligible for a large number of species (TESA, 2003), thus very little is known about the magnitude of illegal cycad trade and the syndicates fuelling it (Smith, 2014). Even though all cycads are listed on either Appendix I or Appendix II, populations continue to decline due to unsustainable or illegal trade and could potentially become the first taxa to become extinct in the wild whilst listed on the CITES Appendices (TESA, 2003). Driving the illegal trade of cycads is the limited risk associated with being apprehended, which speaks to the lack of policy and law enforcement (Smith, 2014).

The most challenging aspect in enforcement of cycad exports and imports is determining whether plants were harvested from the wild or artificially propagated (Donaldson *et al.,* 2013). To determine whether the plant consignment came from the wild or was artificially propagated, the enforcement office can follow a few guidelines, which include, *inter alia*, the uniformity of the group, packaging, transportation and the condition of the leaves, roots and stem (Donaldson *et al.,* 2013). Cycads are resilient plants, which can be left out of the ground for months before being replanted; this makes cycads an even easier target for trafficking as well as determining place of origin (Smith, 2014). The most common way of committing fraud in cycad trade is declaring that the cycad is artificially propagated; the incentive for this is that many countries prohibit the export/import of wild harvested cycads (Donaldson *et al.,* 2013). With these current patterns of illegal trade continuing, it is feared that these plants could go extinct (Smith, 2014). Illegal trade has had the greatest effect on cycad populations found in Australia, Mexico and South Africa (Gilbert, 1984; Osborne, 1995; Donaldson *et al.,* 2013).

3.4. CONSERVATION MANAGEMENT OF CYCADS

There are many organisations which work towards the conservation of cycads, such as, CITES, IUCN and the WWF. Since 2003, the IUCN Red List of Threatened Species has been developed and now includes a better assessment of cycad taxonomies; cycad species listed have increased from 238 (2004) to 330 (2014) (Marler and Marler, 2015). Cycad populations are diminishing across the globe, with populations in Asia, Australia and South and Central America showing an increase in threatened species (Donaldson *et al.,* 2013). In Africa, South Africa, Swaziland, Mozambique, Zimbabwe, Kenya, Tanzania and Uganda are prone to illegal cycad trade and thus have been listed as high priority areas for conservation measures (Golding and Hurter, 2003).

Cycad taxa are placed into threat categories based on quantitative criteria found in Appendix I (Golding and Hurter, 2003). The IUCN categories are extinct, extinct in the wild, critically endangered, endangered, vulnerable, near threatened and least concern (SANBI, 2017). Donaldson (2003) believes that cycads can be considered an umbrella species in areas associated with high diversity and/or threatened habitats. However, the main problem facing conservation authorities is how to conserve wild cycad populations (Donaldson *et al.,* 2003).

Cycads have been seen to decline in numbers across the globe (Donaldson *et al.,* 2013). CITES reports reflect a small amount of trade in wild collected plants implying a large amount of trade is not regulated by CITES (e.g. domestic trade), does not go through official borders (e.g. trade between countries) or evades CITES regulations (illegal trade) (TESA, 2003). The continuing decline of cycad species largely due to illegal trade and the institutional capacity of conservation organisations needs to be questioned and addressed.

3.4.1. IUCN SSC Cycad Specialist Group

The Cycad Specialist Group is a member of the IUCN Species Survival Commission (IUCN / SSC Cycad Specialist Group, 2017). The group, founded in 1987, was established as an international network to promote cycad conservation and decrease non-sustainable trade. The group released a status survey and conservation action plan for cycads in 2003 (Donaldson *et al.,* 2003). The action plan involved (1) artificially propagating cycads from seeds collected in the wild; this aims to restore dwindling wild populations and reduce illegal trade, (2) updating cycad taxonomy on a regular basis, (3) conducting censuses on wild populations and private collections, (4) assisting conservation actions across the globe and (5) establishing a strong network of individuals and institutions aimed at conserving cycads (IUCN/SSC Cycad Specialist Group, 2017).

The Group believes that an important strategy to cycad conservation is improving public awareness about the various threats they face (IUCN/SSC Cycad Specialist Group, 2017). The group launched a website in 2013 (IUCN, 2015) as a new tool to communicate new findings and conservation updates (IUCN/SSC Cycad Specialist Group, 2017). The site also provides taxonomic data to law enforcement as well as images that can be used to verify or identify a species (IUCN, 2015). The Cycad Specialist Group strongly recommends that local communities be included in cycad conservation plans as they form an important part of the ecosystems where cycads are found (IUCN/SSC Cycad Specialist Group, 2017). The inclusion and participation of local communities has seen some success in Mexico, however, the long-term viability of these projects is threatened by insufficient marketing systems and trade partners (Donaldson, 2003). The benefits of such community projects are not limited to cycad conservation, where the techniques learned can be used elsewhere with other endangered flora (IUCN/SSC Cycad Specialist Group, 2017).

3.4.2. Save Our Species (SOS)

SOS was started in 2010 by the Global Environment Facility, the World Bank and the IUCN as a grant-providing initiative aimed at improving the survival rates of threatened fauna and flora whilst benefiting their habitats and surrounding communities which depend on them (SOS, 2016). SOS believes wildlife crime is one of the greatest drivers of species extinction; a third of the projects supported by SOS are related to anti-poaching and wildlife law enforcement activities (IUCN, 2014). Two main functions of the organisation are grant management and capacity building with grant recipients (SOS, 2016). SOS aims to prevent wildlife crime through addressing the following areas: technology, poaching in conflict zones, improving the prosecution rate, changing attitudes and involving local communities (IUCN, 2014).

A quarter of projects in the SOS portfolio involve species management, for example, targeting certain species through propagation (SOS, 2016). The direction of projects to be undertaken is largely influenced by the IUCN Red List (IUCN, 2015). Increases in the portfolio are projects relating to cycads (SOS, 2016); there are six projects relating to cycads in Africa, Asia, Oceania and the Americas (IUCN, 2015). The increase in such projects aims to locate new populations of threatened species and propagate plants successfully on site and *ex-situ* (SOS, 2016).

3.4.3. Conservation Management of the *Encephalartos* species in South Africa

SANBI (2010) believed that due to continuous trade in South Africa, many cycad species would become extinct in the wild in the next 10 years; this has been seen by the continuous decline of cycad populations in the wild. Wildlife crime is difficult to prevent, as it is complex and opportunistic, thus law enforcement initiatives need to be flexible and adaptable to be successful (IUCN, 2014). Currently protected areas in South Africa cannot fully monitor cycad poaching due to other problems such as rhinoceros horn poaching; however, the costs of cycad conservation can be carried by the private sector through conserving cycads on private land, private reserves and conservancies (Retief, 2013).

The IUCN (2011) believes that South African authorities should place a blanket ban on all cycad trade until a non-detriment study has been conducted on all cycad species in Africa. A non-detriment study used to assess the vulnerability of a species in relation to how well that species is managed (SANBI, 2018). Although the South African government has put measures in place against illegal trade, it is thought that this is not enough to eradicate the possibility of more species becoming extinct in the wild (Lochen, 2011). This extreme measure is needed due to years of poor trade management resulting in the large decline in population numbers (IUCN, 2011).

All *Encephalartos* species are listed on CITES Appendix I (Donaldson, 2003), therefore the collection, trade, export of artificially propagated specimens (still permitted in South Africa) and possession without a permit is prohibited (Driver, 2014). Donaldson (2003) highlighted the need to evaluate the impact of illegal trade, the effectiveness of CITES/IUCN listings on the trade of cycads and the benefit for conservation. Despite the current actions to restrict trade, the exploitation of wild cycad populations has continued (Lochen, 2011). Possible reasons for the continuing decline include the large domestic market in South Africa for ornamental and landscaping use and the shortage of plants being propagated resulting in a constant demand for wild harvested plants (CITES, 2003).

In May 2012, an improvement was made to the National Environmental Management Biodiversity Act 2004 (NEMBA). Section 57 (2) is now stricter on the regulation of cycad trade, which is predicted to go further in achieving the goals set out in the Biodiversity Management Plan (BMP) (Retief, 2013). The first species management plan has been developed for *E. latifrons* (Albany cycad) as there are fewer than 100 individuals left in the wild (SANBI, 2010). This species management plan was put together by SANBI, the DEA and various stakeholders in the Eastern Cape to provide incentives to landowners and farmers to manage their cycads effectively (SANBI, 2010).

Artificial propagation is a useful conservation method used to increase wild populations (Donaldson, 2003). Many cycads species, propagated in botanical gardens and nurseries, have been relocated to the wild successfully (Da Silva *et al*., 2012). An alternative approach for such nurseries is to sell rare species instead of replanting them in the wild. This is hoped to reduce the demand for rare cycads and prevent them from being illegally harvested from the wild (Donaldson *et al*., 2003). Studies conducted by Da Silva *et al.* (2012) have successfully reintroduced propagated *E. latifrons* plants from Kirstenbosch National Botanical Garden back into wild populations. This research in conjunction with other traits, for example, pollination, is important in the next steps to implement this approach for other *Encephalartos* species (Retief, 2013).

Propagation methods have also been successful in Mexico; however, their effectiveness is restricted by marketing and the development of reliable trading partners to establish a self-sustaining business (Donaldson, 2003). The BMP hopes to implement a similar strategy in South Africa for the species *E. latifrons* (Da Silva et al., 2012). This project is aimed at restoring the existing population (Department of Environment Affairs and Tourism (DEAT), 2010). The project will allow landowners and communities to obtain permits, which will allow them to trade propagated *E. latifrons* seedlings for restoration (DEAT, 2010). Currently the market for seedlings is not large enough to justify large-scale commercial production of the plants; as a result, this creates a market for wild-collected plants (Donaldson *et al*., 2013).

Embracing technology has become an important step towards combating wildlife crime (IUCN, 2014). Two new mobile applications, Species ID Tool and Cycad ID Tool, have been released to help law enforcement officers, custom officials, border police and environmental management inspectors by providing identification abilities and can be used on iPhones, iPads, iPod touch and Android operating systems (SANBI, 2014). The software is designed to identify the organism through a series of observable traits, thus helping to monitor and regulate trade in South Africa (SANBI, 2014).

A different approach is the use of microchips. Such chips are placed in plants in the wild and thus can be identified if removed (Da Silva, 2005). Microchips, however, have been seen to have limited success as they can be detected by x-ray equipment and removed by poachers (Da Silva, 2005). A more feasible method, which involves spraying plants with microdot paint containing identification tags, has been more successful (Nordling, 2014). This method is dependent on the fact that the relatively large amounts of chemical element's isotopes vary naturally in different geographical locations, thus as the plants grow, they integrate the chemical element isotope signatures which provides evidence of the geographical area they were growing (Nordling, 2014).

3.5. SYNOPSIS

Species are the fundamental components to biodiversity (SOS, 2016) as cycads have been a part of our diverse world for approximately 300 million years (Donaldson *et al.,* 2013) and are of great scientific importance genetically (CITES, 2003). However, cycads are the most highly threatened group of plant species (Walter and Gillett, 1998; SANBI, 2010; Rutherford *et al.,* 2013) as a result of habitat destruction, harvesting for traditional practices, use as food (in times of famine) and removal from the wild for landscaping and ornamental use (Donaldson, 2003).

As explained in Section 3.3, cycads are extremely rare and valuable; unfortunately, this is paired with a large monetary value increasing the desire for poachers to remove plants from the wild (Retief, 2013). Plant collectors in South Africa are believed to be the greatest influences in the decline of wild cycad populations (Golding and Hurter, 2003). Possible reasons for this decline may be due to the shortage of plants being propagated (CITES, 2003). There are several conservation policies and strategies in place to protect cycads and restrict illegal trade, yet the exploitation of wild populations has continued (Lochen, 2011).

The next chapter outlines the methods used in identifying whether an AAE is present in the *Encephalartos* species in South Africa and how the current conservation measures in place will be analysed to determine their successfulness.

CHAPTER 4
EMPIRICAL METHODS OF DATA ANALYSIS

4.1. INTRODUCTION

Chapter 4 explains the methodological approach taken to determine whether an AAE exists and to determine the successfulness of current legislation. In order to determine whether an AAE exists, previous studies on the AAE were discussed and the analytical procedure followed to prove the assumptions of an AAE. This was done for the year 2010. A description of current legislation in place was completed and the factors to be addressed were identified. The demand and supply of the market for cycads was addressed to help determine the effectiveness of the legislation in place to protect cycads.

4.2. METHODOLOGICAL APPROACH

The following section describes the methodological approach used to analyse cycad conservation and trade policies and to determine whether an AAE exists. The proposed research, due to its quantitative and qualitative nature, is defined within a mixed methods research paradigm.

In order to determine the existence of an AAE, the following three points need to be proven true:

1. Assumption 1: A linear regression is used to determine whether the dependent variable, price, is positively correlated with the independent variable, rarity.
   Rarity is divided into the following IUCN categories: least concern, near threatened, vulnerable, endangered, critically endangered and extinct in the wild (IUCN, 2015).
2. Assumption 2: A linear regression is used to determine whether the dependent variable, harvest level, and independent variable, price, are positively correlated.
   As assumption 2 requires an in-depth assessment of the demand side of the market it is relatively difficult to prove, yet in cases where demand is reinforced, such as in the collection of rare items, the assumption is fulfilled when collectors are willing to pay any price to acquire the last few individuals of the population (Courchamp *et al.,* 2006).
   Therefore, if assumption 1 is satisfied we will assume assumption 2 has also been

fulfilled as three species have already gone extinct in the wild due to overexploitation, it follows that the other species are subject to the same fate.

3. Effect of change in IUCN red listing: A linear regression is used to determine whether a positive correlation exists between the independent variable, harvest level, and dependent variable, rarity.

   If a change in rarity fuels demand, increasing the price (assumption 1), resulting in an increase in the harvest level to meet demand (assumption 2), will the harvest level further increase rarity?

To evaluate the 'success' of conservation and trade policies, the following factors need to be analysed, with reference to previous and current policies, in order to create a benchmark to use in comparing the relative successfulness of policies with one another: time frames, objective setting, attribution, resources (Pullin *et al.,* 2013) and rarity (Hall *et al.,* 2008). Additionally, the past/current status of the species and conservation policies need to be analysed and described. Lastly, the effect of the implementation of the policy on illegal trade will be discussed and conclusions drawn on the relative success/failure of the policy.

By comparing and applying successful policies to the cycad market in South Africa, it can be determined why illegal cycad trade has not been eradicated by legal cycad trade, and where such gaps in legislation exist, followed by recommendations.

The rest of this chapter will explore previous applications of the AAE, factors influencing the successfulness of conservation policies, data collected and analytical procedure followed.

4.3. PREVIOUS APPLICATIONS OF THE ANTHROPOGENIC ALLEE EFFECT

Branch *et al.* (2013) argued that the advancement in research of the AAE of rare species has shown the importance of the direct and indirect consequences of such an effect induced by humans as it is now seen in almost every area of conservation and ecology. According to research, consumers may place a higher value on wildlife or wildlife derived goods that are considered to be rare (Gault *et al.,* 2008; Johnson *et al.,* 2010; Lyons and Natusch, 2013). Environmental conservation monitoring, enforcement and policies are thus vital indicators used to distinguish what species are perceived to be more highly valued and becoming popular in trade (Lyons and Natusch, 2013). It is vital for conservationists and government to consider the indicators of a potential AAE (Lyons and Natusch, 2013), as studying the effect of the consumers' change in perceived rarity of a species will ensure successful implementation of conservation and trade policies aimed at minimizing extinction risk (Hall *et al.* 2008). Several studies have been completed to determine the existence of an AAE and the implications on conservation management (Lyons and Natusch, 2013; Slone *et al.* 1997; Tournant *et al.* 2012).

Lyons and Natusch (2013) collected data on wild harvests, preferences of pet keepers and sales prices of different populations within a species for green pythons. In order to determine the commonality in the market (most desired species by pet collectors), they created a survey questionnaire. Linear regressions were conducted to determine the relationships between the number of green pythons harvested, commonality in the market and price. The data was $\log_{10}$– transformed to meet the assumptions of normality and homogeneity of variance. The results showed a positive correlation of the rarity of green pythons to their price and a negative correlation to harvest levels (Lyons and Natusch, 2013).

Slone *et al.* (1997) conducted a comparison of price and rarity and rarity and wing size of butterfly specimens, where they collected ratings of butterfly rarity from Parsons (1991), namely rare, occasional, common, abundant and dominant and prices were obtained from a number of insect retailers. A comparison was made between butterfly rarity and prices and the trend was tested for significance (Slone *et al.,* 1997). The results showed that prices increased with rarity but rarity was not positively correlated to wing size (Slone *et al.,* 1997).

Tournant *et al.* (2012) focused on the hobbyist trade of stag beetles in Japan to determine whether the market value of the beetles is driven by rarity and if this may lead to overexploitation. Data was collected on characteristics (colour, body length, thorax width and mandible length), quantity imported, price and rarity for the year 2008 (Tournant *et al.,* 2012). Each species was allocated a score between one and five for rarity; where one represented very rare and five represented very common (Tournant *et al.,* 2012). Pearson's correlation tests were performed to analyse these relationships. In this study, as rarity of stag beetles decreased, the selling price of stag beetles decreased; and a positive correlation existed between rarity and volumes imported (Tournant *et al.,* 2012). Tournant *et al.* (2012) concluded that species rarity drives purchases by collectors, thus stag beetles are vulnerable to an AAE.

4.4. ANALYSIS OF CONSERVATION POLICIES

Government and other conservation organizations apply two approaches to protect wildlife from poaching and illegal trade: implement policies or take actions that will influence (1) the supply for wildlife and wildlife derivatives or (2) the demand for wildlife and wildlife derivatives (Chen, 2015). A major challenge to implement such policies is the demand for rarity (Hinsley *et al.,* 2015). Supply-side policies decrease the incentive to poach, however this is largely offset by the demand for rarity as it is driven by the willingness to pay more for rare wildlife and wildlife derivatives (Chen, 2015). Targeting a change in consumer behaviour to reduce demand would need to be addressed in addition to supply-side policies (Hinsley *et al.,* 2015).

The next challenge for policy makers is to determine which conservation efforts to prioritize. The IUCN has produced a list of species, ranked by threat status, for this reason (Hall *et al.,* 2008). However, there is evidence to suggest that sellers use this information to capitalize on increased consumer demand for rare wildlife and wildlife derivatives (Rivalan *et al.,* 2007; Hall *et al.,* 2008).

4.4.1. Implementing Successful Conservation Policies

In order to design successful conservation strategies, Hall *et al.* (2008) suggest the need to identify and understand the social and economic forces that maintain the profitability of harvesting of threatened species and the consequences for the exploited wild population. To understand the economic forces influencing the survival of cycad populations, Donaldson (2003) created a conceptual model. This model provides “a template for developing and evaluating conservation policies and actions” (Donaldson, 2003: 55). The following factors, as described by Pullin *et al.* (2013), need to be addressed when developing and evaluating conservation policies:

- Time frames: ecosystems or areas targeted by conservation policies can often take an extended period of time to show results; this time frame is often longer than what funding allows for.
- Objective setting: conservation policies often designed to address multiple objectives and may be poorly expressed.
- Attribution: conservation policies aimed at achieving multiple objectives simultaneously may lead to difficulties in achieving outcomes.
- Resources: funding for conservation efforts may be scarce, especially when there is uncertainty around successfulness of policies.

4.4.2. Conservation and Trade Legislation in South Africa

In 1975, South Africa accepted the CITES (Torgersen, 2017), which is aimed at regulating the international trade of wildlife and wildlife threatened by international trade (DEA, 2016). The implementation of CITES, however, only arose later through the NEMBA, and the Threatened or Protected Species Regulations of 2007 (TOPS) (Torgersen, 2017). In 2016, the DEA published a New Strategy and Action Plan for the Management of Cycads in South Africa to be implemented between 2016 and 2023 (DEA, 2016). This plan will take into account legislation currently in place (discussed below) and recommendations from the Scientific Authority, the Convention on Biological Diversity and the Global Strategy for Plant Conservation (DEA, 2016). The plan will also consider different methods for monitoring, evaluating and reporting which are used by other organisations, such as SANBI (DEA, 2016).

One of the most important legal frameworks used to protect wildlife species' in South Africa is CITES. This framework is much needed in South Africa due to the high levels of poaching and trading of wildlife and wildlife derivatives (Torgersen, 2017). CITES encourages all member countries to implement national legislation and other instruments, such as specialised prosecution offices, to avert poaching and international and domestic trade of wildlife and wildlife derivatives (Vié *et al*., 2008). As discussed in Chapter Three, all *Encephalartos* species are listed on CITES appendix I; as such the collection, trade and possession without a permit is prohibited (Donaldson, 2003). The consequences for engaging in illegal activities are effectuated in national legislation (Torgersen, 2017).

On 1 October 2004, NEMBA came into effect (DEA, 2016). NEMBA aims to, amongst other goals, control restricted activities, which are negatively affecting threatened or protected species, which is done using a permit system (DEA, 2016). In 2007, TOPS was implemented to regulate the permit system (DEAT, 2007). Based on the guidelines set out by NEMBA, if an individual is found guilty of an offense involving cycads, such an individual is legally responsible to: (1) pay a fine not greater than R10 million; or (2) pay a fine equivalent to three times the marketable value of the specimen; or (3) imprisonment for a period not greater than 10 years; or (4) to pay a fine in addition to imprisonment (DEA, 2016). In addition to national legislation, provincial legislation may be used to conserve cycads, along with prosecuting offenders (Torgersen, 2017).

4.4.3. Change in IUCN status

Prescott *et al.* (2011) investigated if a change in IUCN status would affect the demand for African bovid trophies. Previous studies have shown that rarer species have higher trophy prices (Johnson *et al.,* 2010; Palazy *et al.,* 2011). Prescott *et al.* (2011) collected prices from a number of hunting operators and used the IUCN Red List as a measure for rarity. Prices for the same species were averaged as to have a single value for each species. The change in IUCN status was monitored over the years 2004 to 2010 and the change in species status was sorted into three groups; deteriorated, improved and none (Prescott *et al.,* 2011). Prescott *et al.,* (2011) calculated the mean price change, median price change, inter-quartile range and standard error for species, for each of the status changes deteriorated, improved and none. Prescott *et al.,* (2011) concluded that the bovid species', whose IUCN status deteriorated, had a larger increase in trophy prices in comparison to the species' whose IUCN status improved or did not change. This result is aligned with the expectation that rarer species are more highly valued, thus reflecting an increase in price.

4.5. DATA COLLECTION

The data collected aimed to (1) prove the existence of an AAE and the implications, (2) understand the trade penalties and conservation and trade policies in place, and (3) evaluate the effectiveness of such trade penalties and conservation and trade policies in place.

4.5.1. Primary Data

Panel data was collected for each species in the *Encephalartos* genus (Appendix A). Panel data is a set of data whereby the behaviour of individuals is observed across a period (Torres-Reyna, 2007). Data was observed in three areas: (1) rarity of each species was observed over the period 1998 – 2015; (2) average price per centimetre of each species was observed over the period 2005 – 2015 (excluding 2008, 2011, 2012 and 2014); and (3) population size was observed for the year 2010.

The measure of rarity and population size for each species was taken from the IUCN Red List; the IUCN categories are least concern, near threatened, vulnerable, endangered, critically endangered and extinct in the wild (IUCN, 2015). Auction and sales data was collected from multiple sources. The sources included: Trollip (2005); Fanfoni (2006); Cycads 4 U (2006); Coetzee (2006); Smuts and Smuts (2006); Florida Park Auction (2007); Cycads Online (2007); Fanfoni (2007); Pietersburg Primary Sports Ground Auction (2009); Hagerman and Hagerman (2009); Fanfoni (2009); Global Cycads (2010); Pietersburg Primary Sports Ground Auction (2010); Helm (2010); Fanfoni (2010); Cycad Afrika, (2013a); Cycad Afrika (2013b); Cycad Wofi (2013); Fanfoni (2015); Van Der Schijff (2015). The auction and sales data were sorted by species and the price per centimetre for each sale was calculated. Due to limitations, to be discussed shortly, only one year of data (population size) was available from the IUCN Red List (IUCN, 2015) for the *Encephalartos* genus.

Qualitative data was collected from four organizations; these organizations were SANBI (SANBI, 2010), DEA (DEA, 2016), IUCN (IUCN/SCC Cycad Specialist Group, 2017), and the SOS initiative (SOS, 2016). The information collected included: (1) a brief overview of the organization (Section 3.4); (2) conservation policies pertaining to cycads (Section 3.4); and (3) empirical examples. This data was used to build a conceptual model representing economic forces present in illegal cycad trade and possible interventions.

4.5.2. Data, Limitations and Adaptions

The data was collected from the 37 species in the *Encephalartos* genus existing in South Africa. Average price, wild population size and IUCN Red List status was captured for each species. The data aimed to show values for the years 2000 – 2015. However, due to various limitations this was not possible.

A number of difficulties arose whilst collecting data for each species in the *Encephalartos* genus; mainly data missing for a number of years. Due to illegal prices being unavailable, the data set is made up of auction and sales prices collected from various sources. Illegal prices are unavailable, thus auction and sales prices were used to give an indication of the consumer's willingness to pay. No data could be found for the years 2000, 2001, 2002, 2003, 2004, 2008, 2011, 2012 and 2014.

Due to very few Red List Assessments being conducted on cycad species populations around the country in the past; there is very little data available on population sizes. In 2010, a Red List Assessment was conducted by the IUCN and the population sizes were captured on the IUCN Red List Database (IUCN, 2015). No new data has been published since 2010. A select few individuals have knowledge on a species' population size in an area; however, this information is not available in order to protect these wild populations. As only one year of data is available, the harvest rate could not be calculated. As such data was unattainable, the population size will be used for the analysis of assumption 2.

4.6. ANALYTICAL PROCEDURE

The analytical procedure presented in this section is divided into two sections: calculating the effect of a change in IUCN status and determining the existence of an AAE. The first section discusses the equations used to determine the results needed to draw a box and whisker plot to determine whether a link exists between a change in IUCN listing (from 2006 to 2010) and an increase in demand. The second section sets out to determine whether the assumptions of the AAE are met. Linear regressions were run using the method of least squares to determine whether these assumptions are met thus indicating whether an AAE exists in the *Encephalartos* species in South Africa.

4.6.1. Calculating the Effect of a Change in IUCN Status

The method used to determine whether there is a link between a change in IUCN listing and an increase in demand follows that set out by Prescott *et al.* (2011).

The primary data used was taken from 2006 and 2010 auction data; the price per centimetre for each year was averaged for each species to account for variation in a species' auction/sales price across the country. The IUCN listing was observed for each species for 2006 and 2010 to categorize the species into one of three statuses: improved, deteriorated and no change. The change in price from 2006 to 2010 was calculated for each species. To determine the relationship between the change in IUCN listing and change in price, the mean price, median price and interquartile range was calculated for each category (improved, deteriorated and no change). The standard error was omitted due to the low sample size of each category.

The following equations show how the mean price, median price and interquartile range were calculated for each category (Wan *et al.,* 2014).

Mean price:

$$\mu = [\frac{\sum_{i=1}^{n} X_i}{n}]$$

Where μ is the sample mean and X_1, X_2,…, X_n a random sample of size n.

Median price:

$$M = \frac{1}{2}(n+1)$$

Where M is the median and n the sample size.

Interquartile range of

$$Q_1 = \frac{1}{4}(n+1)$$

$$Q_3 = \frac{3}{4}(n+1)$$

$$IQR = [\frac{1}{4}(n+1)] - [\frac{3}{4}(n+1)]$$

Where Q_1 is quartile one, Q_3 is quartile 3, IQR the interquartile rand and n the sample size.

This information was calculated in Microsoft Excel and used to create a box and whisker plot**.**

4.6.2. Determining the Existence of an AAE

The method used to determine whether an AAE exists among cycad populations follows that set out by Lyons and Natusch (2013). The primary data used included auction data for each species (price per centimetre), the wild population size of each species and the IUCN listing from 2010. The data was log-transformed. Linear regressions (using the ordinary least squares method) were completed to determine the relationships between rarity and price and wild population and price.

The method of ordinary least squares is illustrated by the following equation (Gujarati, 2003):

$Y = \beta_1 + \beta_2 X + u$

Where Y is the dependant variable, β_1 and β_2 are the parameters of the model, X is the explanatory variable and u is the error term.

Three linear regressions were run, using Microsoft Excel, to:

1. Determine the correlation between price and rarity.
2. Determine the correlation between wild population size and price.
3. To show the relationship between the wild population of species and rarity status. This is to demonstrate how the IUCN allocates a status to a species.

To determine whether the model shows a linear relationship between the two variables, for example price and rarity, a test of overall significance was conducted using Microsoft Excel. The hypotheses for the F-test of the overall significance are as follows:

- Null hypothesis: $\beta_1 = 0$
- Alternative hypothesis: $\beta_1 \neq 0$

4.7. QUALITATIVE PROCEDURE FOR THE ANALYSIS OF THE MARKET FOR CYCADS AND LEGISLATION

The procedure presented in this section will aim to identify different factors within the legislation, such as time frames (Pullin *et al.,* 2013), understand the market for illegal trade in cycads and analyse the effect current legislation has on supply and demand in the market. The goal of this method is to determine whether legislation highlighted in 4.4.2 has been successful.

The Strategy and Action Plan for the Management of Cycads on South Africa will be analysed using the factors highlighted by Pullin *et al.* (2013) in Section 4.4.1. A good understanding of the legislative policies in place was vital in determining whether they are successful or not.

In order to analyse the effect of current legislation on the market for cycads, a conceptual model was created to illustrate the illegal market for cycads driven by collectors. This model is based on a model created by Donaldson (2003). The supply and demand of illegal wildlife, with the assumption that rarity drives demand, was discussed in Section 2.2.4. Based on this model, current legislation was assessed to determine their effect on supply and demand in the market. Supply-side factors looked at, included, availability of cultivated alternatives, protection of wildlife, trade enforcement and poaching penalties (Hinsley *et al.,* 2015). Demand-side factors included conservation education and high profile media and campaigns (Oldfield, 2003).

4.8. SYNOPSIS

Chapter Four provided a detailed explanation of the methodological approach used in this study. The chapter discussed previous applications of the AAE, analysis of conservation policies, data collection and availability, limitations and the analytical procedure followed. Due to data limitations, the determination of an AAE was based only using data from the year 2010. Although this will not fully prove the existence of an AAE, it will provide an indication of its existence as discussed in the next chapter.

The next chapter will show the results of the analytical and qualitative procedures.

CHAPTER 5
EMPIRICAL RESULTS

5.1. INTRODUCTION

This chapter presents the results in two sections. Section 5.2 explains the conceptual model devised for the market for cycads, an overview of the Strategy and Action Plan for the Management of Cycads in South Africa and the effect on the price of cycads when an IUCN Red List status changes. Section 5.3 shows the results of the linear regressions run in order to determine whether an AAE exists within the *Encephalartos* species in South Africa.

5.2. ANALYSIS OF THE MARKET FOR CYCADS AND LEGISLATION

This section will, firstly, illustrate the illegal market for cycads, the actors involved, and a simplistic view of an illegal trade occurring with an intermediary in play. Secondly, the section will discuss the Strategy and Action Plan in terms of time frames, objective setting, attribution and resources. Lastly, how demand and supply in the illegal market is addressed by the current implementation of the Strategy and Action Plan.

5.2.1. Conceptual Model of the Illegal Market for Cycads

To show the economic forces influencing the main threat to cycad populations in South Africa, the illegal market for cycads, the conceptual model below was assembled. Figure 4 shows the existence of wild cycad populations within the illegal economy. To simplify Figure 4, all other relationships with wild populations, such as habitat destruction, have been removed. The market for illegal trade is complex as there are multiple avenues in which collectors can fulfil their demand. Figure 4 illustrates a simple version of demand for cycads driven by private collectors, and poachers satisfying that demand through harvesting wild populations.

The status of wild cycad populations is impacted by the demand for cycads from private collectors; this is often fuelled by rarity. Plants received from poachers often end up in private gardens in Gauteng (Torgersen, 2017).

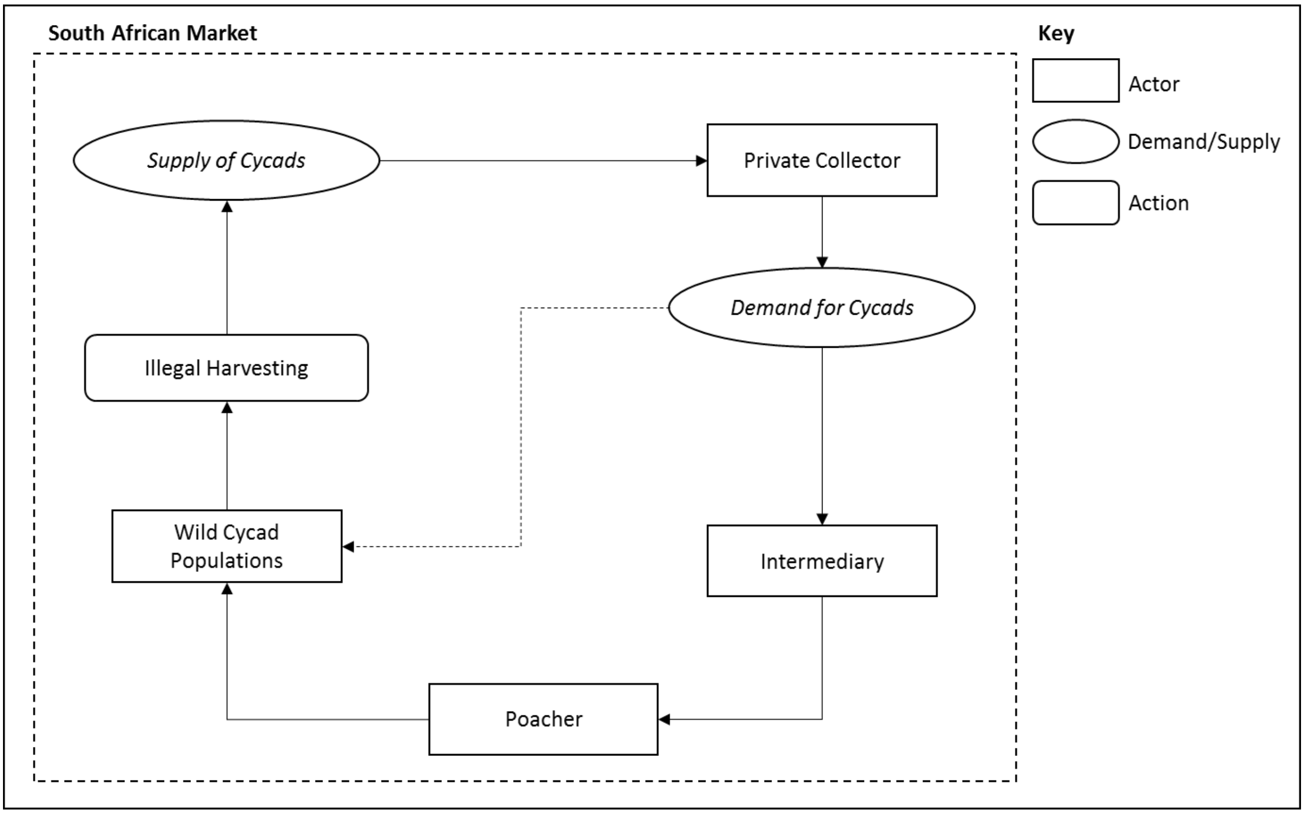

Figure 4. Conceptual model illustrating the domestic illegal market for cycads.

Wild populations of cycads have an intermediate association with poachers. It is suggested that poachers are connected to private collectors through organised crime syndicates ('intermediary' in Figure 4) to supply plants (Smith, 2014). The poacher, who is often from a poverty stricken background (Torgersen, 2017), bases their decision to harvest from wild populations on potential financial benefits and the risk of being caught (Smith, 2014). There is a possibility of a collector harvesting from the wild themselves, however, this would entail the collector being in an area where cycad populations grow, have the knowledge of where the populations are and have the means to transport the plant. This action of collectors removing plants themselves was an historic action before laws were put in place prohibiting the removal from the wild.

5.2.2. Overview of the New Strategy and Action Plan for the Management of Cycads in South Africa

In South Africa, one of the largest threats to wild cycad populations is trade (Golding and Hurter, 2003; SANBI, 2010; Donaldson *et al.,* 2013). Although there are methods to purchase cycads legally, the market is largely driven by illegal means (TESA, 2003). Effective legislation is therefore of the utmost importance to prevent the extinction in the wild of the species' left. The table below shows information from the New Strategy and Action Plan for the Management of Cycads in South Africa on the following factors: time frames, objective setting, attribution and resources.

Table 2. Table showing a brief overview of the New Strategy and Action Plan as based on Time Frames, Objective Setting, Attribution and Resources (Pullin et al., 2013; DEA, 2016).

Factors	**New Strategy and Action Plan for the Management of Cycads in SA**
Time Frames	The various objectives are to be implemented between 2016 and 2023.
Objective Setting	The Strategy and Action Plan has the following objectives: • Security: prevent illegal harvesting of wild cycads to avoid detrimental influences on the sustainability of wild populations • Population Management: ensure a minimum viable population size for each species • Habitat Management: management and protection of habitat where wild populations are found • Sustainable Use: ensure sustainability of consumption of cycads in the interest of conservation • Communication, Education and Public Awareness: development and implementation of education and awareness in collaboration with landowners, managers and stakeholders • Research: ensure scientific research is used to support conservation methods
Attribution	NEMBA is aimed at managing and conserving biodiversity rather than focussing on one species. The New Strategy and Action Plan is aimed at managing cycads, which will aim to fulfil the much-needed objectives above.
Resources	The main resource requirement identified is financial. The plan aims to source funding from the DEA budget and other conservation organisations. The funding will be needed to procure equipment and technology. The other resource needed is dedicated human resources.

Cycads are currently under threat of extinction in the wild with the current conservation policies in place. The Strategy and Action Plan seeks to prevent the extinction of cycad species and close the gap for those species' that do not have biodiversity management policies in place (DEA, 2016). The Strategy and Action Plan aims to decrease the demand for cycads and decrease the incentive to supply cycads; with reference to Figure 2 (page 17), the objectives of the Strategy and Action Plan will be addressed. All information is sourced from DEA (2016).

a. Supply and Demand-side Methods used in the New Strategy and Action Plan for the Management of Cycads in South Africa

Supply-side methods include cultivated alternatives, protection of cycads, trade enforcement and poaching penalties. In Figure 4, successful supply-side methods would inhibit or deter poachers from harvesting.

The demand for cycads sourced from the wild is high, indicating the need for cultivated alternatives. Cultivated alternatives are used to supply legal trade; thus reducing harvesting of wild individuals, which is currently the biggest threat to wild populations in South Africa. Trade in artificially propagated cycads will be allowed in terms of the CITES guidelines and for international trade, only CITES registered nurseries are allowed to export cycads. Additionally, the following guidelines must apply to trade in artificially propagated cycad plants: (1) the Scientific Authority of South Africa must indicate that the trade will not be harmful to wild populations; and (2) individual plants must have a stem diameter of less than 15cm, and dwarf/slow growing species must have a stem diameter of less than 7cm.

Through trade enforcement, the Strategy and Action Plan aims to promote the legal trade of artificially propagated cycad plants. This will help free up resources to address other areas of conservation of cycads. A challenge of this is ensuring that the individuals are in fact artificially propagated and not sourced from the wild. This highlights the need to develop scientific methods and the use of new technologies to differentiate between the two. Improving law enforcement and institutional capacity (through education, training and the use of new technologies for identifying species and differentiating between wild versus cultivated plants) poaching penalties can be more strictly enforced and thus, decrease the incentive to poach. In order to prevent further poaching, the Strategy and Action Plan aims to create a database to monitor wild populations, include isotope maps of wild populations in order to trace origin of poached plants, increase security at priority sites to prevent illegal harvesting and identify incentives for landowners and bordering communities to protect wild populations.

Demand-side methods include conservation education and high profile media campaigns. In Figure 4, successful demand-side policies would encourage private collectors to acquire cycads through legal means and not from wild populations.

Conservation education will not only be aimed at training law enforcement agents to identify cycads, but will target all stakeholders to create awareness of the importance of conserving cycads. High profile media campaigns will be put in place to create awareness to prevent demand for cycads as well an encouraging cycad owners to apply for and obtain permits for their cycads.

b. Challenges to the New Strategy and Action Plan for the Management of Cycads in South Africa

It is difficult to say whether the Strategy and Action Plan has been effective as it is still relatively new and a census has not been conducted since the plan has been implemented. Thus, there is no new evidence to show whether there has been a positive impact on wild populations. This was discussed in more detail in Chapter 6. However, there is a multitude of various challenges that will be faced which will influence the successfulness of this legislation. There are many challenges to implementing the Strategy and Action Plan successfully. These challenges include:

1. Rarity: the wants of buyers are irrational, creating difficulty in predicting actions of collectors (Torgersen, 2017).
2. Law Enforcement: cycads are sturdy plants, which are easy to uproot and transport, making them easy targets for poachers; and due to poor law enforcement throughout the country, there is little to discourage the poaching of cycads (Torgersen, 2017). Additionally, some officials are underqualified and unable to identify different species or differentiate between illegal and legal cycads and therefore, fail to make the necessary arrests (SANBI, 2014).
3. Artificial Propagation: as noted above, only small plants may be traded. This does not curb the demand for large plants, which is arguably one of the main drivers of poaching.
4. Financial Resources: there are methods in place to identify cycads, which have been removed from the wild. These include microchips (Da Silva, 2005), microdots

(Nordling, 2014), DNA barcoding (Torgersen, 2017) and stable isotopes (Nordling, 2014). However, none of these methods have been fully implemented due to inadequate funding and thus it is difficult to prove poaching in court (Torgersen, 2017).

There are substantial challenges facing conservation efforts and previous legislation has done little to curb illegal trade, highlighting the importance of effective implementation and funding of the Strategy and Action Plan.

5.2.3. Change in IUCN Status

To demonstrate how the IUCN allocates a status to a species, a linear regression was run to show the relationship between the wild population and rarity status of cycads (*Encephalartos*). Where '1' represents the status 'least concern' and '6' represents the status 'extinct in the wild'. Figure 5 shows a visual representation of this relationship.

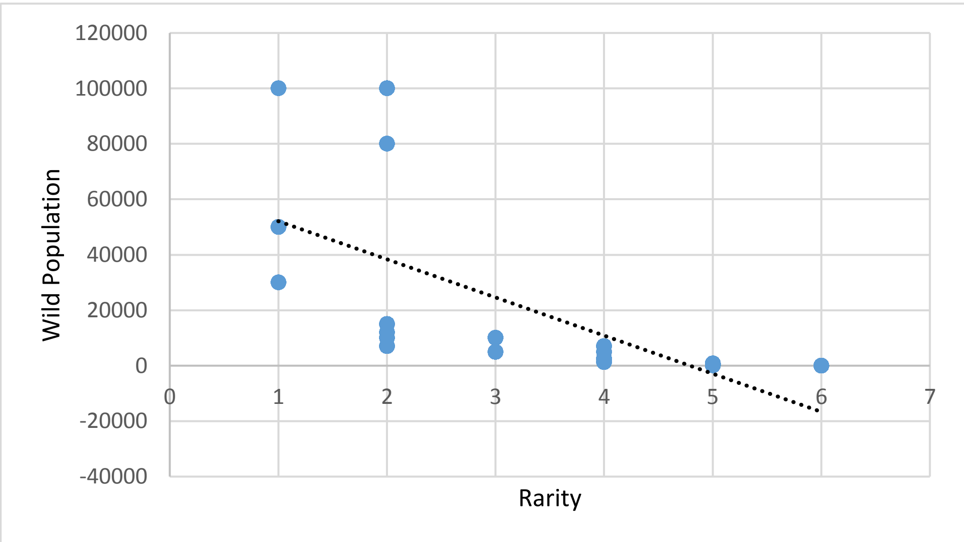

Figure 5. Graph showing the relationship between the wild population and rarity.

Where '1' represents the status 'least concern' and '6' represents the status 'extinct in the wild'.

Figure 5 illustrates the negative relationship that exists between wild populations and their rarity. Larger wild populations are classified as 'less rare' while those with small wild populations are progressively rarer, suggesting that a cycads wild population is indicative of its rarity.

To determine whether a link exists between a change in IUCN listing and an increase in demand (represented by a change in price) the change in status was compared to the average change in price. Table 3 and Figure 6 show the results of a change in IUCN status from the data collected in Appendix B. Included in Appendix B is each species' current IUCN Status (as per the last assessment done in 2010) and the population trend.

Table 3. Analysis of the change in the average price per centimetre of the combined IUCN statuses.

Change in IUCN Status	**Mean Price Change (R/cm)**	**Median Price Change (R/cm)**	**Inter-quartile Range (R/cm)**	**Sample Size**
Deteriorated	25,54	-8,59	-14,42 – 48,44	3
Improved	500,00	500,00	n/a	1
None	144,53	10,88	-3,87 – 66,46	33
Total				37

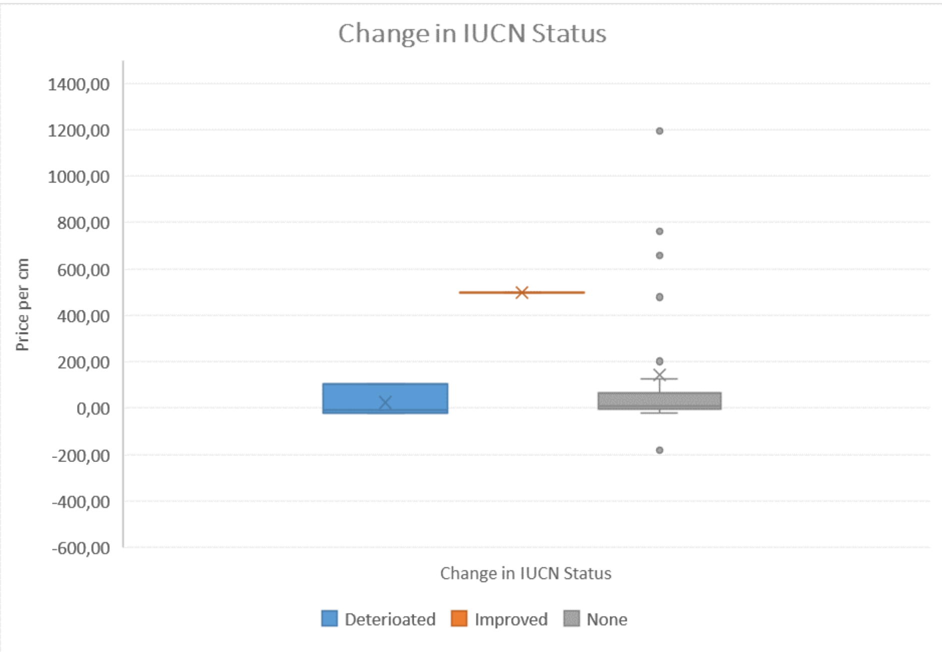

Figure 6. Boxplot showing the effect on the price per centimetre of cycads due to a change in IUCN listing from 2006 - 2010.

As per the data in Appendix B, one species improved in status (from Extinct to Extinct in the Wild), while three species decreased in status and the remaining 33 species experienced no change. This shows that the species populations are declining.

a. Deterioration in IUCN Status

The three species which deteriorated in status were *E. ferox* (Near Threatened), *E. inopinus* (Critically Endangered) and *E. cerinus* (Critically Endangered). *E. ferox* and *E. cerinus* had a mean price change which decreased by less than R25/cm and *E. inopinus* increased by more than R100/cm. The average of the three species within the 'deteriorated' group had an increased mean change of R25,54/cm.

The expectation of a species deteriorating in status would be an increase in price. However, this is not the case for *E. ferox* and *E. cerinus.* This could possibly be attributed to the availability of plants up for auction. In 2006, according to the data collected, 12 *E. ferox* plants were up for auction as opposed to 26 in 2010. This was an increase of 14 plants, which could potentially affect the behaviour of collectors, as it would appear abundant rather than rare. The data in 2006 has larger variability in prices per centimetre (σ^2 = 29,98) as opposed to 2010 (σ^2 = 5,06). The maximum in 2006 was R100,00 and the minimum R10,29. This could suggest that the average price for *E. ferox* is skewed due to a plant being sold for a much larger value in 2006 as opposed to the others on auction. This could be attributed to: (1) a large plant (>25cm), which would be more highly valued for landscaping or (2) the plant had an unusual physical feature, such as an extra branch or cones.

E. cerinus has similar levels of variability (σ^2_{2006} = R65,81; σ^2_{2010} = R70,09), numbers sold at auction (n_{2006} = 29; n_{2010} =27), minimum (2006 = R100,00; 2010 = R75,00) and maximum (2006 = R375,00; 2010 = R350,00) values. This could be the possible reason for a very small change in the average prices between 2006 and 2010.

E. inopinus is the best representative of the fundamental theory as the price increases with a deterioration in status (or an increase in perceived rarity). The level of variability (σ^2_{2006} = R63,54; σ^2_{2010} = R89,71), numbers sold at auction (n_{2006} = 53; n_{2010} =34), minimum (2006 = R61,54; 2010 = R75,00) and maximum (2006 = R312,50; 2010 = R500,00) values. Apart from deteriorating in status, the number of plants up for auction was also low, leading to an increase in the perceived rarity. The minimum value for 2006 and 2010 are relatively close, yet the maximum value for 2010 is a lot larger. The change in average price for *E. inopinus* could also be that much larger than *E. ferox* as it has a higher rarity rating on the IUCN redlist.

b. Improvement in IUCN Status

E. woodii, which improved in IUCN status from Extinct to Extinct in the Wild, had an average price in 2010 of R500/cm. It was expected that a species whose status improved, would decrease in mean price. However, as *E. woodii* was thought to be extinct, there was no data suggesting what its price would have been in 2006. As this is the case, there is not anything that can be concluded from this sale in 2010 other than the price per centimetre is exceptionally high (n = 1).

c. No Change in IUCN Status

The 33 species that had no change in status had a large range of changes in average price per centimetre. As such, the fundamental theory of the impact in a change of IUCN status cannot be proven. However, what can be shown by the data collected (Appendix A) is that average prices for more rare species, in particular Critically Endangered and Extinct in the Wild, are substantially higher. Figure 7 shows the average prices for each IUCN status categories for the years 2006, 2007, 2009, 2010, 2013 and 2015. This shows that perceived rarity has caused the price to increase. This shows that perceived rarity has caused the price to increase.

In this case, it is difficult to determine whether a change in status has an impact on price, but the status allocated does have an impact. As seen below in Figure 7, the average prices per cm for Critically Endangered and Extinct in the wild are very high.

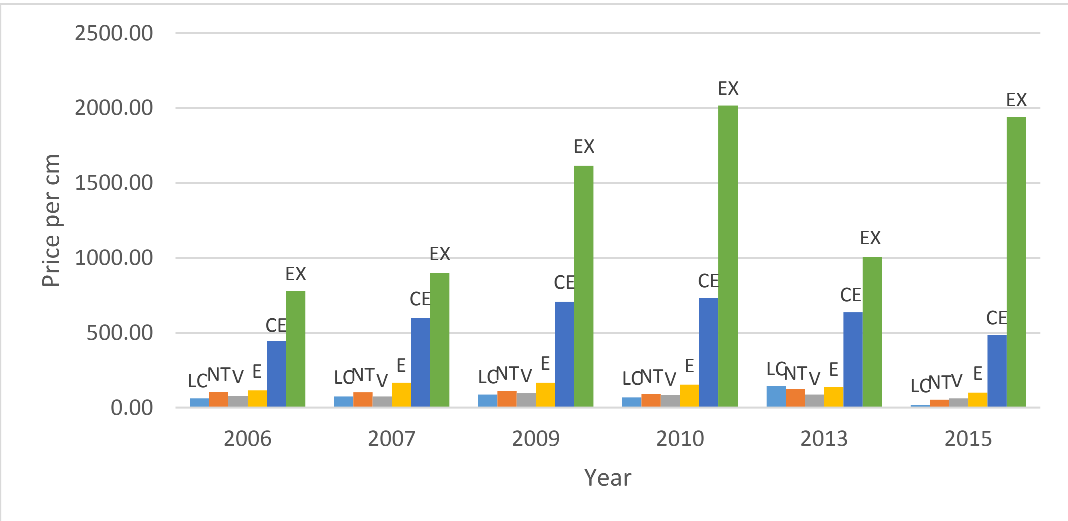

Figure 7. Graph showing the average price per centimetre of IUCN Red List ratings.

LC: Least Concern; NT: Near Threatened; V: Vulnerable; E: Endangered; CE: Critically Endangered and EX: Extinct in the wild.

5.3. DETERMINATION OF AN AAE WITHIN WILD *ENCEPHALARTOS* CYCAD POPULATIONS IN SOUTH AFRICA

In order to determine whether an AAE exists within cycad populations, two assumptions need to be met: (1) the correlation between species rarity and its value must be positive; and (2) this positive correlation, between species rarity and its value, adequately increases demand such that the market price exceeds the escalating cost of locating and harvesting a declining population (Courchamp *et al.,* 2006). The results of the linear regressions are highlighted in Table 4 and Figures 7 and 8.

Table 4. Linear regression results for 'price x rarity' and 'price x wild population'.

Assumption	*1. Price x Rarity*	*2. Price x Wild Population*
n	1625	1625
r	0,60	0,53
r^2	0,36	0,28
Standard Error	1,09	0,33
Y-intercept	-0,7056	2,8321
Slope	2,0776	-0,2293
F-value	909,71	617,55
T-Statistic: Intercept	-4,9642	82,8088
T-Statistic: X Variable	30,1614	-24,8505
P-Value	< 0.00001	< 0.00001

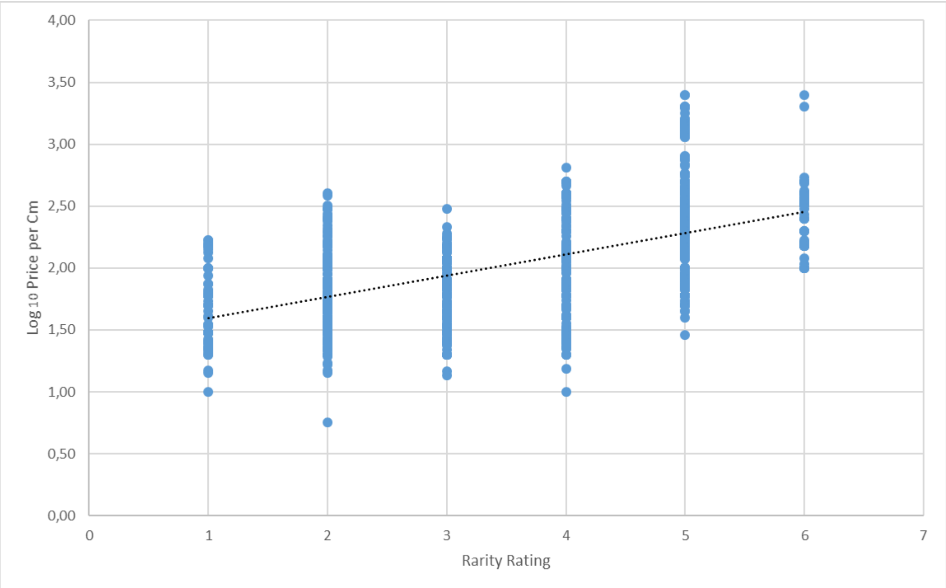

Figure 8. Linear regression results for price x rarity.

Where '1' represents the status 'least concern' and '6' represents the status 'extinct in the wild'.

The linear regression equation for assumption 1 is Y = -0,7056 + 2.0776x. The regression has a correlation coefficient (r) of 0,60. This illustrates a positive relationship between price and rarity, which is in line with assumption 1. The coefficient of determination (r^2) for assumption 1 suggests 64% of the variation in the price is due to other factors. The regression was tested for significance and was found to be significant at $p < 0.05$. As stated in Section 4.2, "if assumption 1 is satisfied we will assume assumption 2 has also been fulfilled".

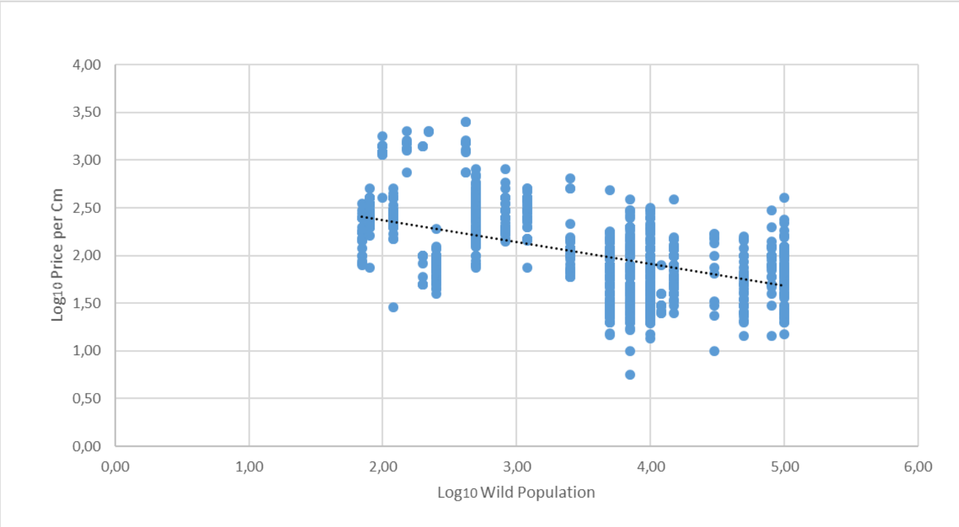

Figure 9. Linear regression results for price x wild population.

The second linear regression run to test the assumptions of the AAE, contributes towards the understanding of the demand side of the market. Figure 9 does not include the status 'Extinct in the Wild' as assumption 2 speaks to wild populations and *E. woodii, E. nubimontanus* and *E. brevifoliolatus* no longer have individuals in the wild. The regression equation is Y = 2,8321 – 0,2293x. The regression has a correlation coefficient (r) of 0.53. This illustrates a moderate negative relationship between price and the wild population. This indicates that smaller populations (which are perceived to be rarer) fetch a higher price. The coefficient of determination (r^2) suggests 72% of the variation in the price is due to other factors. The regression was tested for significance and was found to be significant at $p < 0.05$.

Although assumption 1 has been met for the year 2010 and indicates that an AAE exists in wild populations in South Africa, there is not enough data to fully support this. An area for future research is to conduct this analysis once a new census has been completed and additional information is available for a multitude of years.

5.4. SYNOPSIS

The conceptual model drawn in this chapter addresses the illegal trade of cycads with a specific look at illegal trade where an intermediary is involved. The objectives, attribution, resources and timeframes are addressed for the Strategy and Action Plan. The Strategy and Action Plan has appropriate methods in place to address demand and supply in the market, however, it is not possible to determine the successfulness of the Strategy and Action Plan. We can conclude that the plan is much needed to help curb the decline of wild populations. The linear regressions run suggest an AAE trend does exist for the year 2010. Due to lack of data, an AAE cannot definitely be confirmed. However, due to three species now being extinct in the wild in combination with the results of 2010, and the drive collectors have for rare cycads, we can assume, in this instance, that an AAE exists. The existence of an AAE is an issue which needs to be addressed urgently in order to avoid cycads going extinct in the wild.

The next chapter will firstly discuss the legislation for cycads. The second section will discuss, with recommendations, areas for future research, followed by the thesis's conclusion.

CHAPTER 6
DISCUSSION, RECOMMENDATIONS FOR FUTURE RESEARCH AND CONCLUSION

6.1. INTODUCTION

The following chapter is divided into three sections. The first section will recap the purpose of the study, the second section aims to analyse the successfulness of the Strategy and Action Plan for the Management of Cycad in South Africa. The third section reviews the research limitations for the analytical procedure and provides recommendations for future research. The last section will conclude the study.

6.2. PURPOSE OF THIS STUDY

This study aimed to determine the effect of illegal trade of cycads in South Africa through investigating why populations are dwindling with the current conservation policies in place. It explored whether or not illegal cycad trade has induced an AAE in *Encephalartos* cycad populations in South Africa. The results indicated that for the year 2010, an AAE trend existed for cycads in South Africa. This implies that the illegal market is largely driven by cycad collectors, who themselves are driven by the rarity and status of the plant – the more rare the cycad is perceived to be the greater the demand, higher the price and greater the incentive to poach from the wild. This suggests that the rarity status needs to be considered when designing and implementing conservation policies.

The study also reviewed a recent policy establish for the protection of cycads in South Africa - the Strategy and Action Plan for the Management of Cycads in South Africa. A number of activities were suggested (Table 5) for the effective achievement of the six main objective of the Strategy and Action plan.

6.3. ANALYSIS OF THE SUCCESSFULNESS OF THE STRATEGY AND ACTION PLAN FOR THE MANAGEMENT OF CYCADS IN SOUTH AFRICA

It is difficult to comment on the effectiveness of the Strategy and Action Plan in curbing illegal harvesting and trading of cycads as no new census has been conducted by the IUCN since

2010. There is no new evidence to indicate what impact the plan has had on wild cycad populations and the market for illegal trade. However, it is possible to review the Strategy and Action Plan's objectives and the activities in place to achieve these objectives. This section will focus on some of the activities highlighted to achieve the six objectives and compare these to other similar policies in foreign countries and South Africa. The lessons learnt will be highlighted from this analysis and recommendations put forward for the Strategy and Action Plan.

The Strategy and Action Plan was critiqued according to the six objectives listed in Table 5. A number of activities, with various deadlines, have been highlighted to help achieve these objectives.

Table 5. Table highlighting the various activities to be completed in order to achieve the six objectives of the Strategy and Action Plan (DEA, 2016).

Objective		**Activities**
1	Security	a. Source funding and equipment b. Identify all species and prioritize their populations for marking c. Create a database of marked populations d. Develop processes and procedures for marking e. Create a stable isotope map for cycad populations f. Increase security at priority sites g. Improve law enforcement
2	Population Management	a. Identify viable populations and create a metapopulation management strategy b. Identify and engage with collectors who own priority species c. Identify targets for population sizes for priority species d. Improve and implement Biodiversity Management Plans e. Identify key population management interventions and implement
3	Habitat Management	a. Classify and map critical cycad habitat b. Classify and list the properties of wild cycads c. Categorize cycad habitats as potential stewardship sites d. Identify areas for introduction or reintroduction e. Recognize programmes aimed at increasing reproductive success of cycads
4	Sustainable Use	a. Create gene banks for cycads b. Promote legal trade of propagated individuals c. Identify economic incentives for land owners and communities to protect wild populations and stewardship opportunities.

Objective		Activities
		d. Identify partnerships for propagation programmes for critically endangered and endangered species e. Develop and implement a conservation management strategy in the National Botanical Gardens
5	Communication, Education and Public Awareness	a. Design and roll out a national cycad communication plan b. Create and conduct training on cycad identification for law enforcement officials
6	Research	a. Identify gaps of implementation and enforcement of legislation b. Develop scientific methods for distinguishing between wild and propagated plants c. Develop a method for identifying *ex situ* plants that have been harvested from the wild d. Research new technologies and their potential application in wildlife trade

It is important to note that the objectives highlighted in Section 6.2 must be implemented inclusively and not individually due to the crossover and dependency in activities.

6.3.1. Security

The Security strategic objective of the Strategy and Action Plan aims to prevent the illegal harvesting of wild cycads to avoid the detrimental influences on the sustainability of wild populations (DEA, 2016).

Activity 1a requires that adequate funding be sourced in order to procure equipment, such as microdots, chips, GPS and scanners, which will be used to mark cycads in the wild by 2020. Activities 1b, 1c and 1d refer to the identification of species for marking, the prioritization of the species, the creation of the database where this data is to be stored and the development of the marking procedure.

Microchips are used to prevent the illegal trade of cycads, but with little success as they are easily detectable using metal detectors (Donaldson, 2008). Microchips are argued to be useful for monitoring plant populations; the DEA has procured improved unique microchips, which will be used to mark priority wild *Encephalartos* populations (DEA, 2017). In addition, pilot studies are to be conducted on marking wild plants with microdots. These discs contain unique information linked to the *Encephalartos* species and habitat and have a laser-etched code, which can be stored on the national verification database (DEA, 2017). While there is little research on the successfulness of using microchips and microdots in conservation, microchips have been widely used for domestic animals, such as dogs, for identification purposes. In the case of cycads it might be useful to mark wild plants to monitor their location in the wild; however it is not an effective method of deterring poachers. Microchips can also be used to mark cycads in private collections for data collecting purposes.

Activity 1e refers to the creation of isotope maps. The use of stable isotopes and carbon dating is currently being piloted in an *Encephalartos* species investigation. The next phase of this investigation will be to develop a database for all wild *Encephalartos* populations to be used in future investigations and prosecutions (DEA, 2017). The use of isotope maps has been used successfully to curb illegal trade of ivory from elephants in Africa (Universität Mainz, 2010). The African elephant is listed on CITES Appendix I (except for populations in Botswana, Namibia, South Africa and Zimbabwe), prohibiting the trade of ivory; however, illegal trade has continued to grow (Ziegler *et al.,* 2012). A project conducted an analysis of isotope profiles on samples of known geographical areas in Africa to determine the origin of confiscated ivory pieces. A database is being developed which allows for the identification of the origin of ivory (Universität Mainz, 2010). Another project conducted by Ziegler *et al.* (2012) built on previous studies in order to identify the origin of ivory and determine smuggling routes. Although there is a positive outlook for the use of stable isotopes in future, currently they are not valuable in court due to underdevelopment (Torgersen, 2017).

Increasing security at priority sites (activity 1g), such as the National Botanical Gardens, by installing surveillance equipment and fencing, may help curb theft (DEA, 2017). The National Botanical Gardens have faced various theft incidents. In August 2014, 24 cycads were stolen from the Kirstenbosch National Botanical Gardens in Cape Town; 22 of these cycads are listed as critically endangered (Smith, 2014). Botanical Gardens are used as areas for propagation and conservation of plants (Gundu and Adia, 2014) and attract many tourists annually (Department of Tourism, 2015), thus increasing security should be a high priority. Increasing security at priority sites is particular difficult, costly and requires a great deal of support, but can be highly effective. Nepal, for example, was able to achieve 365 days of zero poaching on two occasions: in 2011, zero rhinoceros' were poached and in 2013/2014 no rhinoceros', tigers and elephants were poached due to an improvement of security (WWF, 2015b). This success was largely attributed to rangers, the Nepal Army and community anti-poaching patrols and sniffer dogs that were deployed to national parks to assist park staff (WWF, 2015b).

The last activity listed in the Security objective is the improvement of law enforcement. In an article written by Smith (2014), Professor John Donaldson said, “In contrast to the rhinos and elephants where there’s been a lot of investment in trying to understand the network and where it’s going, we know far less about the poaching of plants.” This is a significant challenge for law enforcement. The collection, trade and possession without a permit is prohibited in South Africa (Driver, 2014). The export and domestic sale of artificially propagated specimens is allowed, which is aimed at reducing demand for wild cycads (Driver, 2014). However, due to a shortage of propagated plants this method is outweighed by the demand for wild cycads (CITES, 2003). To prevent this, Turkey implemented a ‘wild population quota system’ that allows for and regulates the harvesting and sale of wild tubers and bulbs (Robbins, 2000). This system has been effective in managing wild populations and is argued to be highly effective for plant conservation (Robbins, 2000).

6.3.2. Sustainable Use, Population and Habitat Management

The population strategic objective aims to secure a minimum viable population size for endemic cycad species (DEA, 2016). Although wild cycad populations are decreasing, there is estimated to be over one million cycads in private collections (Donaldson *et al.,* 2003), which could provide and secure a minimum viable population size to prevent species from going extinct.

The activities surrounding objective two are largely based on identifying viable populations, priority species and targets, as well as implementing the BMPs and other interventions (DEA, 2016). Johannesburg is believed to be a large hub for illegally collected plants (Torgersen, 2017). And is therefore a good place to initiate an awareness campaign aimed at private collectors. The awareness campaign should engage with collectors to improve their knowledge and understanding of the cycad poaching problem and the various challenges around protecting wild populations. This will hopefully encourage them to only purchase legal cycads and to report any illegal activity. In addition, the campaign should establish a species list and database of the various species owned by private collectors and done so with complete anonymity so collectors can share their collections without the fear of prosecution. Such a database of “private populations” can be used by conservation agencies to purchase seeds or individual plants for rehabilitation or propagation programmes. The campaign must not be limited to private collections but also be extended to auctions and nurseries.

The habitat management objective aims to protect and manage habitat for wild cycad populations (DEA, 2016). Cycads grow extremely slowly and take a long time to reach reproductive maturity (Retief, 2013). This presents a temporal challenge in determining the effectiveness of the Strategy and Action Plan. Measuring differences in wild populations may not necessarily reflect a reduction in illegal harvesting as a result of the policy because new wild populations have not had a chance to establish and grow yet.

Robbins’ cinquefoil was the first plant species to be removed from the Endangered Species List due to conservation efforts (Framingham, 2013). Robbins’ cinquefoil wild populations had decreased substantially by the 1990s due to illegal harvesting by collectors and hikers and by 1996, it was classified as endangered (New England Wild Flower Society, 2018).
In an effort to prevent the extinction of Robbins’ cinquefoil the New England Wild Flower Society collected seeds for propagation and reintroduction back into the wild. The White Mountain National Forest and the Appalachian Mountain Club, on the other hand, started stewardship and enforcement programmes (Framingham, 2013). These programmes were aimed at educating visitors and physically protect the species by rerouting hiking trails (New England Wild Flower Society, 2018). This is a great example of how population and habitat policy has been implemented and successfully saved a species.

The sustainable use objective aims to promote and ensure the sustainable use and trade of cycads (DEA, 2016). Due to the significant poaching problem (as illustrated in Figure 4), policy aimed at incorporating local communities and stewardship programmes, including prorogation programmes, for example, are of vital importance to prevent species extinction. Successful stewardship programmes also have a number of socio-economic benefits and often provide rural communities with alternative livelihood opportunities.

A good example of where a community has been actively involved in the preservation of a species, is in Mexico. In order to address the issues of illegal trade and habitat destruction, authorities in Mexico started a propagation programme in 1990 for the cycad, *Dioon edule* (Vovides *et al.,* 2010). Cycad producers and villages were able sell plants they propagated along with other forest products, as such 80 hectares of cycad habitat conserved was conserved and it provided the community with an alternative source if income (Vovides *et al.,* 2010). This project is relatively effective due to the small nature of the nurseries and relatively small financial requirements to keep them in operation (Vovides *et al.,* 2010). These lessons from Mexico suggest small scale cycad farming would be more successful in South Africa rather than large scale commercial farming.

Establishing such a project in South Africa would not only go a long way in the conservation of cycads, but provide various socio-economic benefits to participating communities as well. In addition to cycad management, these communities should be encouraged to harvest and sell alien invasive plants for biomaterial as an alternative fuel source. Not only does this reduce the impact of invasive plants on cycad and other indigenous plant populations but it provides additional sources of income to those communities and contributes to a more sustainable society.

Establishing such 'cycad stewardship' projects requires significant planning and policy and regulatory support, such as the establishment of biomaterial/alternative fuel markets. Determining the age at which a cycad should and can be reintroduced into the wild is another challenge. Vovides *et al.* (2010) planted 300 seedlings of various ages and monitored for 10 years to establish the best age at which they can be reintroduced. Cultivation training and resources are also needed.

6.3.3. Communication, Education, Public Awareness and Research

The communication, education and public awareness objective aims to generate and implement effective communication strategies in collaboration with all cycad related stakeholders.

The communication, education and awareness campaign on the white rhinoceros poaching problem is a good example to follow for cycad awareness raising (Mah, 2018). The white rhinoceros is threatened due to the poaching for their horns, which is largely driven by the traditional medicine market in Asia (Mah, 2018). Local awareness programmes have been rather successful and a large amount of financial support has been donated to conservation efforts (Save the Rhino, 2012). However, as we have no control over awareness in the Asian market, the demand for rhinoceros horn is still high. Similar media campaigns can and should be used in creating awareness around the cycad poaching problems. An alternative media campaign would be to, at concerts and events held at the National Botanical Gardens and/or zoos, have awareness drives at the entrance to educate the visitors coming in.

The research objective aims to improve conservation measures with scientific research into innovative solutions for reducing the illegal harvesting and trading of cycads in South Africa. (DEA, 2016). To improve conservation measures, it would be beneficial to investigate the feasibility of community based propagation programmes (as in place in Mexico) and cycad stewardship programmes. These programmes have the potential to increase wild populations, preventing extinction in the wild, and increase the supply of cycads for the legal market. Community based programmes also have a number of socio-economic benefits in addition to supporting and driving biodiversity protection.

6.4. RECOMENDATIONS FOR FUTURE RESEARCH

Considering the research limitations, discussed in Section 4.5.2, one can identify areas for future research. The results reported on the trend of an AAE is not complete, as the data considered came from only one year, 2010. In addition to a lack of population data, no data could be found on prices in various years. Therefore, an analysis to prove the existence of an AAE could be improved with additional population and price data. To prove an AAE in cycad populations, one could perhaps look at species, other than the *Encephalartos* genus, where data could possibly be available or wait until the next census has been conducted. By gathering more data on wild population numbers and prices, the methodology used in this study could provide more accurate results and thus improve our understanding the demand-side of the market.

A total of 634 cycads listed on the IUCN Red List, were confiscated between 2011 and 2016 in the Eastern Cape; this suggests that poachers are targeting rare species (Torgersen, 2017). However, rare cycads can be purchased from nurseries legally, which suggest that collectors are after something other than rarity, possibly the size of the plant. Due to the market being driven by rarity, it is difficult to predict the actions of collectors. Thus it may be beneficial to conduct research into what effects the prices of cycads apart from rarity, such as visual distinctions.

The AAE methodology used in this thesis can be applied to other endangered fauna and flora to understand the relationship between rarity and price within illegal markets. This may provide valuable information for conservationists and government agencies in creating policies, which target fauna and flora that are at the greatest risk of extinction.

6.5. CONCLUSION

Illegal wildlife trade is one of the largest illegal markets in the world and occurs for various reasons, such as for medicinal use, pets, collections and food. Yet there is little known on the magnitude of this trade. It also presents one of the most significant threats to biodiversity other than direct habitat destruction. Biodiversity, in turn, is vital for sustaining ecosystem services on which human well-being is built. Therefore, research into illegal wildlife trading and markets is imperative to for improving our understanding of these markets and the factors that drive them.

While a lot of global attention is given to illegal animal trade and poaching, such as tigers, lions, rhinoceros and elephants, far less attention is given to endangered plant species. Cycads are one of the oldest living plant families and also one of the most threatened (Rutherford *et al.,* 2013). In South Africa wild cycad populations are declining drastically and effective policy is urgently needed to prevent their extinction in the wild.

There are a number of successful conservation programmes from around the world with similar objectives to that of the Strategy and Action plan, and which provide important lessons for the South African context. Analysing these policies suggests the Strategy and Action plan can be successful in South Africa provided synergies between biodiversity benefits and human well-being benefits are maximised. The Strategy and Action Plan is well positioned to address the vast majority of identified issues; and should be successful provided sufficient resources are made available. There is, however, always room for improvement, which is likely to come from deeper investigation and research into improving our understanding of both the legal and illegal market for cycads, particularly on the demand side.

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APPENDIX A

Appendix A1: Table showing the change in rarity of individual Encephalartos Species' observed over the period 1998 – 2015 (IUCN, 2015).

Species	Year																	
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
E. cycadifolius	V	V	V	V	V	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
E. villosus	-	-	-	-	-	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
E. transvenosus	R	R	R	R	R	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC	LC
E. friderici-guilielmi	V	V	V	V	V	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. lanatus	R	R	R	R	R	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. natalensis	R	R	R	R	R	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. lehmannii	R	R	R	R	R	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. ferox	R	R	R	R	R	LC	LC	LC	LC	LC	LC	LC	NT	NT	NT	NT	NT	NT
E. caffer	V	V	V	V	V	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. longifolius	V	V	V	V	V	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT	NT
E. princeps	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. ngoyanus	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. ghellinckii	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. senticosus	-	-	-	-	-	V	V	V	V	V	V	V	V	V	V	V	V	V
E. humilis	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. paucidentatus	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. trispinosus	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. altensteinii	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V
E. arenarius	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
E. eugene-maraisii	V	V	V	V	V	E	E	E	E	E	E	E	E	E	E	E	E	E
E. horridus	V	V	V	V	V	E	E	E	E	E	E	E	E	E	E	E	E	E
E. lebomboensis	R	R	R	R	R	E	E	E	E	E	E	E	E	E	E	E	E	E
E. dolomiticus	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. dyerianus	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. heenanii	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. hirsutus	V	V	V	V	V	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE

Species	Year																	
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
E. inopinus	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE/ PE	CE/ PE	CE/ PE	CE/ PE	CE/ PE	CE /PE
E. laevifolius	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. middelburgensis	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. latifrons	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. msinganus	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. aemulans	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. cerinus	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE/ PE	CE/ PE	CE/ PE	CE/ PE	CE/ PE	CE/ PE
E. cupidus	E	E	E	E	E	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE	CE
E. nubimontanus	E	E	E	E	E	CE	CE	CE	EXW	EXW	EXW	EXW	EXW	EXW	EXW	EXW	EXW	EXW
E. woodii	EX	EX	EX	EX	EX	EX	EX	EX	EX	EX	EX	EX	EXW	EXW	EXW	EXW	EXW	EXW
E. brevifoliolatus	E	E	E	E	E	CE	CE	CE	EXW	EXW	EXW	EXW	EXW	EXW	EXW	EXW	EXW	EXW

Key

LC	Least Concern
R	Rare
NT	Near Threatened
V	Vulnerable
E	Endangered
CE	Critically Endangered
PE	Possibly Extinct in the Wild
EXW	Extinct in the Wild
EX	Extinct

Appendix A2: Table showing the average price per centimetre of individual Encephalartos Species' observed over the period 2005 – 2015.

Species	**Year**													
	2005		*2006*		*2007*		*2009*		*2010*		*2013*		*2015*	
	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*
E. cycadifolius	ND	ND	122,06	10	135,67	15	151,02	11	126,75	12	203,69	7	ND	ND
E. villosus	36,09	11	23,48	50	24,89	32	40,62	15	28,83	12	ND	ND	ND	ND
E. transvenosus	36,09	2	52,97	62	60,84	43	71,84	64	47,50	54	82,76	1	19,41	43
E. friderici-guilielmi	53,28	18	90,15	22	87,80	19	94,25	27	95,44	36	204,17	1	47,21	36
E. lanatus	80,40	5	72,26	23	66,93	15	92,79	20	79,44	13	75,67	5	47,21	24
E. natalensis	54,55	11	44,55	82	43,96	90	51,40	105	40,68	86	32,49	7	20,00	54
E. lehmannii	70,79	45	111,97	83	97,32	100	120,98	99	98,63	150	79,36	13	47,68	34
E. ferox	50,98	7	47,09	12	32,03	23	40,00	40	26,84	26	ND	ND	10,48	90
E. caffer	283,51	1	228,09	29	312,50	4	262,99	10	215,75	12	257,96	4	167,30	16
E. longifolius	57,55	1	82,32	62	76,12	70	116,97	66	84,28	103	98,06	6	34,83	34
E. princeps	97,65	26	83,20	54	86,31	23	118,69	41	104,11	36	99,89	16	77,11	11
E. ngoyanus	ND	ND	98,21	14	74,56	9	90,00	14	81,83	12	55,08	3	60,00	20
E. ghellinckii	134,41	3	96,93	24	94,96	19	132,77	26	130,38	19	117,32	6	150,00	2
E. senticosus	68,01	10	55,71	44	38,88	12	51,80	61	33,82	46	55,77	2	29,72	12
E. humilis	99,42	5	77,92	19	98,55	9	122,12	12	100,00	4	166,67	1	ND	ND
E. paucidentatus	138,29	3	67,94	14	72,62	22	87,78	33	78,82	31	110,26	4	41,58	15
E. trispinosus	75,66	9	83,74	58	68,37	84	83,27	100	83,97	114	57,45	11	47,18	28
E. altensteinii	67,46	5	59,17	57	52,61	45	84,81	53	54,86	49	39,70	14	25,17	45
E. arenarius	75,43	44	81,79	65	121,42	32	156,39	48	131,19	56	127,85	11	90,00	25
E. eugene-maraisii	252,02	32	226,33	31	260,57	27	323,37	42	292,79	48	225,91	16	195,91	47
E. horridus	78,01	13	100,90	87	113,90	83	146,91	87	140,84	119	92,41	13	99,65	28
E. lebomboensis	50,37	14	53,55	30	44,57	34	40,14	37	43,94	67	109,93	15	15,33	96
E. dolomiticus	513,44	3	652,85	9	1331,43	5	1510,00	10	1414,81	9	757,97	7	1600,00	4
E. dyerianus	570,19	4	512,31	12	463,06	9	542,38	26	331,38	49	327,81	11	158,74	24
E. heenanii	627,68	2	849,25	8	1076,92	6	1500,00	3	1509,29	10	983,85	6	1500,00	3
E. hirsutus	1026,50	2	1418,75	8	1309,52	4	2000,00	1	2613,10	4	3062,50	1	ND	ND
E. inopinus	164,44	8	174,74	53	265,00	5	362,11	19	280,21	34	304,59	9	317,91	19

Species	Year													
	2005		*2006*		*2007*		*2009*		*2010*		*2013*		*2015*	
	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*	AP (R)	*n*
E. laevifolius	439,32	4	165,85	41	264,99	21	312,47	35	369,12	55	314,47	15	515,48	42
E. middelburgensis	230,91	40	227,46	23	333,00	13	328,34	38	287,79	74	183,74	18	172,48	30
E. latifrons	520,34	3	851,73	46	1450,00	4	1290,91	11	1330,89	15	748,12	6	857,37	11
E. msinganus	113,01	2	68,70	3	67,45	18	86,88	16	87,55	17	64,29	1	37,50	10
E. aemulans	72,80	3	86,83	39	85,31	34	92,61	79	85,07	90	ND	ND	27,81	16
E. cerinus	171,59	5	190,67	29	267,08	8	248,74	16	182,08	27	110,10	5	51,79	20
E. cupidus	178,32	6	140,38	54	258,94	14	214,55	47	267,83	73	139,74	6	93,37	22
E. nubimontanus	206,11	31	231,88	46	194,80	29	345,49	52	299,34	61	244,07	18	128,56	36
E. woodii	ND	ND	ND	ND	500,00	1	500,00	1	500,00	1	1231,25	2	ND	ND
E. brevifoliolatus	ND	ND	1051,28	3	2000,00	1	4000,00	1	5250,00	3	1538,47	1	3750,00	10

Key

AP	Average Price per cm
n	Number of Auction Sales
ND	No Data

Appendix A3: Table showing the wild population size and population trend of individual Encephalartos Species' observed in 2010 (IUCN, 2015).

	2010	
Species	Population Size	Population Trend
E. cycadifolius	<30 000	Stable
E. villosus	100 000	Decreasing
E. transvenosus	50 000	Decreasing
E. friderici-guilielmi	10 000	Decreasing
E. lanatus	<80 000	Stable
E. natalensis	<12 000	Decreasing
E. lehmannii	<7 000	Decreasing
E. ferox	100 000	Decreasing
E. caffer	<10 000	Decreasing
E. longifolius	<15 000	Decreasing
E. princeps	5 000	Decreasing
E. ngoyanus	<5 000	Decreasing
E. ghellinckii	<10 000	Decreasing
E. senticosus	<10 000	Decreasing
E. humilis	<10 000	Decreasing
E. paucidentatus	<5 000	Decreasing
E. trispinosus	10 000	Decreasing
E. altensteinii	<10 000	Decreasing
E. arenarius	<2 500	Decreasing
E. eugene-maraisii	<1 200	Decreasing
E. horridus	<7 000	Decreasing
E. lebomboensis	5 000	Decreasing
E. dolomiticus	151	Decreasing
E. dyerianus	<500	Decreasing
E. heenanii	420	Decreasing
E. hirsutus	<219	Decreasing
E. inopinus	80	Decreasing
E. laevifolius	<820	Decreasing
E. middelburgensis	120	Decreasing
E. latifrons	<100	Decreasing
E. msinganus	<200	Decreasing
E. aemulans	<250	Decreasing
E. cerinus	<70	Decreasing
E. cupidus	<500	Decreasing
E. nubimontanus	0	N/A
E. woodii	0	N/A
E. brevifoliolatus	0	N/A

APPENDIX B

Appendix B1: Table showing the average change in auction prices between 2006 and 2010.

Species	2006 (R)					2010 (R)					Change in AP (R)
	n	AP	Min	Max	σ²	n	AP	Min	Max	σ²	
E. ferox	12	47,09	10,29	100,00	29,98	26	26,84	15,00	40,00	5,06	-20,25
E. inopinus	53	174,74	61,54	312,50	63,44	34	280,21	75,00	500,00	89,71	105,47
E. cerinus	29	190,67	100,00	375,00	65,81	27	182,08	75,00	350,00	70,09	-8,59
E. woodii	ND	ND	-	-	-	1	500,00	500,00	500,00	-	500,00
E. cycadifolius	10	122,06	62,50	225,00	42,10	12	126,75	60,00	166,67	40,40	4,69
E. villosus	50	23,48	5,71	44,06	10,54	12	28,83	10,00	34,62	6,61	5,35
E. transvenosus	62	52,97	21,43	105,00	20,51	54	47,50	14,29	150,00	28,12	-5,47
E. friderici-guilielmi	22	90,15	34,38	228,57	46,89	36	95,44	14,29	300,00	48,81	5,29
E. lanatus	23	72,26	27,27	184,00	34,25	13	79,44	25,00	300,00	72,84	7,18
E. natalensis	82	44,55	10,59	106,38	17,09	86	40,68	5,63	262,50	29,17	-3,87
E. lehmannii	83	111,97	40,74	281,82	50,13	150	98,63	20,00	400,00	42,37	-13,34
E. caffer	29	228,09	144,44	366,67	66,22	12	215,75	100,00	319,00	71,10	-12,34
E. longifolius	62	82,32	18,00	225,81	39,51	103	84,28	25,00	385,71	44,15	1,96
E. princeps	54	83,20	34,72	181,82	23,81	36	104,11	14,76	180,00	40,32	20,91
E. ngoyanus	14	98,21	56,67	164,29	30,49	12	81,83	50,00	173,75	34,49	-16,38
E. ghellinckii	24	96,93	44,64	201,92	42,37	19	130,38	59,09	300,00	52,04	33,45
E. senticosus	44	55,71	10,00	128,57	27,82	46	33,82	20,00	54,05	9,38	-21,89
E. humilis	19	77,92	37,50	150,00	34,37	4	100,00	100,00	100,00	0	22,08
E. paucidentatus	14	67,94	32,69	136,90	30,80	31	78,82	34,29	120,00	20,04	10,88
E. trispinosus	58	83,74	36,00	566,67	67,72	114	83,97	25,00	150,00	20,08	0,23
E. altensteinii	57	59,17	16,67	163,64	30,42	49	54,86	13,64	189,47	32,02	-4,31
E. arenarius	65	81,79	35,29	200,00	31,65	56	131,19	60,00	648,15	105,59	49,40
E. eugene-maraisii	31	226,33	125,00	490,00	102,79	48	292,79	75,00	500,00	94,25	66,46
E. horridus	87	100,90	36,00	193,18	34,00	119	140,84	10,00	386,79	46,47	39,94

Species	2006 (R)					2010 (R)					Change in AP (R)
	n	AP	Min	Max	σ²	n	AP	Min	Max	σ²	
E. lebomboensis	30	53,55	8,75	94,74	22,82	67	43,94	15,38	480,00	57,73	-9,61
E. dolomiticus	9	652,85	350,00	800,00	155,46	9	1414,81	750,00	2000,00	333,07	761,96
E. dyerianus	12	512,31	216,67	909,09	219,82	49	331,38	150,00	692,31	105,29	-180,93
E. heenanii	8	849,25	295,45	1333,33	311,81	10	1509,29	750,00	2500,00	602,91	660,04
E. hirsutus	8	1418,75	800,00	2100,00	525,27	4	2613,10	1952,38	4500,00	1258,14	1194,35
E. laevifolius	41	165,85	28,57	514,71	114,17	55	369,12	140,00	5000,00	645,86	203,27
E. middelburgensis	23	227,46	100,00	512,20	116,03	74	287,79	150,00	500,00	63,04	60,33
E. latifrons	46	851,73	210,53	1627,91	266,28	15	1330,89	1142,86	1785,71	160,10	479,16
E. msinganus	3	68,70	61,11	75,00	7,03	17	87,55	50,00	125,00	25,33	18,85
E. aemulans	39	86,83	31,25	275,00	53,73	90	85,07	40,00	151,79	19,37	-1,76
E. cupidus	54	140,38	42,31	276,47	63,10	73	267,83	80,00	3025,11	354,70	127,45
E. nubimontanus	46	231,88	55,00	645,83	143,64	61	299,34	100,00	541,67	127,27	67,46
E. brevifoliolatus	3	1051,28	1000,00	1153,85	88,82	5	2250,00	2000,00	11250,00	5202,16	1198,72

Key

AP	Average Price per cm
σ²	Standard Deviation
n	Number of Auction Sales
ND	No Data

Appendix B2: Table showing the change in rarity status of Encephalartos species and the average change in auction prices between 2006 and 2010.

Species	**IUCN Status**	
	2006	**2010**
E. ferox	LC	NT
E. inopinus	CE	CE/PE
E. cerinus	CE	CE/PE
E. woodii	EX	EXW
E. cycadifolius	LC	LC
E. villosus	LC	LC
E. transvenosus	LC	LC
E. friderici-guilielmi	NT	NT
E. lanatus	NT	NT
E. natalensis	NT	NT
E. lehmannii	NT	NT
E. caffer	NT	NT
E. longifolius	NT	NT
E. princeps	V	V
E. ngoyanus	V	V
E. ghellinckii	V	V
E. senticosus	V	V
E. humilis	V	V
E. paucidentatus	V	V
E. trispinosus	V	V
E. altensteinii	V	V
E. arenarius	E	E
E. eugene-maraisii	E	E
E. horridus	E	E
E. lebomboensis	E	E
E. dolomiticus	CE	CE
E. dyerianus	CE	CE
E. heenanii	CE	CE
E. hirsutus	CE	CE
E. laevifolius	CE	CE
E. middelburgensis	CE	CE
E. latifrons	CE	CE
E. msinganus	CE	CE
E. aemulans	CE	CE
E. cupidus	CE	CE
E. nubimontanus	EXW	EXW
E. brevifoliolatus	EXW	EXW

Key	
LC	Least Concern
R	Rare
NT	Near Threatened
V	Vulnerable
E	Endangered
CE	Critically Endangered
PE	Possibly Extinct
EXW	Extinct in the wild
EX	Extinct
I	Improved in Status
D	Deteriorated in Status
N	No change in Status