ANALYZING THE ANTHROPOGENIC ALLEE EFFECT IN CYCAD (*ENCEPHALARTOS* SPECIES) POPULATIONS IN SOUTH AFRICA

Sasha Earle[1] and Gavin Fraser[2]

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, which are among the world's most threatened plant species; also declining in South Africa at a rapid pace, with threat of extinction in the wild. Although economic theory assumes that the exploitation of a species is unlikely to result in extinction, 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.

1. Introduction

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

[1] Master's Student, Department of Economics and Economic History, Rhodes University, Grahamstown, South Africa
[2] Professor, Department of Economics and Economic History, Rhodes University, Grahamstown, South Africa

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). 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 largely 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, as one of the most environmentally diverse countries in the world (Driver, 2014) make 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 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 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.

The primary research goal is to determine the economic effect of illegal cycad (*Encephalartos* species) trade in South Africa. More specifically to explore whether 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. The investigation of 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 will determine the possible effects of consumer preferences for perceived rarity.

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). 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).

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. 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):

$$G(x) = rx(k - x) \quad (1)$$

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).

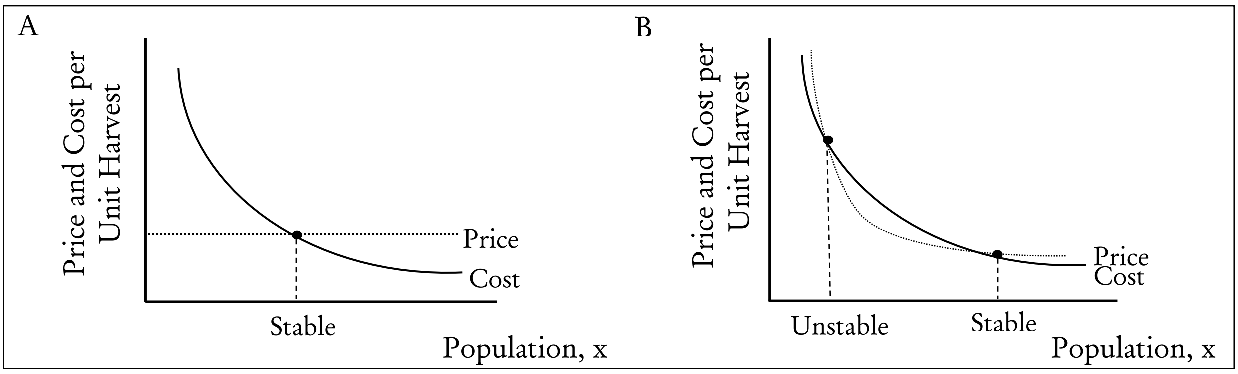

Figure 1. Illustration of an Anthropogenic Allee Effect of an Exploited Species.
Source: Courchamp et al. (2006)

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.

3. 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.

3.1. 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.

3.1.1. 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.

3.1.2. 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.

3.2. 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.

3.2.1. 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 $X_1, X_2, \ldots, X_n$ 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 range and n the sample size.

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

3.3.2. 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. EMPIRICAL RESULTS

This chapter presents 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. This is followed by the results of the linear regressions run in order to determine whether an AAE exists within the Encephalartos species in South Africa.

4.1. 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.

4.2 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.

4.3 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

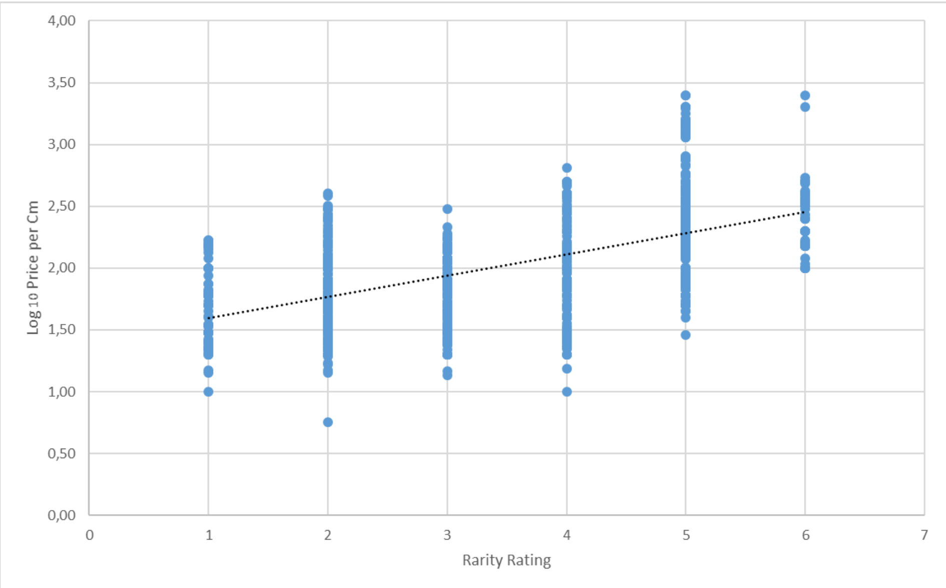

Figure 8. Linear regression results for price x rarity.
Where '1' represents the status 'least concern' and '6' represents the status 'extinct in the wild'.

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".

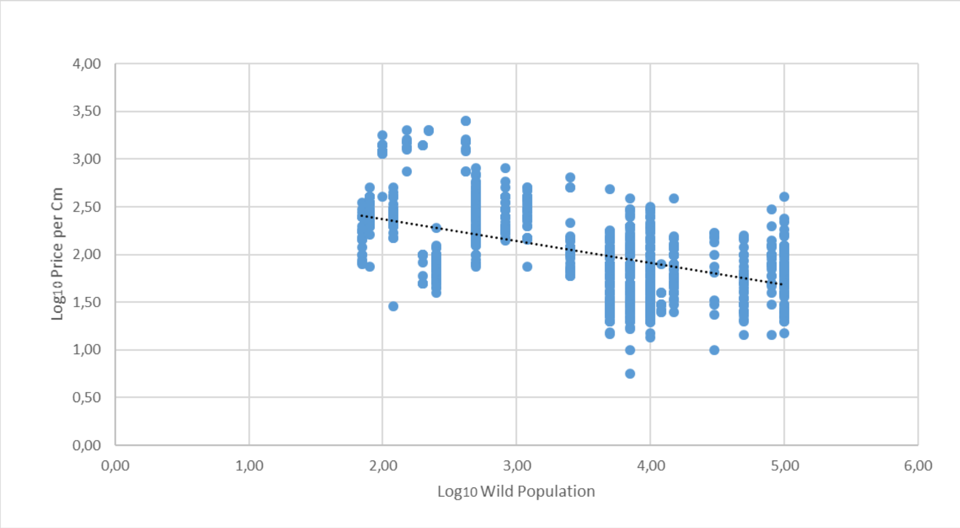

Figure 9. Linear regression results for price x wild population.

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. 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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