Distribution, population structure and threats of an endangered cycad-*Encephalartos sclavoi* in Tanzania

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Abstract

Despite their ecological, socio-economical and historical importance, cycad plants are increasingly recognized to decrease in abundance, distributional range and to undergo species extinction due to habitat change, loss and over utilization by man. Thus, control of habitat degradation and over utilization is fundamental to restore and preserve the remaining cycads. However, this requires understanding of spatial distribution pattern and population structure trends particularly for species with limited recruitment, small population and threatened such as cycad. Therefore, I surveyed 25 randomly selected plots of 5-m radius each and collected information on location, life stage, sex, occurrence, number of cones and human disturbance variables to investigate the pattern of spatial distribution, population structure and threats of critically endangered cycad (*Encephalartos sclavoi*) in and around Magamba Nature Reserve, Lushoto, Tanzania. I further compared field work results and previously published reports to get better understanding of population trends of *E. sclavoi*. Data were analyzed in R and QGIS programmes. Results show that *E. sclavoi* is found in Gologolo and Sungwi as opposed to previous reports which showed that the species was found only in Gologolo. There is also less population of matured plants than previously reported (i.e. ~50), suggesting that the population is decreasing at the Gologolo site. Sungwi had more seedling, sapling and adult individuals than Gologolo site. At both sites, fire was observed to be the major current threat to the sustenance of *E. sclavoi*. Current increase in human disturbance should be discouraged to restore and conserve *E. sclavoi* in and around Magamba Nature Reserve, Lushoto, Tanzania.

Keywords: Usambara; Nature Reserve; Eastern Arc Mountains; Cycad; Human disturbance; Habitat change

Introduction

Cycads are important plants as they provide immense environmental goods and services including atmospheric nitrogen fixation, cultural and religious benefits and medicinal value. They are a source of income in form of horticultural crops in many parts of the world. Cycads represent revolutionary history as they are the most ancient group of oldest living seed plants. Thus, even though they compose only a small group, they attract a disproportionate interest to scientists and general public. However, despite their unique importance to the environment, society and history they are considered to be the most threatened group of organisms facing a growing threat of extinction. For example, a recent empirical study on status of 308 cycads shows that up to 63% of all cycads are threatened in South Africa (Donaldson 2008). This calls for systematic studies and holistic approach to restore and preserve cycads.

It is known that the majority of cycads do occur in subtropical and tropical regions of the world. In these regions, fragmentation and loss of forests is a major threat to global plant biodiversity. Moreover, experience shows also that many of the species in tropical forests may disappear before they are identified, studied and documented (Gentry 1992). Individual species of many cycad plants show very limited distribution. This may however be a reflection of the paucity of regular field surveys, monitoring and documentation particularly in Africa. Studies on spatial distribution and population structure of cycads are still few compared to studies on tree species in tropical ecosystems. However, if such studies are carried out do facilitate setting baseline information for future monitoring work,

establishment of population trends and forging specific conservation efforts on the target sites.

The study species *Encephalartos sclavoi* (hereafter referred to *E. sclavoi*) grows in the West Usambara Forests of the Eastern Arc Mountains in Tanzania. It was first discovered in 1998 and when the last assessment was done (in 2009) it was reported that there were only limited population size and narrow distribution range (less than 50 matured plants and at only one site) and therefore the species was declared critically endangered (IUCN 2017). In the same year, it was also reported that the species was declining in population and was threatened by habitat degradation and change.

Knowledge on distribution, trends of population structure and threats are important to effectively develop mitigation strategies of plant extinction and restore degraded habitats. The overall objective of this study was therefore to generate current information on distribution, population structure and update previous information e.g. like those documented by IUCN in 2009 for improved conservation and management of the species in the Eastern Arc Mountains. I specifically (i) mapped the abundance and spatial distribution of *E. sclavoi* in and around the Magamba Nature Reserve, (ii) determined an estimate of population size of *E. sclavoi* in different life stages (i.e. seedling, sapling and adult) and (iii) assessed human disturbance threatening *E. sclavoi* populations in and around Magamba. Since most cycads in *Encephalartos* genera occur in many different habitats, I predicted that *E. sclavoi* would be found in other sites not previously documented in the West Usambaras. It is anticipated that information generated will facilitate monitoring of population trends and development of concerted effort to restore and preserve *E. sclavoi* for sustainable forest management.

Materials and methods

Study area

This study was conducted in and around Magamba Nature Reserve, Lushoto District, Tanga Region, Tanzania. Magamba Nature Reserve is located between 4°40'S and 38°15'E (Fig. 1). It is the largest among the 14 forest reserves in Lushoto District that lies within the Eastern Arc Mountains. The nature reserve is within the elevation range of 900 – 2250 m.a.s.l. The mountains cover an area of 4 500 km^2, which is 90% of the total area of Lushoto district (Msuya and Kideghesho 2009).

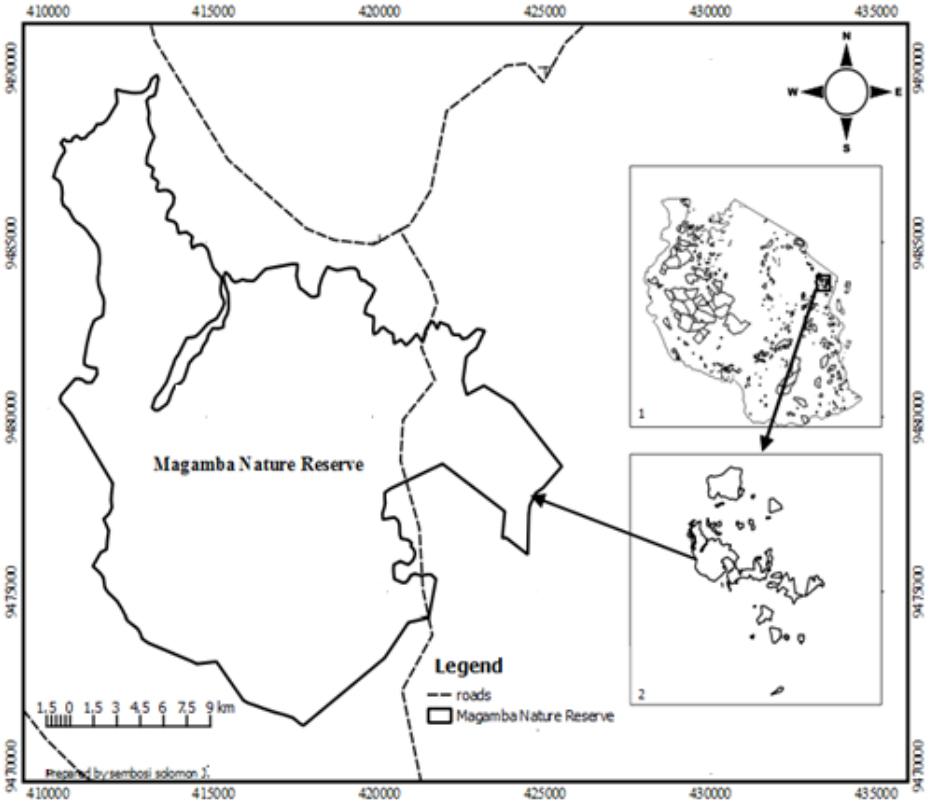

Figure 1: Map of the study area in and around Magamba Nature Reserve, Lushoto, Tanzania

Geologically, Magamba Nature Reserve lies within the basement blocks of the Usambara Mountains. These blocks are believed to have been comparatively stable for more than 20 million years and they consist of complex series of ancient metamorphic rocks (Wiersum 1985). The soils are predominantly loams with inconsistent amounts of sand and color that vary from red through gray-brown to black with a pH value ranging between 3.5 and 8.5 (Andrew and Sembosi 2017). The cool conditions prevail throughout much of the year, with temperatures ranging between 15°C and 21°C from June to September. Temperature ranges between 25°C and 30°C during the hot season (October–December). Mean annual rainfall is 1,200 mm, with long rains from mid-March to May and short rains between October and December.

The reserve comprises sub-montane and upper montane forests, wetter than those of the Pare Mountains further west. Wet montane forests are dominated by camphor (*Ocotea usambarensis*), with some podo (*Podocarpus usambarensis* and *P. pensiculy*), and have dense undergrowth of *Lansthus cirumilee* and other shrubs. Associated species include *Ficalhoa, Pygium, Rapanea, Fagaropsis* and *Cassipourea*. Dry montane forest occurs in the northern and western portions of Shume and consists mainly of cedar (*Juniperus procera),* with a thick shrub understorey of *Fuclea, Teclea* and *Catha* species (Msuya and Kideghesho). Other vegetation types include grasslands and shrublands, with heather and *Philippia* sp. Endemic plant species restricted in their distribution to this area include *E. sclavoi*.

Focal species

E. sclavoi is an endemic species found in and around Magamba Nature Reserve, West Usambara, Tanzania. *E. sclavoi* also known as Sclavo's Cycad is a very distinctive medium-to-large sized arborescent species that can form a well-developed aerial trunk up to 1 m tall and 35 cm diameter. The most distinguishing feature for this species is its very thick broad leaflets and yellow stalked cones (short stalks in the pollen cones). The broad leathery leaflets, with their strongly revolute margins and downward overlapping arrangement make it easily identifiable even in the absence of cones. It is considered to be one of the most distinctive and handsome Cycads. The species occurs on restricted areas that offer best conditions for growth and reproduction. These areas are all found in high elevations and the Cycad is able to survive in xeric conditions (low rainfall, harsh winds and dry soils) so long as the minimum suitable conditions are met.

Data collection

Ecological survey was conducted in 2017 to assess the abundance, spatial distribution, population structure and threats of *E. sclavoi* in and around Magamba Nature Reserve. Before the actual survey, participatory reconnaissance survey in and around Magamba Nature Reserve was intensively done to obtain all potential sites with *E. sclavoi* in addition to already known site (i.e. Gologolo). A second site i.e. Sungwi was discovered to have populations of *E. sclavoi*. A purposeful study design was therefore adopted whereby areas with *E. sclavoi* were used for plot establishment and survey was made to capture data (on distribution, structure and threats) in the two sites i.e. Sungwi and Gologolo. A total of 25 sample plots of 5 m radius each were used to collect data on life stages (seedling, sapling and adult), sex, occurrence, number of cones and human disturbance threatening *E. sclavoi*. Both

male and female cones on this species tend to be yellow to yellow green colour but female cones are bigger in size and vigour compared to male ones. So the identification of sex used the size of cones. There were however some individuals whom their sexes were not identified during the survey but were recorded and reported separately without mixing with the rest of the Cycad data. To determine human disturbance, I used the presence of burnt *E. sclavoi*, agricultural fields and forest clear-felled areas for settlement. In each sample plot, Global Positioning System (GPS) coordinates were taken by use of handheld GPS (Gamin CSx) for understanding distribution of *E. sclavoi* and to enable future monitoring of the species in the occurrence sites.

Data analysis

Data was summarized in MS excel computer program while R (R Development Core Team 2017) was used in data analysis. Descriptive statistics were used to determine mean population density of *E. sclavoi* by life stages and sex. The frequency of *E. sclavoi* cones and human disturbance was computed using MS excel. One-way analysis of variance (ANOVA) at 5% level of significance was used to compute differences in mean population density of *E. sclavoi* in R. Quantum Geographical Information System (QGIS) version 2.6.1 was used to generate distribution map of *E. sclavoi* in and around Magamba Nature Reserve.

Results

Distribution and population density of *E. sclavoi*

The *E. sclavoi* populations were observed at 2 sites (i.e. Sungwi and Gologolo) in and around Magamba Nature Reserve. There were more patches of *E. sclavoi* at Sungwi compared to few patches of *E. sclavoi* at Gologolo site (Fig. 2). There was 474 and 19 total number of *E. sclavoi* individuals at Sungwi and Gologolo sites respectively. The mean number of *E.*

sclavoi seedlings, saplings and adults were 20.31±4.06 (mean±SE), 16.41±3.28 and 8.67±1.73 per hectare (ha) in and around Magamba Nature Reserve, respectively. There was no any seedling recorded at Gologolo (Fig. 3). There were few numbers of saplings (9) and adults (10) in Gologolo compared to Sungwi area (Fig. 3). On the other hand, Sungwi site had 138, 200 and 136 seedlings, saplings and adults respectively.

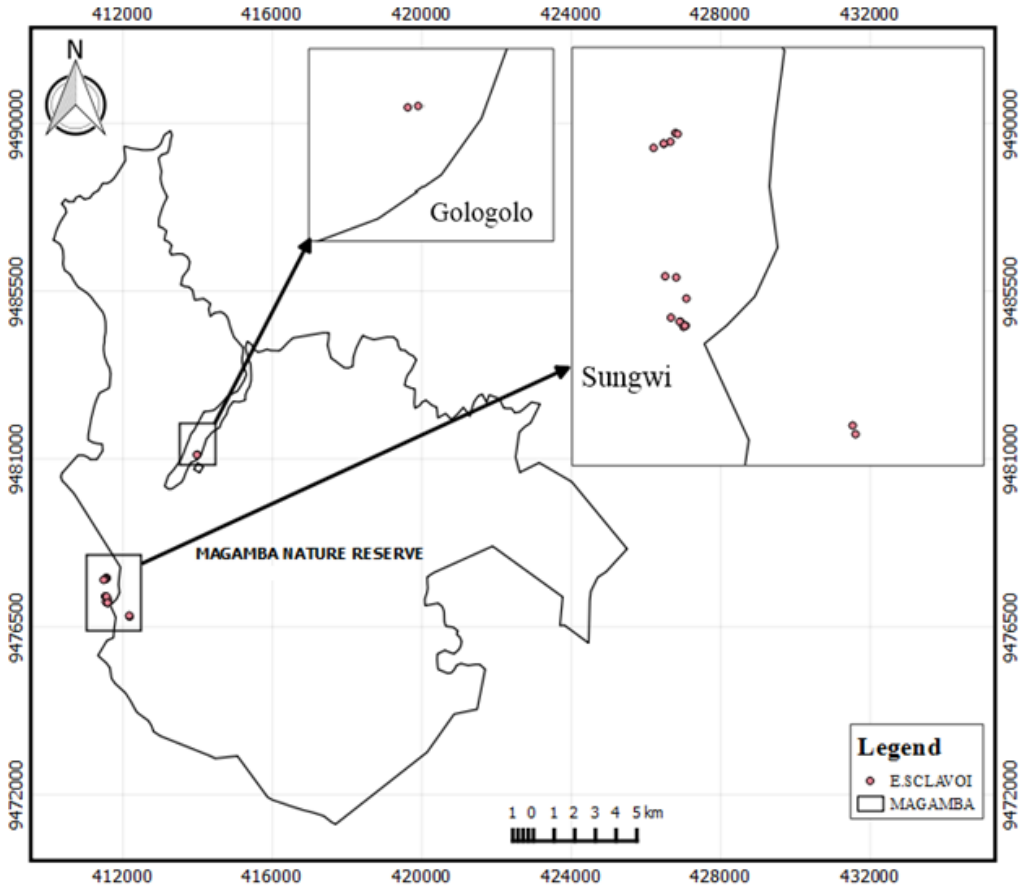

Figure 2: Distribution of *E. sclavoi* individuals in and around Magamba Nature Reserve, Lushoto, Tanzania

Overall, this study found high mean number of female *E. sclavoi* individuals (15.74±2.14) compared to male ones (8.48±1.75) at the two sites. There were also a certain number of individuals of *E. sclavoi* of which their sex was not identified but the density was 8.70±4.24

per ha at the two sites. Results showed that the mean abundance of saplings was relatively higher than for adults and seedlings (Fig. 3) though their differences were not statistically significant (F= 0.23, P=0.787) at the two sites.

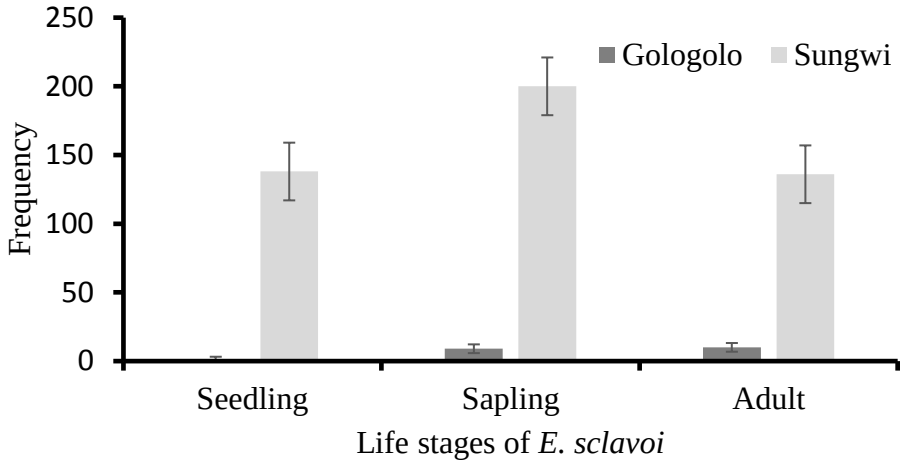

Figure 3: Number of *E. sclavoi* individuals in and around Magamba Nature Reserve, Lushoto, Tanzania

Number of cones of *E. sclavoi* and human disturbance

The lowest and highest number of cones recorded per individual was 0 and 3 for female *E. sclavoi.* It was found that 57.14% of females had 1 cone, 24.49% 2 cones and 18.37% 3 cones. On the other hand, the number of cones ranged between 0 and 1 for male *E. sclavoi* in and around Magamba. Human disturbance within sample plots were observed in this study. This study found that 88% of all observed *E. sclavoi* were disturbed and 12% were in good condition. There were three (3) human disturbance types recorded in the field where fire damage was found to be the most frequent disturbance on *E. sclavoi* and accounted for

51.46% followed by agricultural fields with 27.19% and forest cleared areas for human settlement with 21.35%.

Discussion

Against previous reports, this study is reporting for the first time the presence of *E. sclavoi* at two sites (i.e. Sungwi and Gologolo). All previous studies (see e.g. Eastern Arc Mountains & Coastal Forests CEPF Plant Assessment and Donaldson J.S. 2010) reported *E. sclavoi* to be present only at Gologolo on the West Usambara Mountains. In this study, there were more individuals of *E. sclavoi* at Sungwi as compared to Gologolo. The presence of more individuals at Sungwi than at Gologolo might be because of differences in ecological conditions between the two sites. Sungwi site appear to have a moderate and well balanced supply of moisture compared to Gologolo site thus favouring establishment and development of *E. sclavoi* populations (Donaldson 2008). The other reason for more abundance of *E. sclavoi* at Sungwi than at Gologolo could be that there are more threats at Gologolo compared to Sungwi as a consequence of intensified human activities. Fire and forest clearance for agriculture and settlement establishment have been reported previously in Gologolo (Eastern Arc Mountains & Coastal Forests CEPF Plant Assessment Project and Donaldson J.S. 2010) which reduce the abundance of the species.

Previous survey done in 2009 showed that the population was very small with probably less than 50 adult plants of *E. sclavoi* that had remained at Gologolo. This study has revealed that presently there is no a single seedling, there are only 9 saplings and 10 remaining adults at this site. This shows clearly that the population of *E. sclavoi* is decreasing at a great pace at Gologolo. As indicated above, both natural and man-made fire might be responsible for the absence of seedlings as fire destroys seeds and seedlings. It is also possible that seed

predation is taking place at Gologolo. It has been reported that seed predation is common in *Encephalartos* species where weevils can destroy up to 90% of all the seeds (Donaldson 1993). In addition, due to the changes in climatic conditions particularly in recent times where there are prolonged dry seasons in most parts of the country, it is also possible that seeds undergo additional mortality due to desiccation at Gologolo. In a study involving modelling of *Encephalartos* species, it was reported that survival of populations depends strongly on the number of reproductive adult plants hence removal of adult plants would result in population decline (Raimondo and Donaldson 2003).

In this study, the mean number of *E. sclavoi* adults per ha was less than for seedlings and saplings depicting a reverse J-shaped pattern common in natural forests where stem densities decrease with increasing diameter. This is in line with other studies elsewhere in the world (e.g. Donaldson 2003; 2008) which report that most of *Encephalartos* species in mesic environments have high number of seedlings and saplings and small number of matured plants. The plausible reasons for this pattern are mortality, over harvesting and fire. In a normal setting, not all seedlings will survive to reach maturity due to mortality. The lack of adult plants may also be due to harvesting of such trees for other uses including firewood and timber as evidenced by stumps in the studied sites. Fire may also be a factor for fewer adults as few seedlings may survive to reach mature size.

There were a high mean number of female *E. sclavoi* individuals compared to males (sex ratio of 2:1) in and around Magamba Nature Reserve. This is contrary to other studies on small populations of *Encephalartos* species where there is a strong male biased sex ratio (1:4) (Grobbelaar et al. 1989). The reasons for the observed ratio in this study are likely therefore due to higher natural mortality in males and selective harvesting of male plants at

Lushoto (Eastern Arc Mountains & Coastal Forests CEPF Plant Assessment Project and Donaldson J.S. 2010). It is also possible that most or all of the few *E. sclavoi* individuals whose sex could not be identified in the field are males thus leading to higher numbers of *E. sclavoi* females than males.

Most of the study plots were disturbed to a greater extent and the disturbances are related to human activities. It is known that most the changes in land use and land cover observed across the globe are caused by uncontrolled harvesting of forest products and utilization of services and agricultural expansion (Andrew et al. 2004, Araya 2014). The two study sites are well known to be potential for agriculture and human settlement development and due to population increase; human activities have been intensified in the area in recent times. A recent study by Andrew and Sembosi (2017) on spatial and temporal dynamics of land use and land cover in and around Magamba Nature Reserve Tanzania showed that there have been significant changes of land use during the period 1995-2015. These changes are caused by the intensified pressure on land for agriculture and human settlement. Fire is also used in traditional land preparation and therefore impacts negatively important habitats for *E. sclavoi*.

Conclusion and recommendation

Cycad plants including *E. sclavoi* are increasingly recognized to provide ecological, socio-economical and historical benefits worldwide. However, they are currently threatened by human activities which if not controlled may jeopardize the provision of important benefits they offer. This study sought to investigate the distribution, population structure and threats of *E. sclavoi* in and around Magamba Nature Reserve in West Usambara Mountains,

Tanzania. Indeed this study reports for the first time the presence of *E. sclavoi* on the second site i.e. Sungwi. This is a big achievement in terms of research and protection efforts guidance particularly considering the current population trends worldwide where *Encephalartos* species are increasingly threatened. The new discovered site i.e. Sungwi has abundant and stable population structure (inverse J-shaped distribution) of *E. sclavoi* while the known site i.e. Gologolo has remained with only few sapling and adult plants. Understanding the distribution, population structure and threats is a key step towards effective restoration of *E. sclavoi* and management of nature reserves. Overall, the population of *E. sclavoi* seems to be small and threatened by ongoing human activities through fire, agriculture and forest clearance. Gologolo site is of particular concern, as it appears to be the most negatively impacted by human pressure. Monitoring and effective management of the E. *sclavoi* populations in the Usambara Mountains is therefore strongly recommended.

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