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Population structure of the Cycad along River Mpanga, Western Uganda

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ABSTRACT
Cycads are listed in the International Union for Conservation of Nature Red list of threatened plants. Cycad species *Encephalartos whitelockii* (P.J.H. Hurter) exist in a forest gorge along River Mpanga in western Uganda where human population is rapidly rising and land use practices are dynamically changing. This study examined the population structure of *E.whitelockii* specifically focusing on assessing the population structure and regeneration capacity of *E.whitelockii* and the relative abundance and diversity of indigenous tree species associated with *E.whitelockii*. Stratified random sampling was used to collect ecological data in 33 transects and 165 sample plots covering a total area of 16.5 ha. The results show that the population of *E.whitlockii* consisted of more juveniles than adults. The *E.whitelockii* was most abundant on the lower hill slopes and grew closely to *Combrettum molle* and *Acacia hockii*. In order to conserve the species it is recommended that the entire habitat of *E.whitelockii* should be gazetted into a protected area and on-farm conservation, propagation and ecotourism should be encouraged among the frontline communities. Further research should be conducted on the phenology and reproductive biology of *E.whitelockii*. The local communities should develop bye laws on land use practices aimed at protecting Cycads from seed poachers.

Keywords: Cycads, endangered species, Mpanga forest gorge, population structure, Western Uganda

RÉSUMÉ
Les cycadées sont répertoriées sur la liste rouge des plantes menacées de l'Union internationale pour la conservation de la nature. L'espèce Encephalartos whitelockii (P.J.H. Hurter) est rencontrée dans un habitat forestier le long de la rivière Mpanga, dans l'ouest de l'Ouganda, où la population humaine augmente rapidement et les pratiques d'utilisation des terres changent de façon dynamique. Cette étude a examiné la structure des populations de E.whitelockii en se focalisant spécifiquement sur l'évaluation de la structure de la population et de la capacité de régénération de l'espèce et sur l'abondance relative et la diversité des espèces associées dans son habitat. Un échantillonnage aléatoire stratifié a été utilisé pour mesurer des données écologiques à travers 33 transects et 165 parcelles d'échantillonnage couvrant une superficie totale de 16,5 ha. Les résultats montrent que la population de E.whitlockii était composée de plus de juvéniles que d'adultes. L'espèce est plus abondante sur les pentes de collines et est associée aux espèces comme Combrettum molle et Acacia hockii. Afin de conserver l'espèce, il est recommandé que l'habitat entier de E.whitelockii soit érigé en zone protégée et que la conservation, la propagation et l'écotourisme soient encouragés. Des recherches supplémentaires devraient être menées sur la phénologie et la biologie de la reproduction de E.whitelockii. Les communautés locales devraient élaborer des lois sur les pratiques d'utilisation des terres visant à protéger les Cycadées.

Mots-clés: Cycadées, espèces menacées, forêt de Mpanga, structure de la population, Ouest Ouganda

BACKGROUND

Worldwide, utilization of wild plant resources is recognized as an important economic activity (High and Shackleton, 2000). In Tropical Africa, 21% of plant resources are used by humankind for various purposes (PROTA, 2004). The absence of accurate data on plant species utilized and for what purposes raises fear on their population status in the wild (FAO, 1997). This is because remnants of natural ecosystems exists as small patches surrounded by intensive land use (Bennett, 1998) and much of the biodiversity exists outside protected areas (WWF and IUCN, 1994) where they are threatened by human activities (Rocheleau *et al.,* 1988).

In Uganda, it has been reported that about 30 species of vascular plants including the cycads (*Encephalartos whitelockii*) are endemic (WCMP, 1992). The *E. whitelockii* is highly restricted in distribution and are of conservation concern due to habitat alteration and excessive seed harvesting for ornamental purposes (WWF and IUCN, 1994). Due to its occurrence in highly restricted and degraded habitats (Cristina, 2007), little information is available on the population status of Cycads all over the world. Thus, understanding its population ecology could also provide information about its unique occurrence in the biodiversity hotspots (Plumptre *et al.,* 2003).

The occurrence of Cycad populations outside protected areas where land use practices are not regulated exposes them to various threats such as wildfires, intensive grazing, farming as well as unregulated utilization. These activities have inevitably affected the regeneration, abundance and distribution of the cycads in western Uganda. With persistent illegal seed collection, stem cutting, land clearance for farming and wildfires, the status of cycad populations is not known with consequential conservation challenges. The absence of readily available and published information on the population distribution and human utilization status limits action by local people and the government to protect cycads in their threatened habitats. This study examined the population structure of *E. whitelockii*, specifically focusing on regeneration capacity, distribution and abundance and association with other species along River Mpanga in Western Uganda.

LITERATURE SUMMARY

Cycads are a group of ligneous plants bearing superficial resemblance to palms, although they are not related (Stein, 2004). They belong to the order Cycadophyta which comprise three families: Cycadaceae, Stangeriaceae, and Zamiaceae (Hill, 2004b). Cycads are believed to have reached their highest point of diversity and evolution in the Triassic and Jurasic periods (about 600 million years ago) and since then the population has been declining at an unknown rate. Fossil records show that they existed before the breakup of the ancient landmass of Pangea (Donaldson, 2003). Approximately 185 species in 11 genera are now extinct due to human activities as well as ecological changes (Brian, 2004). All cycads are dioecious (have separate male and female parts) and depend on beetles, weevils and small bees to transfer their pollen grains from male to female parts. Therefore, their regeneration and dispersal is highly dependent on the existence of pollinating agents (Donaldson, 2003). The genus Zamiaceae is the most abundant with nine genera of which Encephalartos is the most abundant in tropical Africa with over 60 species, 30 of them in South Africa alone (Jose, 2004).

Two species (*E. whitelockii* and *E. equatorialis*) occur in Uganda along River Mpanga and on the shores of Lake Victoria, respectively (Hill, 2004c). According to Stevenson *et al.* (2003) there are about 5,000 to 10,000 cycads of the species *E. whitelockii* in Uganda. In western Uganda, *E. whitelockii* exists in a habitat corridor linking the tropical forest along Mpanga River gorge to the savanna grasslands of Queen Elizabeth National Park (QENP) (Kingdon, 1990). Cycads are found within the northern section of QENP and southern parts of KNP (Plumptre *et al.,* 2003). The area of QENP includes a small section of the Mpanga River gorge, leaving more than 90 % of the cycad population on public land (NEMA, 2004). Cycads are found in the grassland -tropical forest mosaic along the River Mpanga gorge, exposing them to pressure from agriculture and human settlement.

In Uganda, Cycad seeds are important sources of carbohydrates for primates and humans, while the leaves are useful for roofing materials (Katende *et al.,* 1995). Cycads are also popular among gardeners and landscapers as ornamentals, an aspect that promotes trade in this group of plants. Cycads are thus under intense pressure from illegal seed collectors which threatens their regeneration and long term population sustainability (Katende *et al.,* 1995). This is exacerbated by the fact that Cycads have low reproductive capacities with long juvenile periods and produce cones infrequently (Donaldson, 2003).

Whereas several species of Encephalartos are insect pollinated, many of the known pollinators are associated with one or a few cycad species (Donaldson, 2003). Surveys of cycad pollinating insects in South Africa, Zimbabwe, Zanzibar and Kenya indicated that many of the pollinators are extinct due to wild fires, leading to low seed production in the cycad populations (Donaldson, 2003). Moreover, cycad seeds take long to germinate, with seedlings experiencing high mortality rates due to fire thereby lowering the population further (Raimondo and Donaldson, 2002). In Australia, the frequent occurrence of fires, especially in the dry seasons has negatively affected regeneration of cycads (Hill, 2004c). Being dioceous, unequal sex ratios among cycads is one of the factors that negatively affect recruitment hence long term population sustainability (Donaldson 2003, Raimondo 2002).

Cycads in Uganda exist as a small highly localized population, which could in future be driven into extinction by unregulated land use practices. In most cases, extinction arises when deterministic events bring the population down to a size where stochastic events such as fires, overgrazing, and farming are influential (Given, 1994). According to Caswell (1989), population size distributions provide useful approach for assessing demographic characteristics of species and different life stages of the population. Population size distribution may also assist in the classification and management of plant communities (Hutchings, 1991), they may also be classified as a basis for land use planning (Oostermeijer *et al.,* 1994) or designation of conservation areas (Ceballos, 1996). Accordingly, assessment of baseline conditions is crucial for conservation planning since it forms a basis for zoning areas under risk (Ceballos, 1996).

STUDY DESCRIPTION

The study was conducted in Ntarama and Rwenshama villages in Kamwenge District of western Uganda (Fig.1). Kamwenge District is located in southwestern Uganda between 30º 15’ - 30º 30’ E and latitude 0º 30’ - 0º 15’ N. Part of Kamwenge District is found within the Albertine rift system (Plumptre *et al.,* 2004) and has numerous aquatic and woodland systems of high conservation importance. The Albertine rift encompasses natural habitats from the northern tip of Lake Albert to the southern tip of Lake Tanganyika. It stretches 100 km on either side of the international border of the Democratic Republic of Congo (DRC). Protected areas such as Queen Elizabeth National Park (QENP), Kibale National Park (KNP) and Katonga Wildlife Reserve are within this rift.

Study design and data collection. A stratified random sampling approach was used to collect data from a total area of 210 ha inhabited by Cycads. Stratified random sampling is deemed appropriate for estimating populations that are rare and localized (Krebs, 1989). The Cycads occur in a limited range, therefore this approach was found to be appropriate for the study. Using a topographical map, the study area was divided into 11 blocks of about 21 ha each, which represents about 10 % of the total area under cycads. Three transects were established in the lower (900 - 1000 meters above sea level), middle (1000 - 1100 meters above sea level) and upper (1100 - 1200 meters above sea level) slopes of each of the 11 blocks making 33 transects. In order to eliminate bias, all transects were laid to start from the same vertical alignment. Each transect had a maximum length of 500 m. On each transect, five plots measuring 50 m x 20 m (0.1 ha) were laid out on alternate sides giving a total sampled area per transect of 0.5 ha. Each plot was further divided into

Fig .1. Cycad plant

five equal sections (strips) of 10 m x 10 m, from which ecological data was collected. Therefore, the total area sampled per block was 1.5 ha, giving the total sampled area of 16.5 ha. This represents 79 % of the total area under cycads. Hence, a sampling intensity of 7.8 % was achieved.

RESEARCH FINDINGS AND APPLICATION

Age class structure of E. whitelocki. The age class structure of *E. whitelockii* showed that there were more juveniles than adults. The proportion of seedlings (700/ha) and saplings (680/ha) were higher than mature trees (250/ha) and poles (80/ha) respectively (Fig. 2).

The fact that there were more juveniles than mature cycads suggests that the population of *E. whitelockii* is disturbed. While studying the response of *Encephalartos villosis* to different harvesting and fire regimes in South Africa, Raimondo and Donaldson (2002) found that the population had more seedlings than mature individuals. They concluded that the high number of juveniles in the population was a result of mortality of mature individuals of *E. villosis* due to human activities (Raimondo and Donaldson, 2002). This is supported by Hutchings' (1997) observation that spatial pattern of recruitment and the modification of this pattern by mortality factors influence distribution of plants.

It is probable that a mortality causing factor was responsible for the observed age class structure of *E. whitelockii* which does not clearly follow the expected reverse –J curve. A report by Williams and Lorea (2009) indicates that land clearance can influence dispersion, regeneration as well

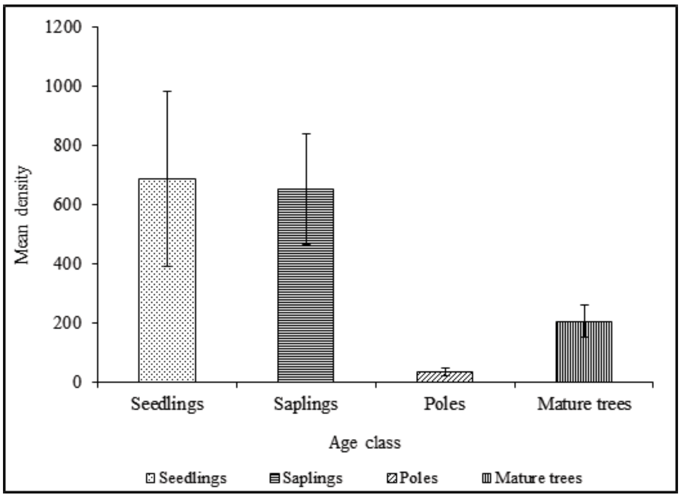

Figure 2: Age class structure of *E. whitelockii*

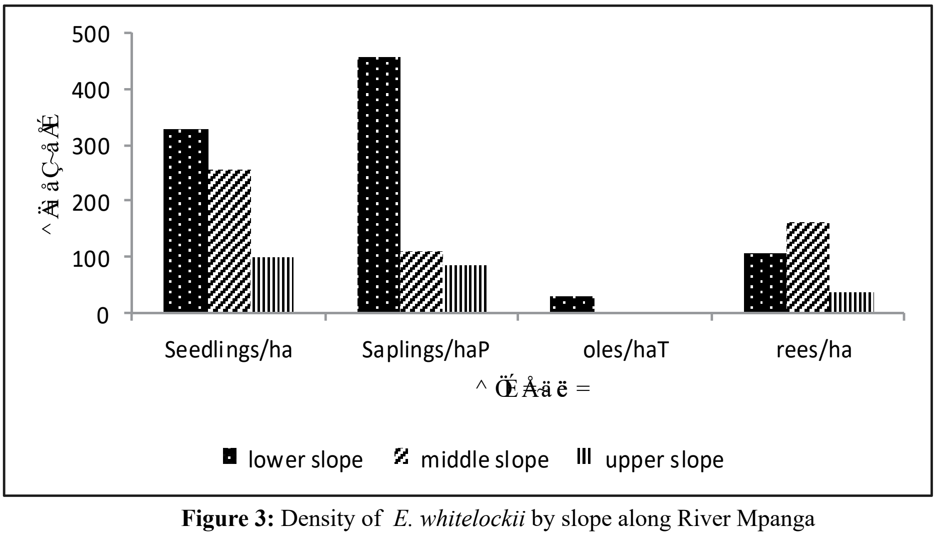

Figure 3: Density of *E. whitelockii* by slope along River Mpanga

as over 90 % of mortality in plant populations. Coupled with the fact that cycads have long juvenile periods (Donaldson, 2003), the observed age class structure could therefore be a result of intrinsic and environmental factors such as nutrient availability, moisture and aspect (Greig, 1983). According to Katende *et al.* (1995), seed collection and land degradation have threatened cycads population and limited its regeneration in Uganda. This raises the fear that the cycads could become extinct in future.

Abundance of *E. whitelockii* by slope position. The population density of *E. whitelockii* changed with slope. On the lower slope, there were more saplings and seedlings than mature trees and poles. On the middle slope, more seedlings were recorded, followed by trees and saplings respectively. On the upper slope, there were more seedlings, and saplings than poles and mature cycads per hectare respectively (Fig. 3).

The variation of density with slope may be attributed to factors such as niche partitioning, moisture availability, presence of organic matter as well as human activity. Most cycads were observed in crop gardens close to the forest edge thus raising concern that farming may have influenced the patterns of abundance of *E. whitelockii* in sections of the study area. A study of diversity of several dry land species in a hilly area of Costa Rica and Nicaragua found that fires, cultivation and grazing influences nutrient availability and hence species diversity (Williams and Lorea, 2009). Similarly in this study the diversity of *E. whitelockii* seedlings and saplings was found to be high on the lower slope. This slope had not been exposed to fires, cultivation and grazing which could have influenced the regeneration of *E. whitelockii.*

A report by Greig (1983) shows that environmental factors such as soil moisture, aspect and elevation can influence germination of seeds within a niche hence, impacting on species richness and diversity. Therefore, the observed difference in abundance with slope positions could be attributed to external factors such as aspect and soil moisture. Under this circumstance, understanding land use practices would be a measure to guide the designation of appropriate community-based conservation programs for tree resources such as cycad (Reisch and Poschlod, 2003).

Species closely associated with *E. whitelockii*. Two tree species (*Combretum molle* and *Grewia mollis)* were the most closely associated with *E. whitelockii* indicating they have preference for similar habitat requirements (Fig. 4). It is likely that the observed relationship between *E. whitelockii* and other indigenous woody species was due to preference for similar environmental conditions or because the existence of one species enhanced the others (Moore and Chapman, 1986). Association is favored when two or more species respond to a similar

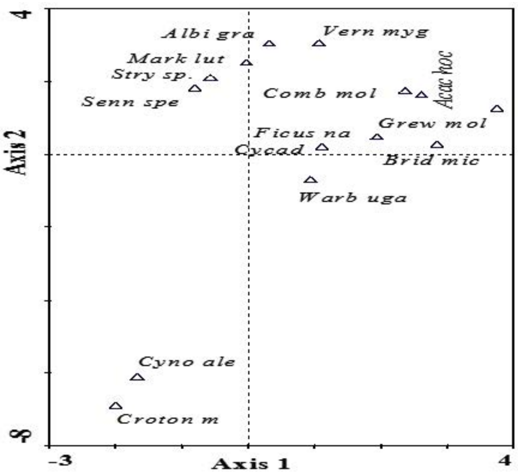

Figure 4: Detrended Correspondence Analysis (DCA) plot of species abundances without down weighting rare species showing species association. The plot shows absence and presence of cycads along the environmental gradient. It also shows species that adapt to similar environmental conditions like cycads. Key: Croton m: *Croton mycophylla*, Cyno ale: *Cynometra alexandri*, Warbugia: *Warbugia ugandensis*, Brid mic: *Bredelia micrantha*, Cycad: *E. whitelockii*, Ficus na: *Ficus natalensis*, Grew mol: *Grewia mollis*, Comb mol: *Combrettum molle*, Acac hoc: *Acacia hockii*, Vern myg: *Vernonia amagydlina*, Mark lut: *Markhamia lutea*, Stry sp: *Strepnus species*, Senn spec: *Senna spectabilis*

combination of environmental factors (Moore and Chapman, 1986). In the present case, *Combrettum molle, Grewia mollis* and *Acacia hockii* whose regeneration was closely associated with that of *E. whitelockii* appear to require similar environmental conditions. It is therefore highly likely that where *Combrettum molle, Grewia molli*s and *Acacia hockii* are found, then cycad is likely to occur.

According to Donaldson (2003), cycads usually grow in a wide range of habitats including tropical forest, riverine areas, savanna grasslands, high altitude forests and rocky landscapes. This implies that the close association of *E. whitelockii* with the savanna grassland species such as *Combrettum molle, Grewia mollis* and *Acacia hockii,* may be a result of rangeland management practices including bush burning which can influence soil chemical properties as well as vegetation resilience, succession and dominance. This view is supported by Bennet (1998) who observed that the flow of energy, materials and nutrients are central to the performance of a landscape and its ecological setting including species association.

RECOMMENDATION

This study has shown that the population of *E. whitelockii* is unbalanced. Therefore, it is recommended that the habitat of *E. whitelockii* should be turned into a nature reserve to promote *in-situ* conservation of *E. whitelockii*. Community-based conservation programs targeting seed collectors, cattle keepers, farmers and the district staff (both political and technical) should be developed and implemented by all stakeholders. The Local Government should develop and enforce bye-laws on land use practices aimed at protecting cycads. Bio-rights programs such as on-farm conservation, propagation and eco-tourism need to be encouraged among the local community in the area. Further studies are needed on micro-catchment conditions, phenology of *E. whitelockii* as well as the social system of communities so as to increase the knowledge base on the species and attract support and funding for its conservation.

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STATEMENT OF NO CONFLICT OF INTEREST

The author of this paper hereby declares that there are no competing interests in this publication.

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