

Soil Factors That Influence the Abundance and Distribution of Threatened and Endangered Species in the Okavango Delta; with Particular Emphasis on *Eulophia angolensis*

Sandra K. Middleton¹, Kelebogile B. Mfundisi^{2*}, Naidu Kurugundla³

¹Environmental Sciences Department, University of Botswana, Gaborone, Botswana

²Okavango Research Institute, University of Botswana, Maun, Botswana

³Department of Water Affairs, Maun, Botswana

Email: *kmfundisi@ori.ub.bw, *kmfundisi@daad-alumni.de

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Abstract

Eulophia angolensis is an endangered plant species found in the Okavango Delta. Generally, there is lack of botanical information on this species in Botswana, which is necessary for its *in-situ* and *ex-situ* conservation. The objectives of this research are to map areas where *E. angolensis* occurs, determine the species that co-exist with it, and establish soil factors that influence its abundance and distribution in the Okavango Delta. A survey of the area where the plant was sighted in 2004 was carried out using recorded GPS points. Soil samples were collected at 0 - 20 cm depth from the floodplain where the species occurred to determine the macronutrients: total nitrogen, phosphorus, potassium (N, P, and K) and soil organic carbon (SOC) contents. The researchers could not find the plant at all GPS locations where the plant was sighted in 2004, but discovered a new unrecorded site for the species. The species was very close to the water channel; approximately 40 cm away, with only one plant about 60 cm away. The mean macronutrients concentrations in the site that contained *E. angolensis* were total N = 2.61 ± 0.61 mg/L, P = 7.02 ± 0.8 mg/L and K = 14.41 ± 4.28 mg/L. SOC concentration was 40.1 ± 10.28 mg/L. Furthermore, there was K biogeochemical gradient within the *E. angolensis* habitat, with more concentrations directly around the plant. Therefore, *E. angolensis* needs critical amounts of N, P, K and SOC, with K, SOC and water requirement being the crucial factors. Frequent monitoring of the endangered species found in the Okavango Delta is required, and *ex-situ* conservation of the species in the country in the form of a bo-

*Corresponding author.

anical garden should be established for future generations.

Keywords

***Eulophia angolensis*, Okavango Delta, Soil Macronutrients, Soil Organic Carbon (SOC), Endangered Species**

1. Introduction

Factors shown to influence wetland species composition and relative abundance include flooding regime, plant life history requirements, water and soil chemistry, species interactions and disturbance by physical processes or animals [1]. Plants constitute a basic feature of the land, contributing to its overall integrity, value and diversity. The ability of each species to become established and persist under existing environmental conditions is one of the major controls of plant diversity. In a given locality, organisms interact with the physical environment and each other as they compete for the building block for growth and reproduction, which are water, nutrients and energy [2]. Wetland ecosystems are amongst the most diverse ecosystems in terms of plant communities. Different species adapt to different conditions and plant populations are affected by a large variety of factors. Wetland plants are amongst the most adapted plants both physiologically and morphologically [3].

There are plant nutrients that have positive bearing on plant growth. Chemical analysis of plants shows that carbon, hydrogen, oxygen and nitrogen are the major constituents, with potassium, calcium, magnesium, phosphorus and sulphur also present in appreciable quantities [4]. Of all these essential elements, nitrogen, potassium and phosphorus are the most likely to limit plant productivity [5]. The nutrient elements necessary for plant growth are absorbed by the roots from the growing medium. The soil is involved as it is the natural growing medium in which the root systems develop, and the fertility of the soil is linked with this association.

At the moment several species are considered to be endangered around the world. An endangered species is a population of an organism which is at risk of becoming extinct because it is either few in numbers, or threatened by changing environmental or predation parameters [6]. Preventing the extinction of species is a top conservation priority because, once lost, species are gone forever.

Humans induce pressure and variation in natural environments and can threaten the integrity of certain plant species. The best strategy for conservation of endemic species is to keep them in their natural habitat as free as possible from any form of abnormal (human related) disturbance, such as grazing by livestock, suppression of wildfires, tourism, water extraction, atmospheric deposition of nitrogen and perhaps the most importantly the invasion of exotic species [7].

The Okavango Delta in Northern Botswana is one of the natural ecosystems which house several rare, threatened and endangered species. In a recent study by [8], 20 threatened and endangered plant species are found in the Okavango Delta. Of the 20 plants identified using the International Union for the Conservation of Nature (IUCN) Red Data List criteria [9], only two species were categorized as endangered. One of the two endangered plant species in the Okavango Delta is *Eulophia angolensis*. It is found along the Moanachira, Okavango and Maboroga Rivers. *E. angolensis* is a terrestrial herb, it is found in swampy grassland, stream banks and seasonally flooded plains, often with sedges and long grasses. Plant Resources of Tropical Africa (PROTA) [10] lists the species as having medicinal use, but it does not specify the medicinal use of this particular species. Generally, there is lack of botanical information on this species in Botswana, which is necessary for its *in-situ* and *ex-situ* conservation. Additionally, no sites were recorded between 2004 and 2006 on occurrence of the species. Therefore, the objectives of this research are to map areas where *E. angolensis* occurs, determine the species that co-exist with it, and establish soil factors that influence its abundance and distribution in the Okavango Delta.

2. Methodology

2.1. Study Area

The study was conducted some kilometers from Xakanaka in Moremi Game Reserve, Okavango Delta (Figure 1).



Figure 1. Location of the study area showing the sites where *E. angolensis* occurred.

2.2. Data Collection

2.2.1. Survey and Mapping

The GPS coordinates from the Peter Smith maps and Department of Water Affairs in Maun, Botswana were used to help locate *E. angolensis* in the Okavango Delta. A survey of the area where the plant was sighted in 2004 was carried out to locate the species habitat. Observations were also made for potential identification of new sites for the species, which were recorded and stored using a GPS.

2.2.2. Vegetation Survey

Line transects were used for vegetation survey of the area covering recorded GPS points. Once the place was found, two line transects of 15 m each from the center of a GPS point were laid out pointing at different directions and a search for the plant was carried out. After the *E. angolensis* species was identified, other species that coexist with it were also identified. The number of *E. angolensis* plants were counted and recorded. Thereafter, the density of *E. angolensis* was calculated using the formula according to [11]:

$$D = n/A$$

where D = density, n = number of species, A = area sampled.

2.2.3. Soil Sampling

Soil samples were collected along transects where the *E. angolensis* species occurred. The samples were collected at 10 cm depth immediately around the plant and at 5 m, 10 m, 15 m away from it. The samples were kept in plastic bags and transported to Okavango Research Institute for laboratory analysis.

2.3. Laboratory and Data Analysis

2.3.1. Laboratory Analysis

Soil samples were allowed to air dry for 5 days and finally for 24 hours in an oven at a temperature of 60 degrees Celsius. The samples were cleaned for stones and plant residues, grinded with a pestle and mortar, and then passed through a 2 mm sieve.

The sieved soils were then digested using the sulphuric acid digestion method, 1 g of soil was digested using 6 mL sulphuric acid, one kjedehl catalyst tablet and 2 g sodium sulphate. The samples were placed in a Block Digester heater at a temperature of 450 degrees Celsius for an hour to boil. After an hour the samples were removed from the heater and put aside to cool for 15 mins, however, still in the fume hood. Distilled water was added. The samples were given a further 30 mins to cool then taken out the fume hood, topped with more distilled water, closed with rubber stoppers and left over night. The digested soils were filtered and analyzed accordingly: Potassium (K) was analyzed using Flame Photometer, nitrogen (N) and phosphorus (P) using a Segmented Flow Analyzer.

2.3.2. Spatial Analysis

Spatial analysis and mapping was carried out using ArcGIS software to map areas where *E. angolensis* was found.

2.3.3. Statistical Analysis

A t-test was used to determine if the macronutrients and SOC concentrations were significantly different directly around the plant compared to its environment.

3. Results

3.1. Vegetation Survey

E. angolensis was not located within all the areas that it was once sighted in the south of the Okavango Delta and quite notably wildfires were reported in the very same areas 6 months before this study quest for the species. However, *E. angolensis* was found in two new sites along the Gadikwe channel. Both sites contained only three species each. The species were very close to the water channel, approximately 40 cm away from the water channel, with only one plant about 60 cm away, and this one species appeared to be unhealthy and dying. **Figure 2** shows *E. angolensis* surrounded by tall fern (thelypteris).

3.2. Soil Biogeochemistry

The average macronutrients concentrations in the site that contained *E. angolensis* as shown in **Table 1** were total nitrogen 2.61 ± 0.61 mg/L, phosphorus 7.02 ± 0.8 mg/L and potassium 14.41 ± 4.28 mg/L. And soil organic carbon concentration in the *E. angolensis* habitat was 40.1 ± 10.28 mg/L.

3.3. t-Test

A t-test was conducted to compare soil macronutrients and SOC contents using samples within *E. angolensis* habitat, *i.e.* soil samples directly around the *E. angolensis* plants species against soil samples collected from the line transects at 5, 10, 15 meters away from the plant species. Of all the four nutrients tested, there was only a significant difference in K (**Table 2**).

3.4. Spatial Analysis

Coordinates of previous sightings of *E. angolensis* and locations where it was not sighted were placed on a map. Of all the 11 coordinates of previous sightings, *E. angolensis* was not found by this study (**Figure 3**). The population density of the plant was less than $1/m^2$ inside $15\text{ m} \times 15\text{ m}$ sampling plot used for this research.



Figure 2. *Eulophia angolensis* in the Okavango Delta (Photo taken by Authors).

Table 1. Soil N, P, K and SOC concentrations from a site that contained *E. angolensis*.

Parameter	Nitrogen (mg/L)	SOC (mg/L)	Potassium (mg/L)	Phosphorus (mg/L)
N	25	25	25	25
Mean	2.61	40.1	14.41	7.02
Median	2.49	39.87	12.70	7
Std. Deviation	0.61	10.28	4.28	0.80

Table 2. t test results from comparisons of soil macronutrients and SOC within the *E. angolensis* habitat.

		Levene's Test for Equality of Variances		t-Test for Equality of Means		
		t	df	Sig. (p = 0.05)	Mean Difference	Std. Error Difference
		Lower	Upper	Lower	Upper	Lower
Soil organic carbon	Equal variances assumed	-0.204	23	0.840	-0.85641	4.20116
	Equal variances not assumed	-0.208	19.991	0.837	-0.85641	4.12080
Nitrogen	Equal variances assumed	0.012	23	0.991	0.00295	0.24740
	Equal variances not assumed	0.012	17.342	0.990	0.00295	0.24090
Potassium	Equal variances assumed	2.999	23	0.006	4.45385	1.48495
	Equal variances not assumed	3.057	20.108	0.006	4.45385	1.45705
Phosphorus	Equal variances assumed	-1.533	23	0.139	-0.47545	0.31005
	Equal variances not assumed	-1.541	22.975	0.137	-0.47545	0.30855

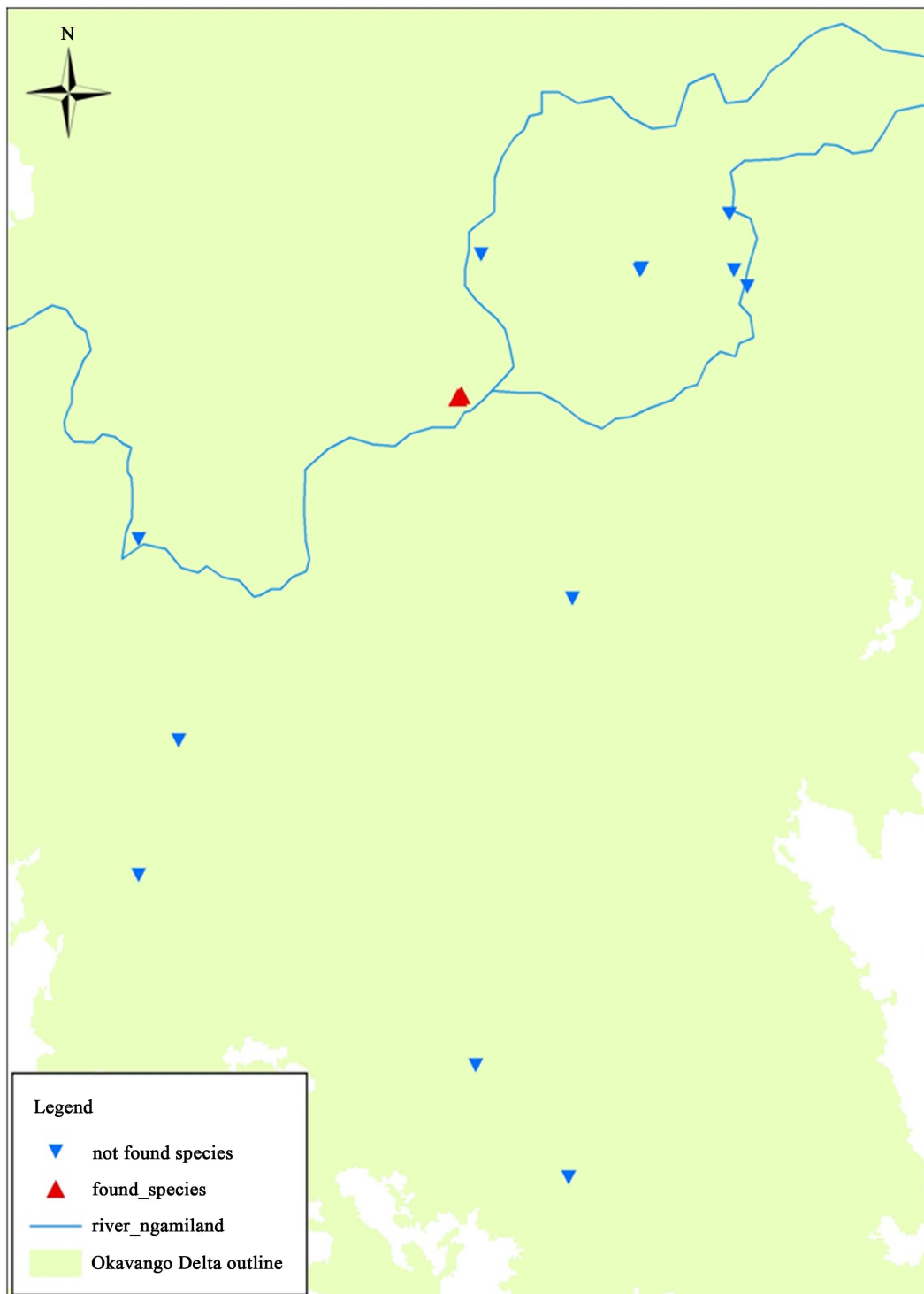


Figure 3. Spatial location of sites where *E. angolensis* was found in the study area.

4. Discussion

According to [3] the three main factors controlling vegetation composition in wetlands are water depth, the effects of flooding in removing litter, and soil fertility gradient. Data from this study confirmed this by illustrating that distance from the water channel and soil fertility was the main controlling factor for occurrence of *E. angolensis*.

lensis. Studies of wetlands in Western Europe and of other terrestrial ecosystems in North America frequently show that nutrient enrichment leads to changes in species composition, declines in overall plant species diversity, and loss of rare and uncommon species [3]. Rare and uncommon species are almost always associated with nutrient-rich communities [12].

In general, the high nutrient content in sites where *E. angolensis* occur can be attributed to high levels of organic matter, higher vegetation density, moisture and microbial activity. Organic matter is a reservoir for soil nutrients [13]. Soil organic carbon (SOC) is relatively high in our study area as shown in **Table 1**. Potassium appeared to be the main nutrient limiting factor of *E. angolensis*. The t-test results illustrated that K concentration was generally higher closer to the water channel. Furthermore, the one species of *E. angolensis* that appeared to be unhealthy and dying was not only the furthest from the water channel, but it also reported the lowest concentrations of K directly around the plant.

The wild fires that were reported in the areas where previous *E. angolensis* species were sighted could be the main reason why this report did not find the species there. The fires could have burnt away the species; [14] reported that low moisture levels result after fires. They also reported that not only did fires attribute to the loss of above ground vegetation; fires also negatively affected levels of soil organic matter and eventually nutrient holding capacity. This greatly affected plant growth especially that of *E. angolensis* as it required high amounts of nutrients. This could prevent the species from re-establishing after the fire.

According to [12], soil moisture is important in influencing the distribution of orchids. The observations made by this report demonstrated that *E. angolensis* was found growing very close to the water channel and the only species found furthest from the water channel appeared to be unhealthy and dying. Furthermore, no species were found as distance from the water channel increased.

5. Conclusion

E. angolensis requires critical concentrations of soil organic carbon, nitrogen, phosphorus and potassium. Potassium and water are the main limiting factors for the species. Frequent monitoring of threatened and endangered plant species is critical for their conservation status. Therefore, monitoring of threatened and endangered plant species in the Okavango Delta should be carried out. General census of the plant population density should be conducted regularly. Furthermore, *ex-situ* conservation of the species in the country in the form of a botanical garden should be established for future generations.

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