A SURVEY REPORT ON EDIBLE ORCHIDS DISTRIBUTIONS, ABUNDANCE AND TUBER MORPHOLOGICAL VARIATIONS: NYIKA NATIONAL PARK, MALAWI

NYIKA VWAZA TRUST (NVT) SMALL GRANTS

MAGANIZO NAMOTO

FORESTRY RESEARCH INSTITUTE OF MALAWI

AND MZUZU UNIVERSITY

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Title:

Edible orchid survey on species distribution, abundance and tuber morphological characterization in Nyika National Park

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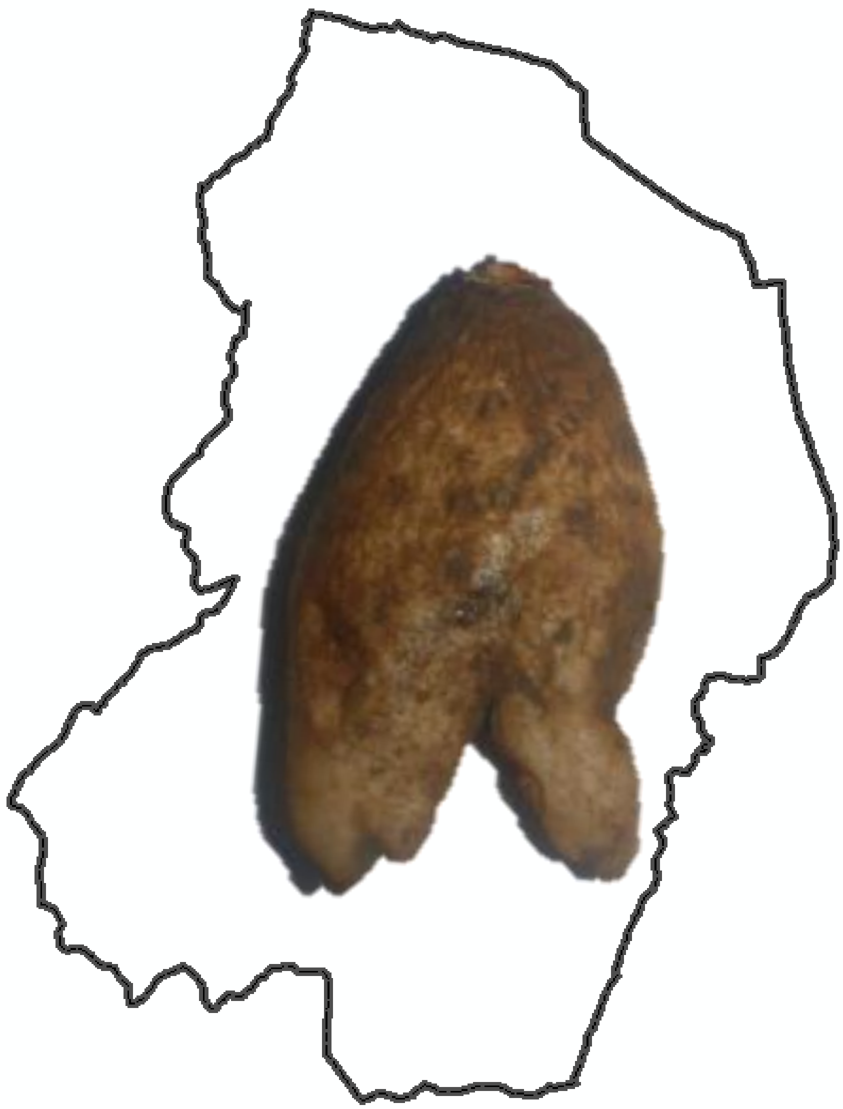
Disa ochrostachya



'Some orchid tuber shapes will most likely take the shape of Nyika National plateau'

Summary

The Nyika National Park is the largest protected area in Malawi with numerous orchid species. For this study, diversity of edible orchids of the Nyika National Park were investigated. Out of 54 species inventoried, forty-three (43) species were identified edible by surrounding communities. The edible orchids identified belong to five genera; Disa (31%), Satyrium (26%), Habenaria (13%), Brachycorythis (5%) and Neobolosia (2%). Other associated orchid genera recorded were Reoperocharis, Brownlea, Cynorkis, Disperis and Eulophia. Results of the study reveal an increase in edible orchid species targeted by communities in the National Park than previously reported.

The ecological habitants for these terrestrial orchids are montane grasslands; montane wetlands; pine plantation, broadleaf evergreen forests and the miombo woodlands. Simpsons' diversity indices reveal that the montane wetlands and montane grasslands had the highest species diversity than the rest, while the pine plantation had the least species diversity. In terms of abundances, the pine plantation (3600 orchids per hectare) and the montane wetlands (2360/ha) were the highest, while the miombo woodland (390/ha) recorded the least. Variations in orchid abundances and species richness according to this study is ascribed to dissimilarities in ecological characteristics that are partly influenced by environmental factors such as altitude and the soil physiochemical properties.

Edible orchid tuber morphological traits that were investigated in the study are, tuber size (breath, width and length), and the diversity of tuber shapes. Results revealed significant differences ($P \leq 0.05$) in all the studied traits. Orchid tuber length ranged from 7.3 to 106 mm and tuber width ranged from 4.5 to 92.8 mm. *Brachycorythis pleistophylla* recorded the longest (103.2 mm) tuber length followed by *Disa robusta* (63mm), while *D. ukingensis* was the shortest. In terms of tuber width, *D. robusta* was the widest (40.9mm) followed by *D. ochrostachya* (30.7mm). Smallest diameter tubers were in *B. pleistophylla* (1.2mm). Heavier tubers were recorded from *Disa robusta* (46.2g) and *Disa ochrostachya* (34.6g). Smaller weights were recorded from *Satyrium carsonii* (2.5g) and *Disa ukingensis* (1.8 g). The number of mature tubers per individual plant shows that 62% of the orchids had two underground tubers, While 29% of the orchids investigated had a single tuber and 9% had averages of 4 tubers per individual plant. The number of tubers per individual plant was maximum in *B. pleistophylla* and *C. kassneriana* with an average of 4 tubers.

Thirteen (13) macro-morphological tuber-shapes were found in the study. The tuber shapes found were elliptical, oblong, long-oblong, globose, compressed, ovoid, obovoid, cylindrical-billobed, elongated, and irregular shapes. The irregular shapes identified were arbitrary classified as heart-shaped, elephant-hooves and toothed-shape tubers. High diversity of tuber

morphological characteristics revealed in the study can be used in the selection of species for conservation and improvement programmes. It is envisaged that the information generated could help formulate conservation, management and improvement strategies for the edible orchids of the Nyika National Park.

1.0 INTRODUCTION

Background information

Edible Orchids belong to the family Orchidaceae. Orchidaceae is regarded as the largest of the plant family on earth (Kew, Royal Botanic Gardens, 2016). The family consists of a unique group of plants, mostly perennial, sometimes short-lived herbs (Barbhuiya and Salunkhe, 2016), with more than 29000 epiphytic and terrestrial non-woody species (Illustrated World Plants compendium of orchids, 2018). The species are known to occupy all habitants of the world except the Antarctica (Chen *et al.*, 2009). In Africa, Madagascar has the highest number (905) of species (Illustrated World plants compendium of orchids, 2018).

Malawi has over 400 orchid species and some of these species are endemic (La Croix and La Croix, 1991; Illustrated World plants compendium of orchids, 2018). The habitat ranges from the high plateau areas of the Nyika and Mulanje ecosystems, to the hot-low lying areas of the Shire basin, including numerous intermediate habitats (La Croix and La Croix, 1991; Burrows and Willis, 2005). Over 200 orchid species are found in the Nyika ecosystem (Burrows and Willis, 2005).

The Nyika National Park is the largest protected area in Malawi covering 3140 km^2 (Stuart *et al.*, 1990; Government of Malawi, 2014). The park has great ecological value comprising of a unique montane ecosystem of evergreen rainforests, montane grasslands, and low-lying wetlands and woodlands which protect a wide range of animal life and numerous beautiful flowering plant species including orchids.

Terrestrial orchids produce underground tubers, which are commonly, referred to as “Chinaka or Chikande" in Malawi (Mwanyambo and Kananji, 2003; Kasulo *et al.*, 2009). The tubers are of various morphological characteristics (number of tubers per plant, tuber shapes, tuber size, tuber weight, eye distributions and skin colour). However, in Malawi, data on morphological characterization of the orchids is still very limited, hence, this study.

Orchids occupy an outstanding position among all the flowering plants because of their long-lasting and beautiful flowers and are commonly valued either for cut flower production or as potted plants in ornamental horticulture (Sugapriya, 2012; Valdman *et al.*, 2017; WGBIS, 2018). In Malawi, various orchids are edible, seven (*Satyrium buchannani, S. abylosaccos, S. carsonii, Disa engleriana, D. robusta*, *D. zombica* and *Habenaria clavata*) of these species are reported as economically important (Kasulo *et al.*, 2009). However, Simkoko (2012) reported 20 wild edible orchid species growing in the Nyika National Park. Thus, there was great need to investigate further on species diversity of edible orchids on the Nyika.

The ground tubers are used to prepare “Chinaka or Chikande" a meatless sausage revered for food and trade (Kasulo, *et al.*, 2009; Valdman *et al.*, 2017). In south-east Asia, orchid tubers are harvested for ‘Salep’ production and constitute a major conservation risk for wild orchid populations in the region (Ghorbani *et al.*, 2014). Medicinal uses of orchids have been reported (Hossain, 2011; Subedi et al., 2013; Dalar *et al.*, 2015; Kreziou *et al.*, 2016), particularly in the treatment of diarrhea, dysentery, intestinal disorders, coughs and tuberculosis. The tubers are also traditionally used to increase potency in men (Ghorbani *et al.*, 2014).The orchids are also taken as stimulants, expectorants, and remedy for joint pains, and breathing distress, e.g. asthma (Sharma and Samant, 2017). Furthermore, orchid products are important for treating malnourished infants and children (Ghorbani *et al.*, 2014).

Apart from the aesthetic appeal which is its main feature, orchids in natural landscapes are viewed as indicators of overall environmental health (Newman *et al.*, 2007; Laroche *et al.*, 2012). Their presence along with other epiphytes is an indication of a healthy ecosystem (Shashidar, 2012). They provide important ecosystem services which are not only food to humans and animals, but tend to complete the ecological systems in landscapes by also inhabiting mutually beneficial fungi (McCormick *et al.*, 2014) that facilitate soil nutrient recycling and enhance seed germination in specialized orchids (Swarts and Dixon, 2009; Jacquemyn *et al.*, 2016).

Additionally, orchids are known to support numerous insect pollinators. In some orchid species, this plant-pollinator relationship has become so highly evolved that removal of the pollinator would spell the end of the orchid (NOSSA, 2014). Some orchid pollinators also have specific requirements for habitat, appropriate food sources and nesting sites. Edible orchids are therefore, important to human kind.

1.2 Research problem

Edible orchids are important for food and medicinal use (FAO, 2016) and have potential to generate income through trade (Ndangalasi 2003, Kasulo et al., 2009). In northern Malawi, the Nyika National Park is the major supplier of edible orchids. Huge trade is taking place which is believed to deplete the resource base. Currently, no species of edible orchids have been reported to have become extinct, but there are indications that the availability of most species is decreasing while their consumption is increasing (Kasulo *et al.*, 2009). This according to Mwanyambo and Kananji (2003) is due to an increase in the number of orchid gatherers that are proportionately increasing with an increase in population. In view of this scenario, there is minimal information available on the edible orchids diversity, distribution and abundance in the Nyika National Park.

1.3 Objectives of the study

1.3.1 General objective

The overall objective was to determine edible orchid population distributions, diversity and abundance and also assess the species tuber morphological variations existing in Nyika National Park.

1.3.2 Specific objectives:

- To collect social data on orchid harvesting and identify areas
- to investigate the diversity and distribution patterns of the orchids in the study area
- To assess abundances of the edible orchids species in the Nyika National Park study sites.
- to investigate the edible orchids tuber morphological variations existing in the Nyika National Park
- Collect seeds for conservation and propagations

2.0 MATERIALS AND METHODS

2.1 Study area description

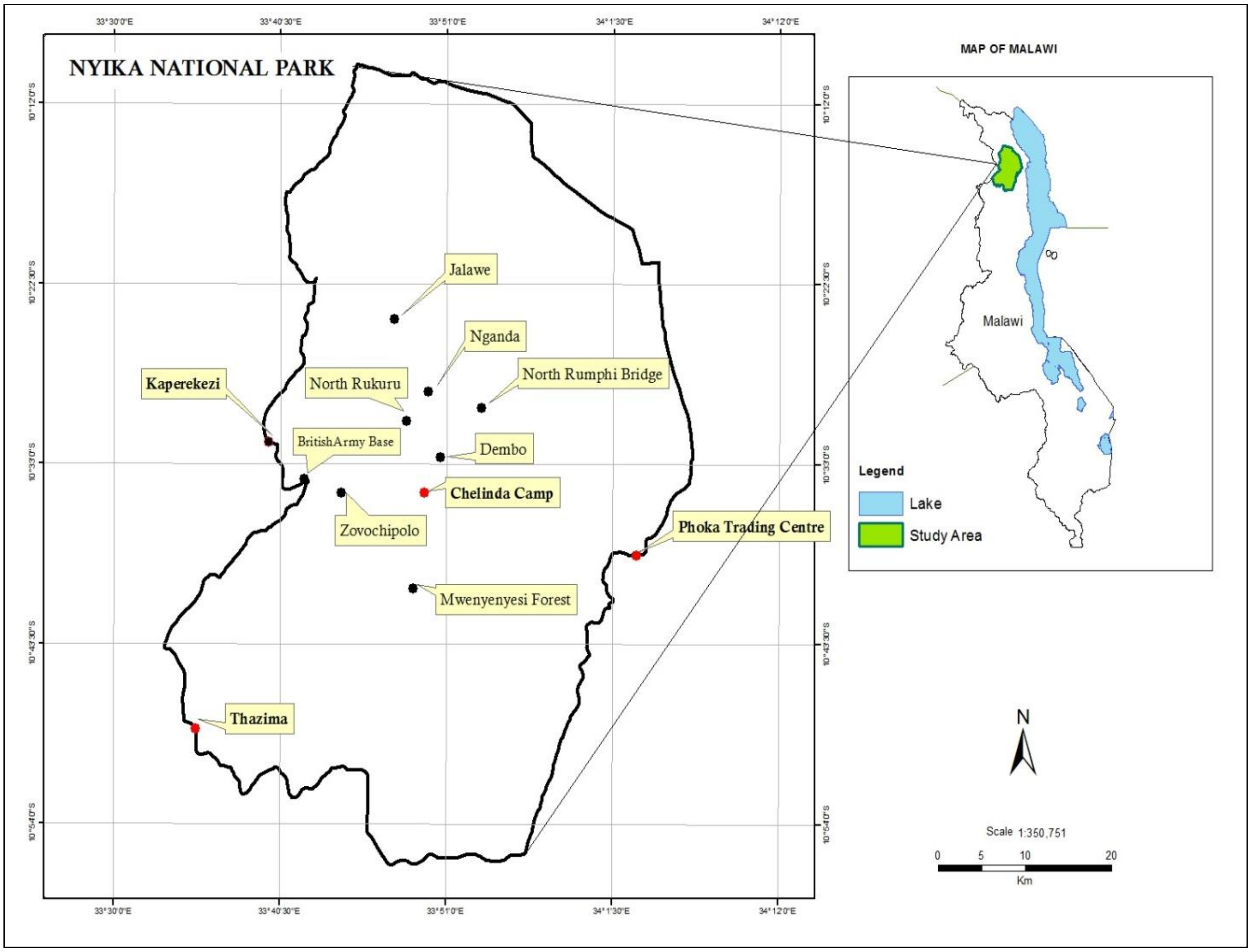


Figure 2.1: Location map showing edible orchid collection areas.

The Nyika National Park is located in the northern region of Malawi (Figure 2.1). It extends from 10^{o} 15'S to 10^{o} 50' and $33^{o}35$' to 34^{o} 05' E covering a surface area of $3,214km^2$ (Stuart et al., 1990, Government of Malawi, 2014). The National Park lies astride the Chitipa, Karonga, and Rumphi Districts.

Geographical relief comprise mainly of undulating upper plateau that ranges from 2100 to 2400 meters above sea level and also the lower escarpments ranging between 1200 to 1800 meters above sea leve1(Table 3.1). Montane grasslands and evergreen forests cover half of the upper plateau of the Nyika National Park (Table 3.2). Rainfall patterns are variable. The mean annual rainfall of the Nyika National Park is above 1,500 mm in high altitude areas in the eastern and western sides of the high plateau. Above 2,200m experiences lower rainfall, averaging 1,000–1,200 mm per annum.

2.2 Survey methodology

2.2.1 Social data collection on edible orchids

Identification of edible orchid collection areas and associated activities by surrounding communities was carried out in March 2017. Activities that were conducted include a review of available literature and field work to acquire data pertaining to edible orchids from collectors, traders and consumers residing close to the Nyika National Park. Interviews by use of a questionnaire and focus group discussions were conducted in 3 villages that share boundaries with the Nyika National Park. The sites for the interviews selected were; Ghamba village at Kaperekezi gate, Myaghalazgha village at Thazima gate, GVH Mkandawire at Phoka trading centre and the Chelinda camp. Twenty-eight (28) key players in orchid trade specifically harvesters (23) and local traders/consumers (5) were interviewed.

Identification of collectors/harvesters was done through inquiries from traditional leaders in respective villages and also amongst themselves. Data collection questions centered on the spatial distribution of edible orchids in the Nyika National Park, the orchid uses and threats and conservation strategies if available. Primary data was acquired through administration of a questionnaire and focus group discussion with key informants. Secondary data was acquired from the Department of Parks and Wildlife and also from other academic reports locally.

Research variables collected includes; where do they collect the edible species?, which species are collected?, what species are preferred most, what are the common species found?, at what period of the year are they collected, how is it collected? Who are the major users or customers if collected for sale?, are the species becoming easy to find or not?, what are the challenges encountered in the collection of edible orchids. What threats are likely to impact on orchid existence in the national park?. to authenticate the dialogue, communities were asked to lead to major collection areas in the national park for edible orchid inventories.

2.2.2 Literature search

A general literature search was conducted to acquire available information on the edible orchids in Malawi and those that are known to occur particularly in the Nyika National Park. Key institutions consulted for advice and information includes; the National Herbarium and Botanic Gardens (NHBG), The National Plant Genetic Resource Centre (NPGRC), The Department of Parks and Wildlife, The Nyika National Park management at Thazima and Chelinda campsite, The Department of Forestry particularly the District Forestry Officer (DFO) Rumphi, Forestry Research Institute of Malawi (FRIM) and Mzuzu University (MZUNI). Other institutions consulted include the Royal Botanical Gardens-Kew (RBG-KEW).

2.3 Vegetation sampling (Field work)

Figure 2.2: modified Whittaker sampling method was employed in data collection. The adopted methodology aimed at trying to capture even the most rare edible orchids in associated habitants.

Selection of sites for the field inventories in the Nyika National Park was based on the knowledge of distribution from surrounding communities residing close to the National Park and also from field reports of orchid diggings/occurrences from the Department of Parks and Wildlife (DNPWL). Forty-five (45) sample plots were established in 16 community identified localities (Figure 2.1) together with staff from the DNPW, the National Herbarium and Botanic Gardens, FRIM and surrounding communities for future monitoring purposes.

At each site, geo-referenced modified Whittaker plots of 20 x 50m (100m^2) were randomly established to collect inventory data (Stohlgren *et al.,* 1995) on orchid types and their numbers in each of the quadrants (Figure 2.2 and 2.3). The number of sample plots established at each representative site relied on the size of the chosen orchid occurrence site (Appendix table 2). GPS coordinates and associated plant species were recorded for each plot.

Other variables that were recorded include; the habitat vegetation type (Table 3.2) and other modifying factors observed. Height of the orchid species and 2-3 herbarium voucher specimens of each orchid species were collected. Identification of orchids was done at the National Herbarium and Botanic Garden, Zomba, Malawi. For the species not identified in Malawi; pictorial identification was done at Bieu Herbaria, Kwazulu-Natal R.S.A.

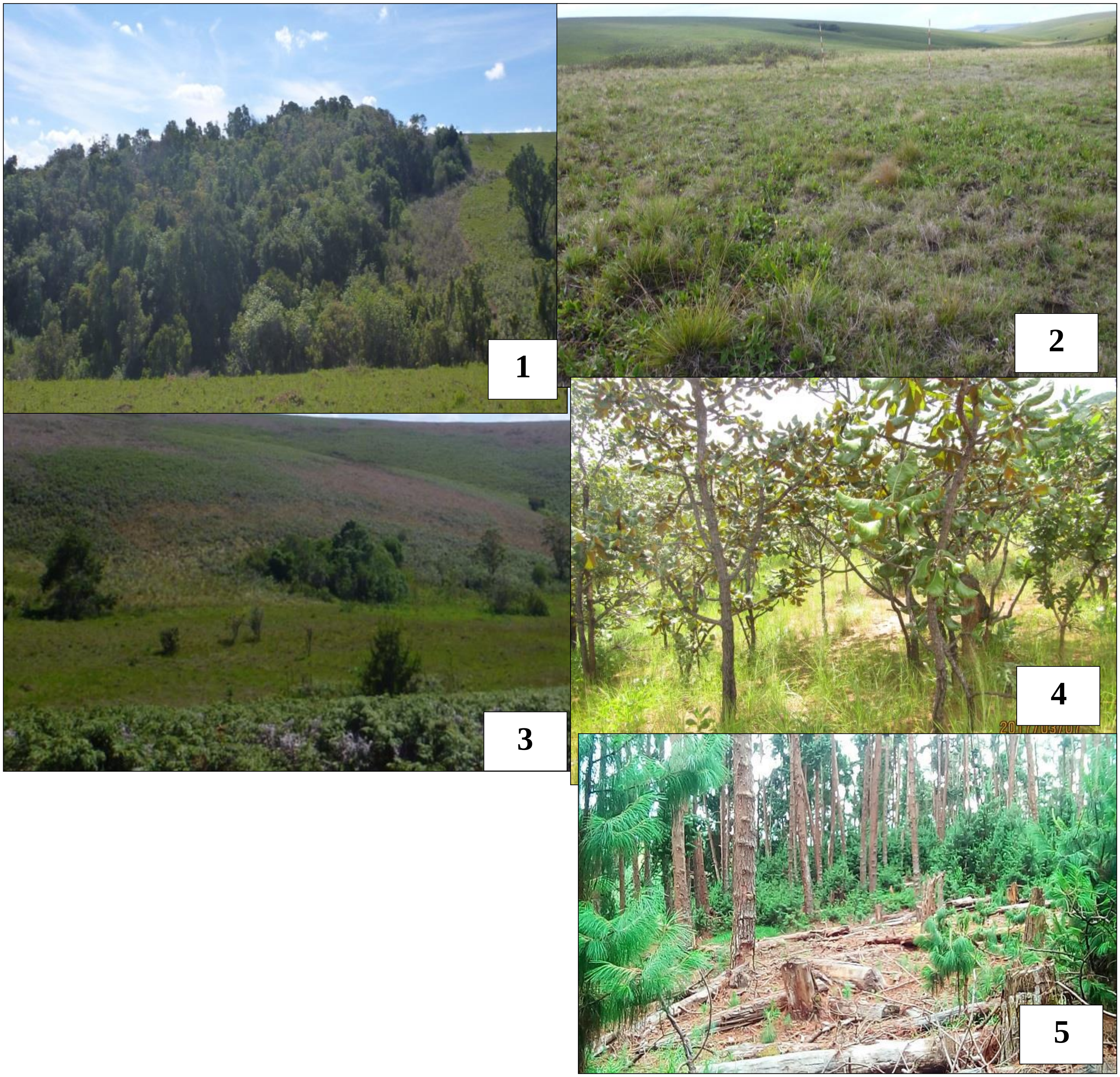


Figure 2.3: Vegetation types recorded for the edible Orchids in Nyika National Park 1=broadleaf evergreen forest; 2= montane grasslands; 3=montane wetlands; 4= miombo woodland and 5=exotic pine plantation

Table 2 Edible orchid collection sites with respect to occurrence vegetation types

Vegetation type	Field description of the orchid vegetation types	Collection site(s)	Altitude (m)	Forest type	Total size sampled (Ha)
1	**Miombo woodlands** On hills and rocky outcrops, Mostly with large trees such as Brachystegia, Uapaca, Joulbernadia	Kaperekezi, Thazima,	1600 – 1800m	Mid-altitude	0.6
2	**Montane wetland** Includes riverine; Mixed grasslands were soils are almost always moist and black. Lies along valleys or along streams in montane grasslands	Nganda, Chelinda Dam3, North Rukuru valley, North Rumphi bridge, Dembo valley, Chelinda, Kaulime dam	1900-2500m	Montane	1.8
3	**Montane grasslands** occupy about 60% of the montane area which lies between 2200 and 2500m the central plateau. Montane grasslands are mostly on gentle slopes above streams	Chelinda dam3, Zovochipolo, British army base near Chisanga falls, North Rukuru valley, North Rumphi river B,	2220-2500m	Montane	1.5
4	**Montane-evergreen forest** Found in patches in sheltered valleys. Vulnerable to wild fires started by lightning, poachers or accident. The southern limit of Hagenia sp	Mwanyenyezi forest; Chelinda	1900-2300m	Sub-montane	0.2
5	**Pine plantation** 0ver 40 years planted forest with mostly Pinus patula. Generally large trees with a closed canopy. No woody vegetation grows underneath	Chelinda camp	2200-2500m	Montane	0.5

2.5 Investigating morphological variations of the edible orchid tubers in the NNP

Mature orchid tuber samples were collected from 21 species. Atleast 10 to 15 identified edible orchid tubers were collected from mature plants from each of the 21 species for tuber morphological data collection. Identified individual plants species were uprooted for tuber sample assessments. Samples were washed in running water and assessed for the following tuber morphological characteristics: tuber shapes, eye distribution, tuber skin colour, texture, tuber width, length ant tuber weight. Photographic pictures were collected of the orchid plants before and after assessments.

Assessment of edible tuber morphological characteristics

Tuber shape: A laminated plate (Figure 2.1) was used as key illustrations to identify the shape of the tubers for each orchid species. In a field data form, the shapes were recorded accordingly.

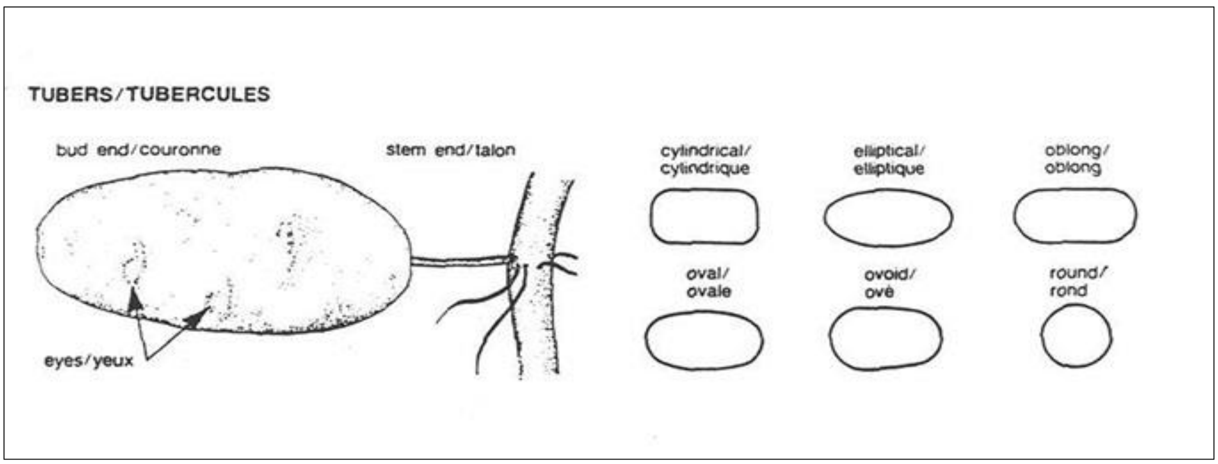


Figure 2.1: Tuber image illustrations (adopted from Canada, G and Agency CF1, 2013)

Tuber length and width measurements: were measured for each tuber using a veneer caliper

Tuber weight: individual tuber weights were measured using a precision balance and data was recorded on a form.

Eye distribution and depth characters were assessed on presence of eyes on the tubers.

Tuber skin colour: A Munsell color chart (Munsell plant tissue color charts, 2016) was used to determine the skin colour of tubers for each species. Data was recorded on a designed form. The tuber skin texture was observed as either: smooth, russet or feathered

3.0 RESULTS

3.1 Social data on edible orchid harvesting in Nyika National Park

3.1.1 Areas where orchids occur and are targeted by surrounding communities

Table 3.1below shows sites and vegetation types where edible orchids are harvested by respondents in the Nyika National Park. Collection areas for the edible orchids are both on customary land and in the Nyika National Park. According to respondents, major collection areas are on the plateau inside the National Park.

Table 3.1: Community groups and edible orchid targeted and their localities inside the Nyika National Park

Village community group	Localities targeted inside the Nyika National park
Gamba/Kaperekezi and Thelele area	Kaperekezi, Chelinda Airstrip, North Rumphi river, Nganda, Zovochipolo, Chisanga falls, British army base, Jalawe,
Thazima	Thazima dam 1, Miombo woodlands, Zovochipolo, Zambia rest house area and Chelinda
Phoka	Dembo, Thakati, Mkalanga, Jalawe, Chelinda, Chelinda_Dam 2, Juniper area, North Rukuru bridge, Libwe la chiphimpha,

3.1.2 Information on orchid collectors

Category of edible orchid collectors and their percent composition

Results of this study show that there are three categories of orchid collectors in the Nyika National Park. These are; the small-scale, medium scale and large-scale harvesters. Total percent composition of orchid collectors shows high number of medium-scale collectors (65%) than the small-scale (20%) collectors. While the least in terms of composition by category are the large-scale (15%). The small-scale harvesters usually collect from nearby miombo woodlands close to the National Park boundaries and collect largely for home consumption. The medium-scale harvesters collect orchids both from the miombo woodlands and inside the National Park and their collection are both for sale and also for home use. While the large-scale collectors collect from the Nyika National Park for sale. The medium-scale and large scale harvesters are the ones used as key informants in the identification of hotspots inside the Nyika National Park.

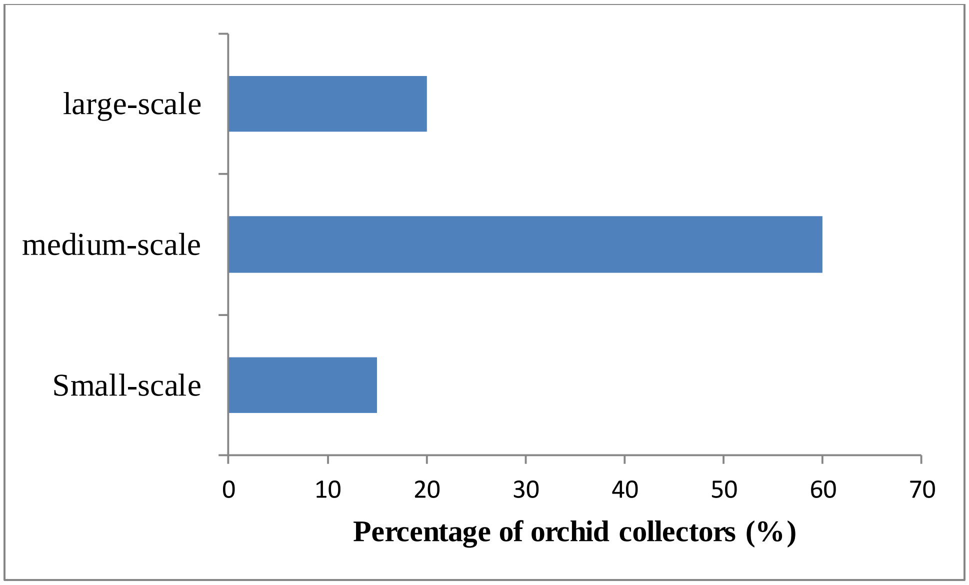


Figure 3.1: Category of orchid collectors and their percentage proportions (Small-scale 15%, Large-scale = 20% and medium-scale = 65%)

Age profile of the edible orchid collectors

The mean age of orchid collectors interviewed was 35.6 (±14.657), and the range was between 9 to 65 years (Figure 3.3). The largest proportion of collectors ranged between 31-40 years (25.0%). While the least in percent proportion (10.7%) were between the ranges 61-70 years. These results of the survey shows that collection of edible orchids is done by mixed age-groups. However, the youth age group (31-40 years) dominates

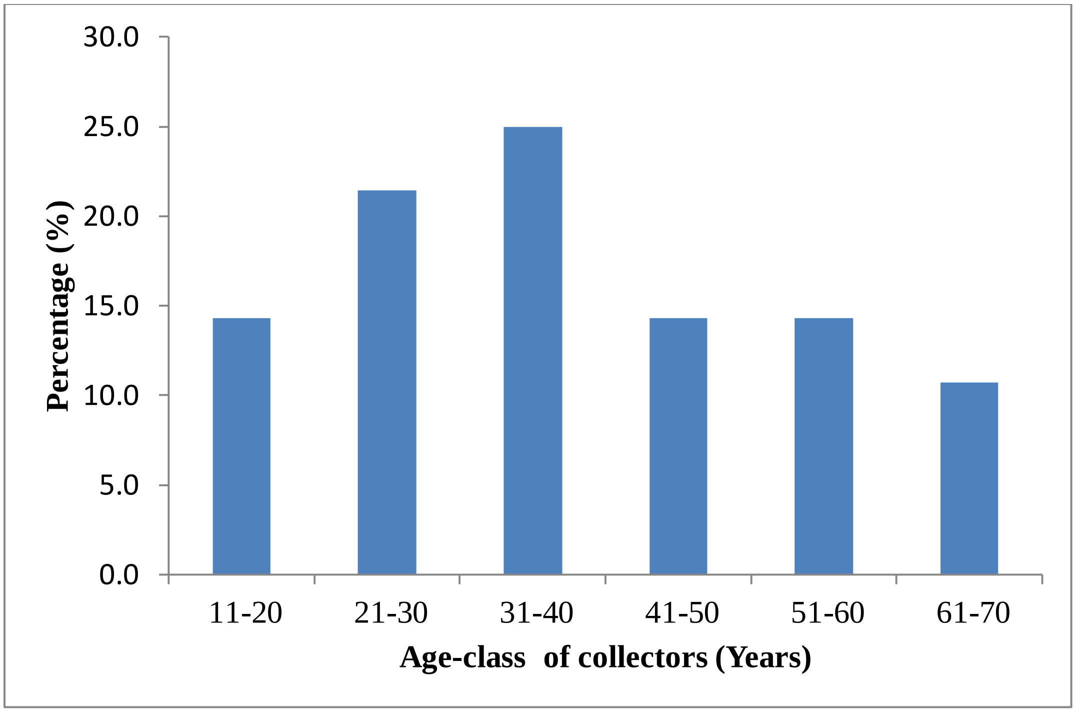


Figure 3.2: Age profile of the edible orchid collectors

Children of ages between 9 to 16 years are also involved in orchid harvests (Figure 3.3). These children normally collect from the miombo woodlands and dambo areas closer to the National Park. Most of these young collectors are small-scale to medium-scale. However, large-scale collectors are exclusively dominated by men (ages between 18-40 years) energetic enough to go up to the plateau and surrounding areas for harvests. However, isolated cases of women have been reported to collect orchids illegally on the plateau. Reports from the Department of Parks and Wildlife at Chelinda camp reported on women from as far as Chitipa to have entered the Nyika National Park to collect orchids.

Collector composition with respect to gender perspective

Proportion of collectors in terms of gender groups involved in collection of orchids in the Nyika National Park are shown in Figure 3.4. Results from the study show that all gender groups are involved in the collection of orchids in the Nyika National Park. However, the proportion of female respondents was higher (83%) as compared to the male collectors (17%). This can be attributed to women being involved in collection of edible orchids for both sale and consumption, while men would be collecting solely to generate cash for the families. Chikande preparation is done by women. The young females as well as the elderly are involved in making

Chinaka- cake. Incidentally, local traders/sellers of '*Chikande/Chinaka'* cake observed from this survey are female. The age groups are mixed. Age groups ranged from 18 to 57 years. The older women were the majority.

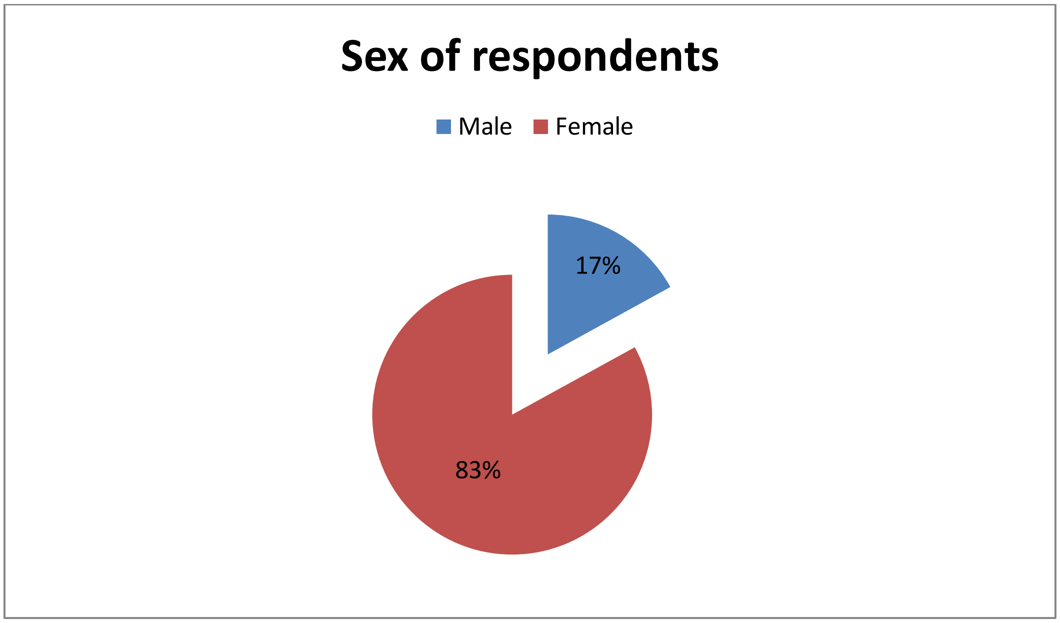


Figure 3.4: Gender composition of the respondents interviewed

3.1.3 Sources of edible orchids

Communities were asked to mention specifically areas where edible orchids are collected and how they acquire the edible orchids. In certain areas respondents reported that edible orchids species are fairly available, and that they access sufficient amounts from around their woodlands particularly around Kaperekezi and Thazima without accessing orchids in the Nyika National Park premise. However, 70% of the respondents voiced concern of the increase of the collectors and traders and the shortages of edible orchids before the collection season ends. Based on the respondent's comments, it was observed that illegal collectors for the edible orchids have several avenues to collect orchids. Some collect (legally?) from around the community woodlands where they acquire without permits, and availability is low, while others opt to collect illegally in the National Park. Not surprisingly, many of the orchid collectors are aware of the penalties for collecting/digging orchids in the National Park, but due to demand, and value attached the orchid tubers from the National Park, they are left with no option but to hunt for orchids in the national park where abundances are relatively higher and orchid tubers from the premise are of high value to traders than the tubers from the Miombo woodlands. Furthermore, due to high demand for the edible orchids from traders afar, collectors around Phoka, Chakaka and others areas closer to the national park demand advance payments for the orchid tubers from traders before they enter the National Park to harvest.

Figure 3.5: Edible orchid's in-situ on the Nyika plateau wetlands

The illegal nature of the trade in orchids was not an impediment to data collection for this survey, however, as most collectors spoke openly, especially when in groups, about the obstacles they encounter in collection of orchids, but were eager to seek solutions to remove the barriers underpinned to the collection of orchids specifically in the Nyika National Park. The reasons to the choices/perceptions to remove the barriers being; a) these orchid tubers are collected mainly for medicinal use, though the surplus sometimes is consumed at household level, b) availability is abundant and cannot exhaust the supply base.

Figure 3.6: local communities at Kaperekezi leading the survey team to potential collection areas in miombo woodlands

3.1.4 Seasonality of collection and tools used in collection

Almost all the respondents in the survey reported that edible orchid tuber collection is seasonal. The seasonality of collection is attributed to the phenology and availability of orchids in the wild. Orchid tubers tend to mature in April or May for most species. However, other species mature in June or July and are ready for collection up to August.

Table: 3.2 average sources of the edible orchids by respondents

Sources of edible orchids		
Customary land	Nyika National Park	Purchase
86%	10%	4%

Table 3.3: Seasonality of edible orchid harvesting

Season of collection		
Rain season	Dry season	Through out
0	98	2

Tools and implements used

Hoes, axes, Phanga knives, knives and sticks are tools and implements used to dig orchids from the national park. Sacks, travelling bags and plastic bags are also used to transport the harvested produce.

3.1.5 Movement to collection sites in the Nyika National Park

Information on the movement of illegal orchid collectors in the National park was not only collected from the community social survey alone, but was also consolidated from the Department of Parks and Wildlife staff. Movement of harvester's from villages and market hotspots into the National Park are shown in figure . Analysis of information from culprits apprehended in 2016 by the DPW staff and from the social survey revealed significant variations in distances covered by the illegal orchid harvesters.

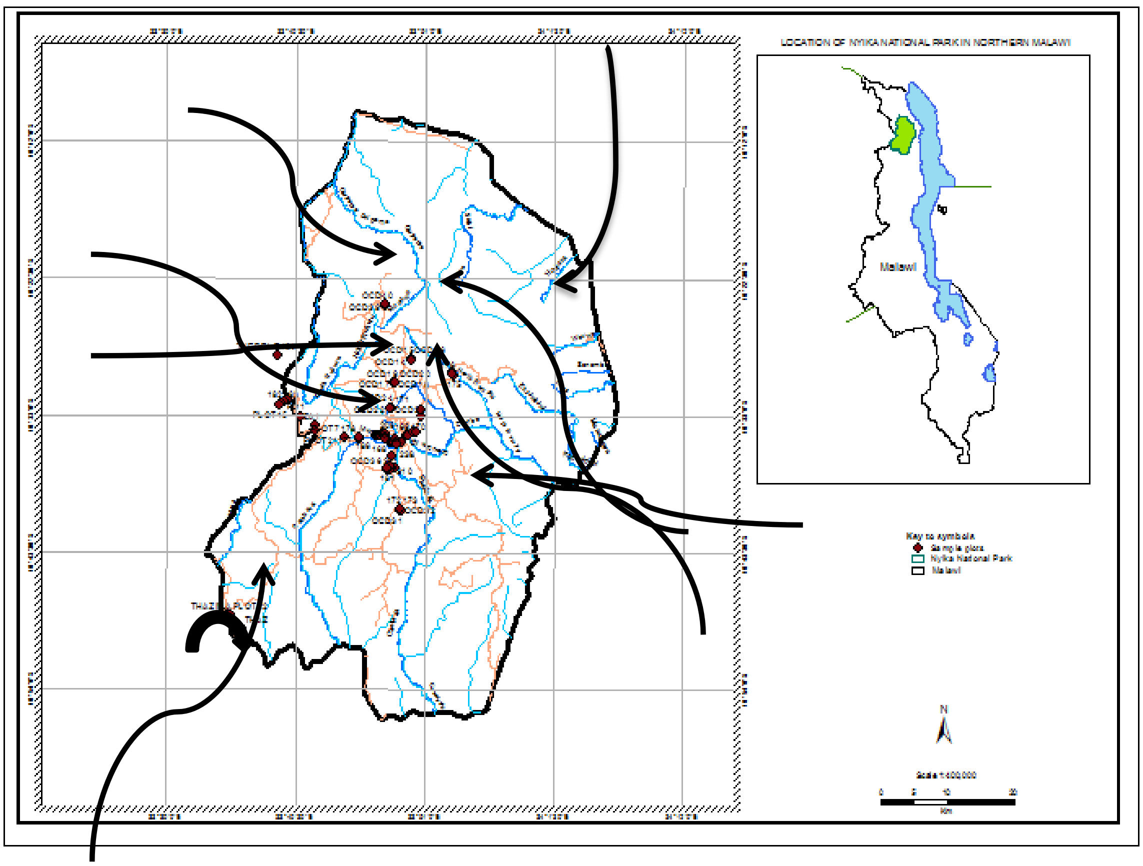


Figure 3.7: Movement of illegal orchid harvesters due to scarcity of the preferred tuber species

Distances to orchid collection areas

How far collectors have to go to collect orchids was one of the central questions in the survey. When asked about this, Orchid gatherers from Kaperekezi, Ghamba, Thelele and Nthalire area would cover a minimum of 5kms and a maximum of 30kms, spending 1 to 2 days in the National Park collecting orchid tubers, while from the eastern side, Phoka, Thakati, Chakaka, Nchenachena and Livingstonia would cover a maximum distance of 40-60 kilometers thereby spending a maximum of 2 to 3 days searching for tubers in one collection trip. Variations in distance covered are a result of geographical and social barriers to collection sites. The main collection areas in the national park lie on the plateau.

3.1.6 Challenges associated to collection of orchids

Geographical barriers which include the difficulty associated with terrain of the area and danger associated with wild animals especially elephants are among the challenges faced by orchid gatherers. But to the illegal gatherers, the main impediment associated to the activity is law enforcement by game rangers. As a measure to protect each other while digging orchids, one of the members is positioned at a slightly higher elevation to signal warning signs to eminent danger. Movements of orchid gatherers from their villages to specific areas/sites in the Nyika National Park vary depending on geographical barriers are shown in Figure 3.7. Access routes vary from site to site and collector to collector, but according to reports from the apprehended collectors, preference is to access the national park along streams and valleys where they mask themselves from game scouts and escape without being noticed. Access routes to the preferred habitants are usually along valleys where terrain is fair for easy movement. Travelling is usually by night to and from the national park. The aim is to try as much as possible to musk themselves from the game scouts. The plateau grasslands and wetlands are sites where availability is guaranteed as orchids are becoming scarce in all community woodlands and along the national park boundaries.

3.1.7 Ranking of edible orchids preferred

The species most hunted by communities are; *Disa ochrostachya, D. robusta, D. satryiopsis, Disa engleriana, Disa zombica, Satyrium saculutum, D. onithantha, S. sceptrum, Satyrium carsonii, D. hicicornis, Brachycorythis pleistophylla (Joyisi) Habenaria clavata* amongst others. Most of the preferred species are from the montane wetlands. In terms of ranking, *Disa ochrostachya, Disa robusta, Disa satryiopsis Satyrium saculatum, Satyrium sceptrum* and *Disa zombica* are the most preferred while *Satyrium carsonii* is among the delicacies but due to smaller tuber size and other baking characteristics is not an option when other species are available. Information gathered from the collectors indicates that the preferred orchid species are less abundant in the wild, hence are usually mixed with other less preferred species to increase yield and subsequently on revenue. Similarly, cake-bakers also mix the tubers when preparing 'Chinaka' cake to increase quantity but are careful not to compromise quality of their products.

Species local names vary from site to site. Through the survey, it was noticed that most collectors are able to identify edible orchids as "*Chinaka Chanalume'* (has produced flowers or seeds) and "*Chinaka Chanakazi*'- to mean has no floral/fruit inflorescence and it is only the leaves with the tubers. Chinaka Chanalume is less preferred. Since there are some species which are non-edible, it was observed through the survey that experienced collectors also use other special characters/attributes to distinguish the edible and non-edible orchid species through tuber morphological characters.

3.1.8 Users of the orchids

Getting data on the users/customers of the edible tubers was not an issue from both collectors and traders as the orchid trade is common in the targeted villages. At village level, immediate customers for the edible orchid tubers collected from Nyika National Park are the local traders (usually middlemen from within the village) and or bakers from within the villages or nearby trading centres. These traders usually display their well-prepared merchandise along roads, market places or at primary schools for profits. Important customers are traders from afar districts who purchase the orchids for sale in Mzuzu, Chitipa, Karonga, Nkhata-Bay and Mzimba districts amongst others. Of late, traders are known to originate from as far as Zambia and Tanzania who are eager to pay highly especially for the orchids of the Nyika Nationa Park.

3.1.9 Availability of edible orchid's overtime

Information on availability of the orchid species was collected by compiling views of the respondents as to whether species supply is thought to be abundant, satisfactory or low in both the communal woodlands and the Nyika National Park. Results of this interview question were mixed as nearly all respondents were able to report on the drastic decline of edible orchid's availability on communal woodlands overtime. But comments on availability of orchids in the Nyika National Park were diverse, Eighty (80%) of the respondents personal perceptions commented that orchids in the Nyika National Park are abundant and cannot finish even if they were given free access. However, respondents from Thazima reported of areas were availability of the edible orchids has become rare due to land use change on customary land. They cited two areas which used to be potential areas for orchid tuber collection near the boundary of the National Park in the past and the land is now being used for agriculture. Similarly, respondents cited areas which are frequently harvested to be areas where availability has drastically gone down. Currently, the most targeted orchid habitants are the montane grasslands and montane wetlands.

Figure 3.8: Women and the young females are involved in collection of orchids in Nyika National Park

3.1.10 Areas where harvesting is more prevalent

Counts of diggings were recorded for each plot/area by local communities. Results show that localities further away from chelinda camp sites which include Jalawe, North Rumphi Bridge and Dembo valley had highest orchid diggings. While, Chelinda East (Libwe La Chiphimpha), Chelinda Dam 2an3 had the least. In terms of habitants, the montane wetlands and montane grasslands were highest in number of diggings. The fewer diggings recorded at sites in Jalawe, North Rumphi valley may indicate frequency of access to the sites as well as ease of access to the areas by collectors as the are far from the camp. While the fewer diggings recorded east of Chelinda indicates fewer orchid harvesters visitations to the area and the sites are frequently patrolled than far areas. However, 60% of the orchid harvesters did not mention specific areas in the National park where availability of the orchid species has declined, but in customary land and along the boundaries of the national park, due to land use change, orchid occurrence have completely been rare. However, basing on the amount of time and the distances travelled inside Nyika National Park to search for orchids, it is evident that areas close to boundaries such as at Thazima woodlands, Kaperekezi, Phoka woodlands are the most frequently gathered and resources are now scare.

Reports on collection activities inside the national park

Figure below shows comparative number of illegal cases reported at Chelinda camp between 2013- 2016. Twenty-eight percent (28%) of the cases reported at this station between the periods were illegally collecting orchids, while 72 % were game poachers.

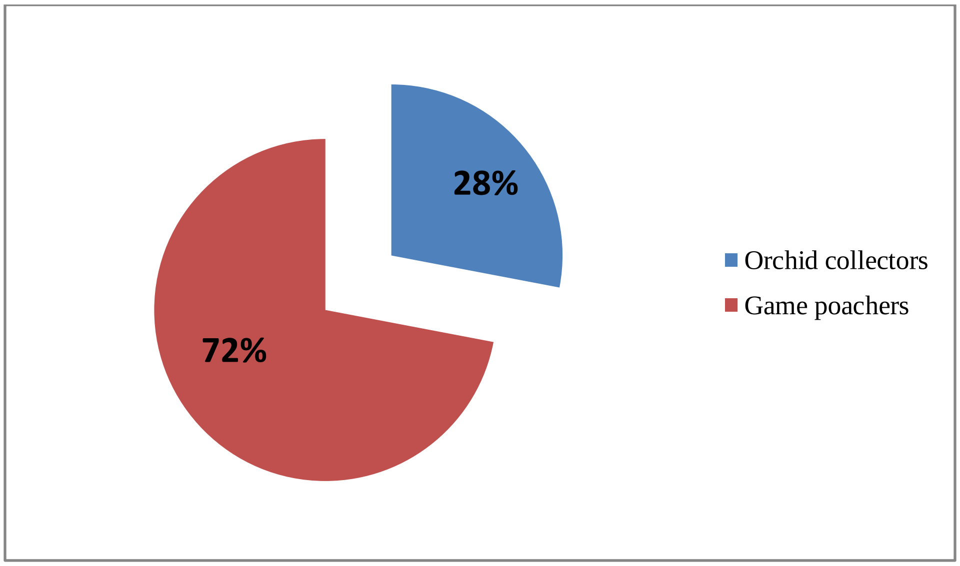


Figure 3.9: Illegal cases reported at Chelinda camp site between 2013 and 2016

3.1.11 Traditional uses of the edible orchids

The greater dependence of the rural people on forest resources as well as on the services of specialists such as traditional healers is enormous around the Nyika National Park. Culturally, orchids are among the targeted plants in traditional use. The predominant use of the edible orchids is in the preparation Chikande "meatless sausage" locally and widely known as *Chinaka* in Tumbuka, Phoka, Lambiya, or *Chikande in* Chichewa. But from this survey, 90% of the respondents reported that orchid tubers from the Nyika National Park were collected for sale and home consumption. The other uses of the orchid tubers recorded from the social survey were in traditional medicine concoctions usage. Some orchid tubers species have been described to have medicinal value. While some tubers are dried, pounded and are shyly used traditionally as 'virgin soap' by women in villages. The common traditional use of the orchids by children is in making of orchid balls. Children around March or April play football made out of mature orchid tubers. The tubers are sliced, crushed and boiled in water to increase ball adhesiveness and elasticity potential of the orchid ball games. However, this social use has some ecological implications if over exploitation occurs due to increased demand for such species. On the other hand, some orchid flowers of some species including *Satyrium buchananii*, *S. carsonii* and *S. crasicaule* amongst others existing in the National Park are cooked and eaten as vegetables. This traditional vegetable use was recorded from older women who once lived inside the Nyika National Park earlier before some parts of the national park were protected.

3.1.12 Revenue realized from sale

Orchid poaching in Nyika National Park is no longer a social activity where households close to the park used to enter to collect orchids for home use, but now, over the years has culminated into a serious occupation by most harvesters and traders. Over 50% of the harvesters interviewed involved in orchid collection in the national park do not depend entirely on edible orchid collection for their survival. They mentioned that collection of orchids is seasonal (April to September). But on the contrary, the orchid sellers (bakers of 'Chinaka' the meatless sausage) however expressed satisfaction in profits realized from the orchid trade and how the enterprise sustains their livelihood through-out the year. This implies that orchid trade alone contributes greatly (over 70%) of their total gross monthly income. Respondents interviewed at Kaperekezi Gate and Thazima rely solely on the trade for most of their household needs.

However, for the collectors, the amount of money realized from a single collection varies from site to site and by collector category (small scale and medium scale). Figure 3.10 shows freshly collected orchids and the cup for measuring the merchandise. Orchids from the forest are sold (cup measuring 500mls) at MK250 in May when supplies are abundant and MK450 to MK 600 in August/September when orchids availability is low. While around Kaperekezi, the main market is at Thelele Trading Centre where most traders converge to purchase the tubers. Large-scale collectors and middle men sale per bucket (20 litres tin). The average prices ranges between MKW 40,000 - MKW50, 000.00 per bucket which is equivalent to USD55 to 67 respectively (Current exchange rate USD1=MKW723).

Edible orchids from the Nyika national park have high preference as they are large tubers and possess preferred mineral nutrients. The trade has reached an advanced level where the orchid poachers now move in gangs ranging from 2-4 individuals. In certain cases, can be upto 7 individuals.

Figure 3.10: Freshly collected orchid tubers ready for sale at Thazima. A cup (500mls) is used as a measure of value by collectors.

3.1.13 Storage of orchid tubers

Around the Nyika National Park, local communities store the edible orchid tubers using different traditional methods to preserve from perishing. Orchid harvesters/collectors usually keep the collected tubers for a short period of time after digging from the forest. The maximum storage period is 1-2 weeks before sales. During this period, freshly collected tubers are kept in dry sacs or on open surface under shade before sales. However, eighty percent (80 %) of the individual sellers involved in baking orchid cakes (meatless sausage) prefer to store orchid tubers for over six months to sustain their trade. The storage period range from 3 to 6 months. The main identified storage method is burying the orchid tubers in the soil and covering with ash. They described this storage method as the best method to keep the tubers fresh until the time of need. They only feared time when it is rainy season as once the orchids get soaked; they start to sprout immediately and thereby loose quality. However, 20% of the respondents opt to dry the orchid tubers and prepare a local powder or flour immediately after purchase to avoid perishing or loss. The flour produced is kept in a jar or bucket for a long time until period of need. There is little wastage of the collected orchid tubers noted through the study.

3.1.14 Regulations pertain to orchid collections

Information on the legality of orchid trade was also one central question which the investigator compiled from the Nyika National Park management at the Divisional headquarters in Mzuzu, Thazima and Chelinda camps. According to the national park management, collection of the wild orchids in the Nyika National Park is strictly prohibited. Authorities' however cited areas where abundance of the orchids currently occur. According to Mr. Peter Wadi and Mr. Mabeti, wild orchids are more prevalent on the plateau grasslands and in the woodlands to mean miombo woodlands. In terms of specific areas, management staff cited orchid abundances to be on the plateau. The following areas were mentioned; Nganda, Chosi, North Rukuku and North Rumphi River valleys. However, they were quick to mention that areas from the western side do not have abundant edible orchids than maybe the northern and the eastern sides. Their observations were based on the number of culprits apprehended from these areas.

Culprits involved in orchid harvesting in the Nyika National Park when caught are charged with the following offences; a) illegal entry in the national park b) Possession and conveying weapons inside the Nyika National Park and c) Illegal harvesting/possession of prohibited vegetation plants. According to the previous Wildlife act, the total amount of fine a culprit apprehended in possession of orchids in the Nyika National Park would amount to MWK10,000 but the recently revised fine would account for a minimum of MWK100, 000 to a maximum of MWK 1,000, 00 (Table 3.4).

Figure 3.11: Orchid collector display orchid tubers and tools used in collecting

Table 3.4: Legal charges of edible orchid collectors under section 35 (a) of National Parks and Wildlife Amendment Act of2004)

Offence Charges	Before 2016		After December 2016	
	Minimum (MWK)	Maximum (MWK)	Minimum (MKW)	Maximum (MWK)
a) Entering protected area without permission	5000	10,000	100,000	1,000,000
b) Possession and conveying weapons inside the park	5000	10,000	100,000	1,000,000
a) Taking or removing of any plant (collecting or digging of orchids) material from park	5000	10,000	10,000	1,000,000

3.1.15 Current status of the edible orchid natural resource base

The current status of the edible-orchid resource base has not completely changed in terms of quality as well as quantity. However, in areas along the boundary where harvesting is so rampant, some edible orchid species have become rare or greatly reduced in quantity. The principal cause has been over collection and or removal of associated species onto which the required species depend for survival. For example, some areas on the plateau, ecosystem quality has been altered by increased growth of invasive species which are somewhat chocking the emerging endemic plant species including orchids by denying them of the available nutrients for survival. In line with this, there happens to be a deliberate programme to reduce the level of occupancy of invasive species or completely eradicate such species.

3.1.16 Major threats to conservation of orchids in Nyika National Park

a) Business people

Even though orchids are browsed by wild animals and rodents which were evident during the survey, the greatest threat to the orchids of the Nyika Plateau lies in the increase of illegal orchid harvesters. Most collectors are surrounding communities who are enticed by traders from as far as Karonga or Chitipa with connections to Tanzania and Zambia using the mentioned districts nationals as conduits. In certain cases, some of the far fetching traders seek supplies of orchids from surrounding villagers to illegally enter the Nyika National Park to risk their lives by collecting orchids illegally. Understandably, some of the traders originate from within the villages and later sale the product to traders from outside.

b) Invasive species

The other challenge faced by the orchids of the Nyika National Park is the proliferation of invasive plant species which are a seriously threat to orchid biodiversity in the Nyika National Park. Sites around Chelinda Airstrip, Chelinda East (Libwe la Chiphimba), Dembo area and North Rukuru Bridge among others are heavily colonized by *Pteridium* species. Other species observed includes *Rubus elypticus* and *Acacia mernsii* (Black wattle). The other species still reclaiming land in areas where orchids thrive best are the *Pinus patula* wildlings. Although attempts were made to remove the species, the remainder plants continue to produce unwanted seeds that germinate and establish with ease.

c) *Poverty and lack of alternative sources of income to surrounding* communities

Poverty was found to be one of the profound causes to natural resources degradation around and inside the Nyika National Park. A large proportion of the village communities surrounding the park are poor and have no alternative sources of livelihood apart from using the natural resources existing in their villages or optionally in the National Park. Further, there is an increased rate of unemployment evidenced by a lot of school leavers failing to get jobs, thus engage in collection of edible orchids as a better livelihood option according to them.

d) *Negligent community based institutions*

Community based conservation clubs are common around the Nyika National Park. These are responsible to the management of natural resources together with the Department of Parks and Wildlife and the chiefs in the area. Notably, wildlife management committees control entry of the village communities into the national park whereby they issue permits to village members to collect firewood, thatch grass, mushrooms and honey amongst others. They also are supposed to check what produce has been collected on exit. However, were members are weak and have not been trained enough; they fail to perform the duty required of them. Orchids and other natural resources continue to diminish both in the National Park and on customary land. Perhaps the local institutions are less motivated to monitor and apprehend culprits digging or trafficking orchids or rather just ignore their social responsibility required of them.

e) *Weak local authorities*

Village headmen in collaboration with local institutions such as the Wildlife Management Committees at local level are supposed to relay messages to communities on natural resource management outside and inside the National Park. In all the villages, community members have the respect for their leaders and are willing to listen to them. However, in some cases, village headmen do not enforce the required rules and regulations governing sustainable utilization of natural resources. Some respondents revealed that village headmen and their advisors allow business people from urban areas to come to their areas and use natural resources through corrupt practices. In such cases, village headmen fail to enforce rules and regulations governing the sustenance of natural resources in their areas hence leave natural resource management on free for all conditions.

f) Patrol teams

Organized patrols are key in the protection of natural resources as they tend to scare away perpetrators. At the same time, confiscation of illegally obtained produce such as orchids and other illegally collected produce tend to detour perpetrators. However, there could be some serious mismatches in the implementation of patrols inside and outside the Nyika National Park where edible orchids are concerned. The difficulties associated to patrols lies in differentiating edible orchids that are from within the park and those from outside especially to orchid collectors found selling outside the park. Therefore, identification of orchids from the park from those from the community woodlands could help in protection of orchids on the Nyika Plateau.

3.2 Diversity, distribution and abundance of edible orchids

3.2.1 Diversity of orchids in study sites

The study identified ten genera of both edible and non-edible orchids (Figure 3.12) from 54 species in the study namely: Satyrium, Disa, Habenaria, Eulophia, Brachycorythis, Brownlea, Cynorkis, Disperis, Neobolosia, and Reoperocharis. The genera Satyrium (28%) and Disa (26%) had the largest number of species, while the lowest number observed were, Disperis (1%), Neobolusia (1%) and Reoperocharis (1%).

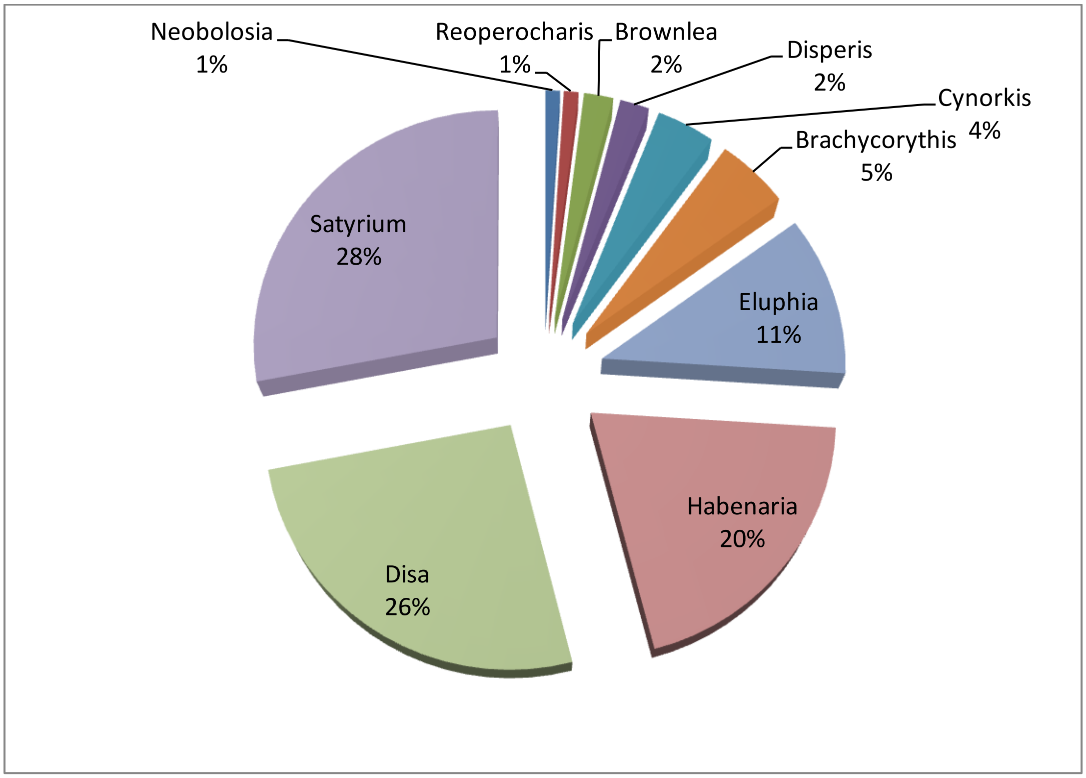


Figure: 3.12: Genera of orchids inventoried in the study sites

3.2.2 Community identified edible orchids

The study identified 43 orchid species as edible from a total of 54 species (Table 3.4). Forty-three (43) species were identified as collected for both trade and home consumption in the Nyika National Park. The identified edible species are from the Genera, *Habernaria*, *Disa*, *Brachycorythis*, *Satyrium* and *Neobolusia*. While other non-edible species recorded from the survey belonged to *Eulophia*, *Brownlea*, *Cynorkis, Disperis and Reoperocharis.* The most preponderant species genera were *Satyrium* (28%) and *Disa* (26%), while the least common genera observed were *Brownlea* (1%), Disperis (1%), Neobolusia (1%) and Reoperocharis (1%) .

Table 3.4: Diversity of orchids (latin and local name) found at 16 sites and their use status in the Nyika National Park

SERIAL NO.	SPECIES	LOCAL NAME	LOCALITY OF COLLECTION	LOCAL USE
NYK01	*Brachycorythis pleistophylla* Reichb.f.	Joyisi	Kaperekezi, Thazima	Edible
NYK02	*Brachycorythis pubescens* Harv.	Joyisi	North Rumphi Bridge	Edible
NYK03	*Brownlea parviflora* Lindl.		Chelinda	Non-edible
NYK04	*Cynorkis anacomptoides* Kraenzl.		Chelinda	Non-edible
NYK05	*Cynorkis kassneriana* Kraenzl.	Chinaka chamu paini	Chelinda	Edible?
NYK06	*Disa celata* Summerh.	Chinaka	Dembo, Chelinda	Edible
NYK07	*Disa concinna N.E. Br.*	Chinaka	Dembo, Chelinda, Nganda, N. Rukuru R.	Edible
NYK08	*Disa engleriana* Kraenzl.	Chinaka cha sekelemo	Dembo, Kaulime, Chelinda, Thazima	Edible
NYK09	*Disa hicicornis* Reichb.f.	Chinaka	Dembo, Chelinda	Edible
NYK10	*Disa ochrostachya* Reichb.f.	Chinaka	Chelinda, British A.B	Edible
NYK11	*Disa onithantha* Schltr .	Chinaka cha sekelemo	Chelinda, Kaulime,	Edible
NYK12	*Disa perplexa* Lindl.	Chinaka	Dembo, Chelinda	Edible
NYK13	*Disa robusta* N.E.Br.	Chinaka	Dembo, Chelinda, Kaulime, Nganda, N. Rumphi R., N. Rukuku .	Edible
NYK14	*Disa satyriopsis* Kraenzl.	Chinaka	Chelinda	Edible
NYK15	*Disa saxicola* Schltr.	Chinaka	Vipiri	Edible
NYK16	*Disa stolzii* Schltr.	Chinaka	Chelinda, Kaulime	Edible
NYK17	*Disa ukingensis* Schltr.	Chinaka	Zovochipolo	Edible
NYK18	*Disa welwischii* Reichb.f.	Chinaka	Chelinda	Edible
NYK19	*Disa zombica* N.E.Br.	Chinaka	Kaperekezi, Thazima	Edible
NYK20	*Disperis anthoceros* Reichb.f.		Cheliinda	Edible
NYK21	*Eulophia coeloglossa* Schltr.		Chelinda	Non-edible
NYK22	*Eulophia milnei* Reichb.f.		Chelinda, N.Rukuru R.	Non-edible
NYK23	*Eulophia seleensis* (De wild.)		Chelinda dam 3	Non-edible
NYK24	*Eulophia speciosa* (R.Br. ex Lindl)		Dembo	Non-edible
NYK25	*Eulophia thomsonii* Rolfe.			Non-edible
NYK26	*Habenaria cornuta* (Lindl.)		Cheinda,Dembo, Dam3, N. Rukuru R,	Edible
NYK27	*Habenaria clavata* (Lindl.) Reichb.f	Chinaka	Thazima	Edible
NYK28	*Habenaria diselloides* Schltr.	Chinaka	North Rukuru	Edible

SERIAL NO.	SPECIES	LOCAL NAME	LOCALITY OF COLLECTION	LOCAL USE
NYK29	*Habenaria filicornis* Lindl.	Chinaka	Dembo, Zovochipolo	Edible
NYK30	*Habenaria insolita* Summerh.	Chinaka	Chelinda dam 3	Edible
NYK31	*Habenaria kyimbilae* Schltr.	Chinaka	Dembo	Edible
NYK32	*Habenaria macrostele* Summerh.	Chinaka	Dembo	Edible
NYK33	*Habenaria praestans* Rendle.	Chinaka	Dembo	Edible
NYK34	*Habenaria shimperana* A.Rich.	Chinaka	Dembo, Chelinda East	Edible
NYK35	*Habenaria zambesina* Reichb.f		North Rukuru R.	Edible
NYK36	*Neobolusia stolzii* Schltr.	Chinaka	Dembo	Edible
NYK37	*Reoperocharis beunettiana* Reichb.f.		Dembo	Non-edible
NYK38	*Satyrium amblyosaccos* Schltr.	Chinaka	Zambia R area	Edible
NYK39	*Satyrium atherstonei* Reichb.f	Chinaka	N. Rukuku,Dembo, Chelinda,Mwanyenyezi	Edible
NYK40	*Satyrium breve* Rolfe.	Chinaka	Nganda, North Rumphi River, Chelinda, Kaulime, Dembo	Edible
NYK41	*Satyrium buchananii* Schltr.	Chinaka	Chelinda,Kaulime, British army base	Edible
NYK42	*Satyrium carsonii* Rolfe.	Kabatika	Thazima, Kaperekezi	Edible
NYK43	*Satyrium crassicaule* Rendle.	Chinaka	Jalawe	Edible
NYK44	*Satyrium chlorocorys* Rolfe.	Chinaka	Kaulime, North Rumphi Zovochipolo	Non-edible
NYK45	*Satyrium monadenum* Schltr	Kabatika wa mu Nyika	N. Rukuru, Kaulime, Chelinda	Edible
NYK46	*Satyrium orbiculare* Rolfe.	Kabatika wa mu Nyika	Chelinda, British army base	Edible
NYK47	*Satyrium princeae* Kraenzl.	Chinaka	British A.Base Chelinda, Zovochipolo, Kaulime,	Edible
NYK48	*Satyrium sacculatum* (Rendle)Rolfe.	Chinaka	Dembo, British army base, North Rumphi R. Chelinda, Zovochipolo	Edible
NYK49	*Satyrium sceptrum* Schltr.	Chinaka	Chelinda, Dembo	Edible
NYK50	*Satyrium rhynchatoides* Schltr.	Chinaka	Chlinda Dam 3	Edible
NYK51	*Satyrium trinerve* Lindl.	Chinaka	Dembo,British army base, Zovochipolo	Edible
NYK52	*Satyrium shirense* Rolfe.	Chinaka	North Rukuru, Airstrip	Edible
NYK53	*Satyrium sphaeranthum* Schltr.	Chinaka	North Rukuru River	Edible

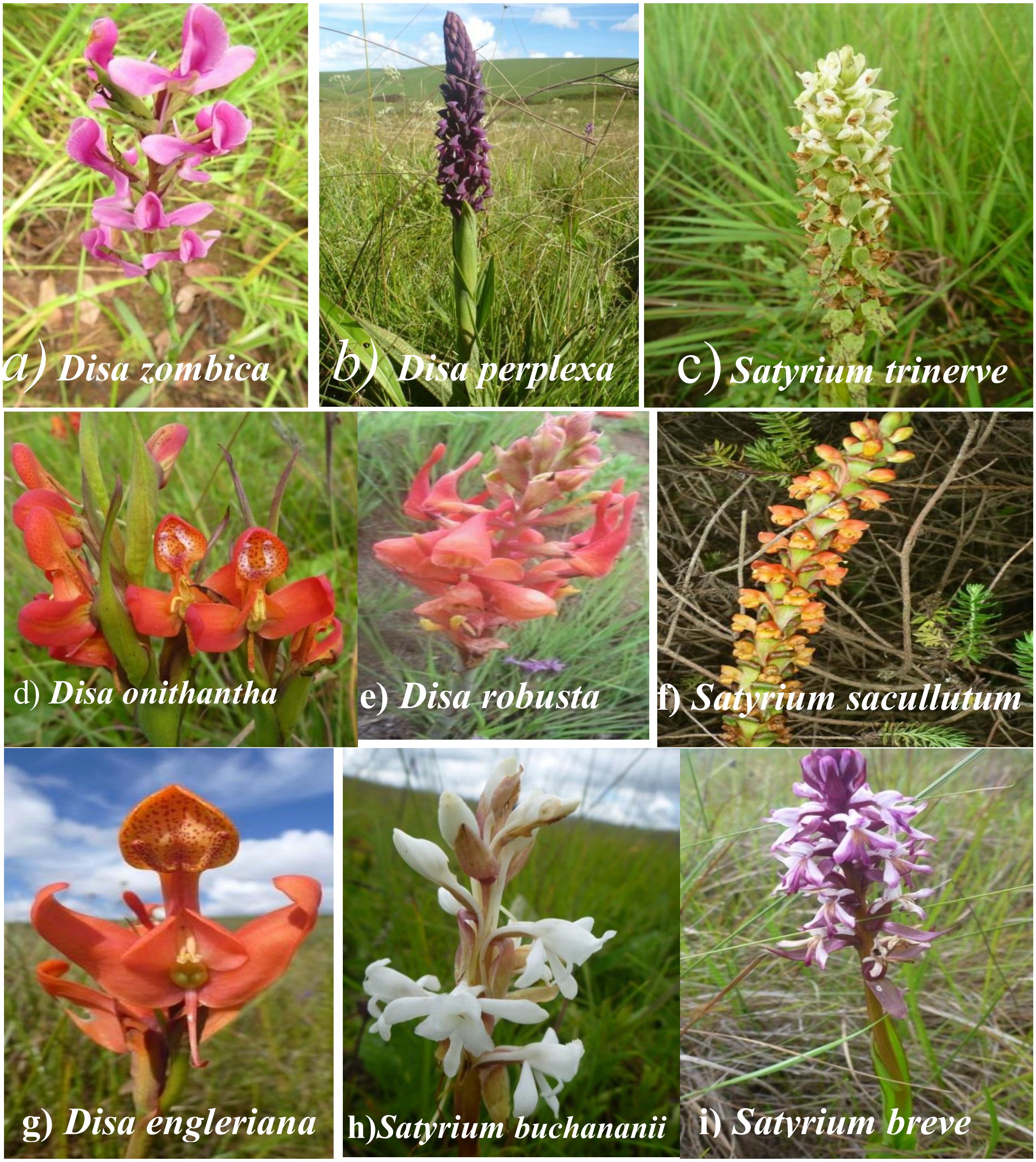


Figure 3.13: Some of the inventoried edible Orchids

3.2.3 Species diversity with respect to vegetation types

Simpson's diversity index for the different vegetation types are presented in Figures 3.14. Orchid species diversity varied significantly (H=26, P $\leq$ 0.05) among the five vegetation types. The montane wetlands had the highest diversity of orchids (median=0.73; average rank= 31.51) followed by the montane grasslands (median=0.51 average rank= 16.9), while miombo woodlands had median= 0.50, average rank 17.0. The pine plantation and the evergreen-forest vegetation types had the least species diversities (median=0.223, Average rank= 4.0) and (Median =0.04, average rank =1.5) respectively. Kruskal-Wallis analysis revealed highly significant differences in orchid species diversity between the vegetation types (H= 26.6, P<0.000). This means that the montane wetlands were more orchid diverse than the other vegetation types.

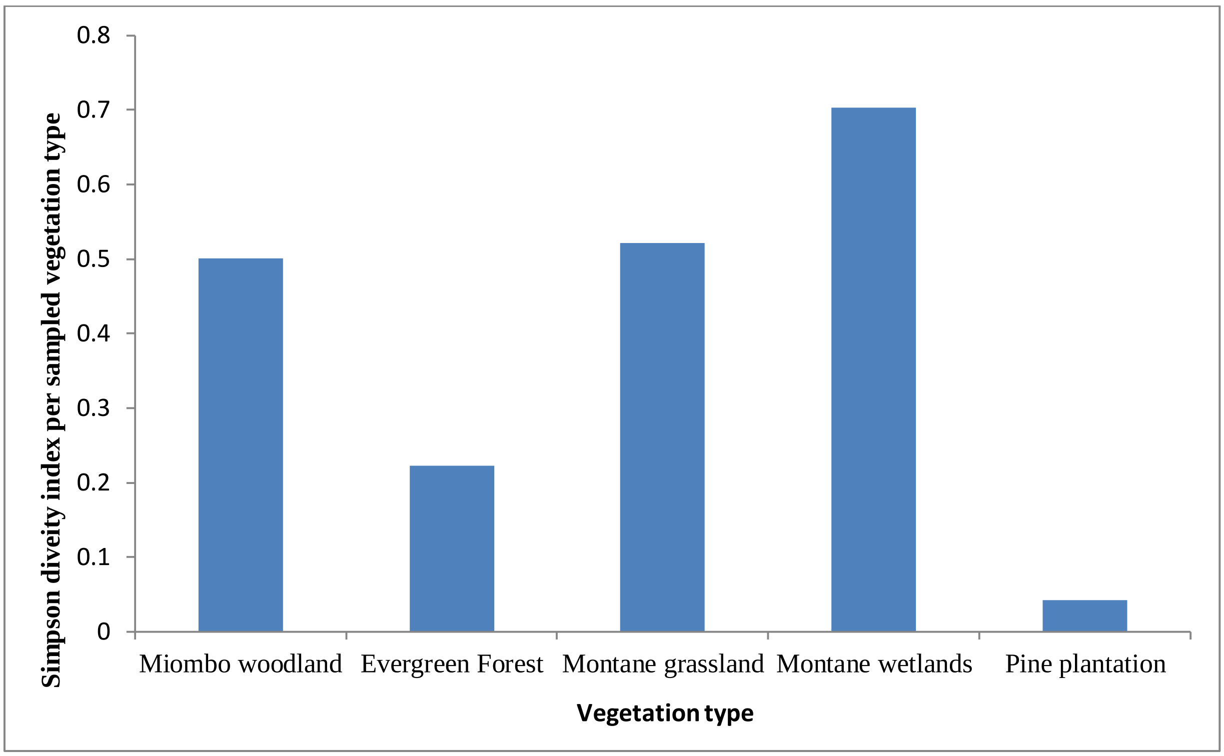


Figure 3.14: Simpson's diversity index of orchids in different vegetation types

3.2.4 Species richness with respect to vegetation type

Species richness estimates were the highest in montane wetlands (41.0), montane grasslands (25.0) Miombo woodlands (4.0), montane evergreen forests (2.0), and the pine plantation (2.0) (Table 2). A total of fifty-four (54) orchid species were observed in the sampled localities (Table 2). Of the total orchid species observed, no species were common in all the five vegetation types identified. Kruskal-Wallis ranking test revealed significant differences between vegetation types (P=0.05). Results of the study reveal that montane wetlands and montane grasslands are orchid diverse than the rest.

3.2.5 Species richness with respect to site

Orchid species richness with respect to sites in the Nyika National Park are presented in Figure 3.15 and Figure 3.16. Species richness varied between sites. High species richness (number of orchid species per site) were recorded in the North Rukuru River valley (23) followed by Chelinda East (22), and Dembo valley (17). While low species richness with respect to site was observed at Jalawe (1) and Manyenyezi forest (2), Thazima (3).

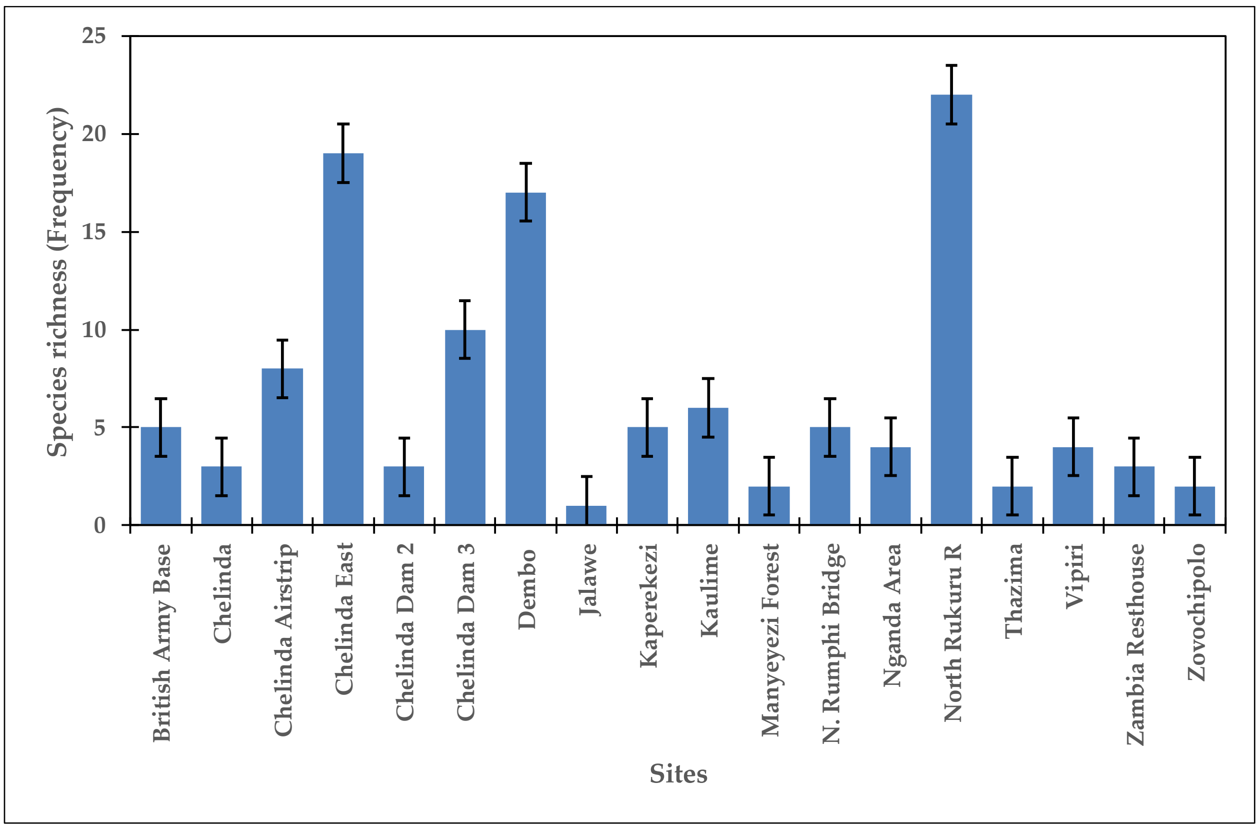


Figure 3.15: Orchid species in Nyika National Park with respect to site

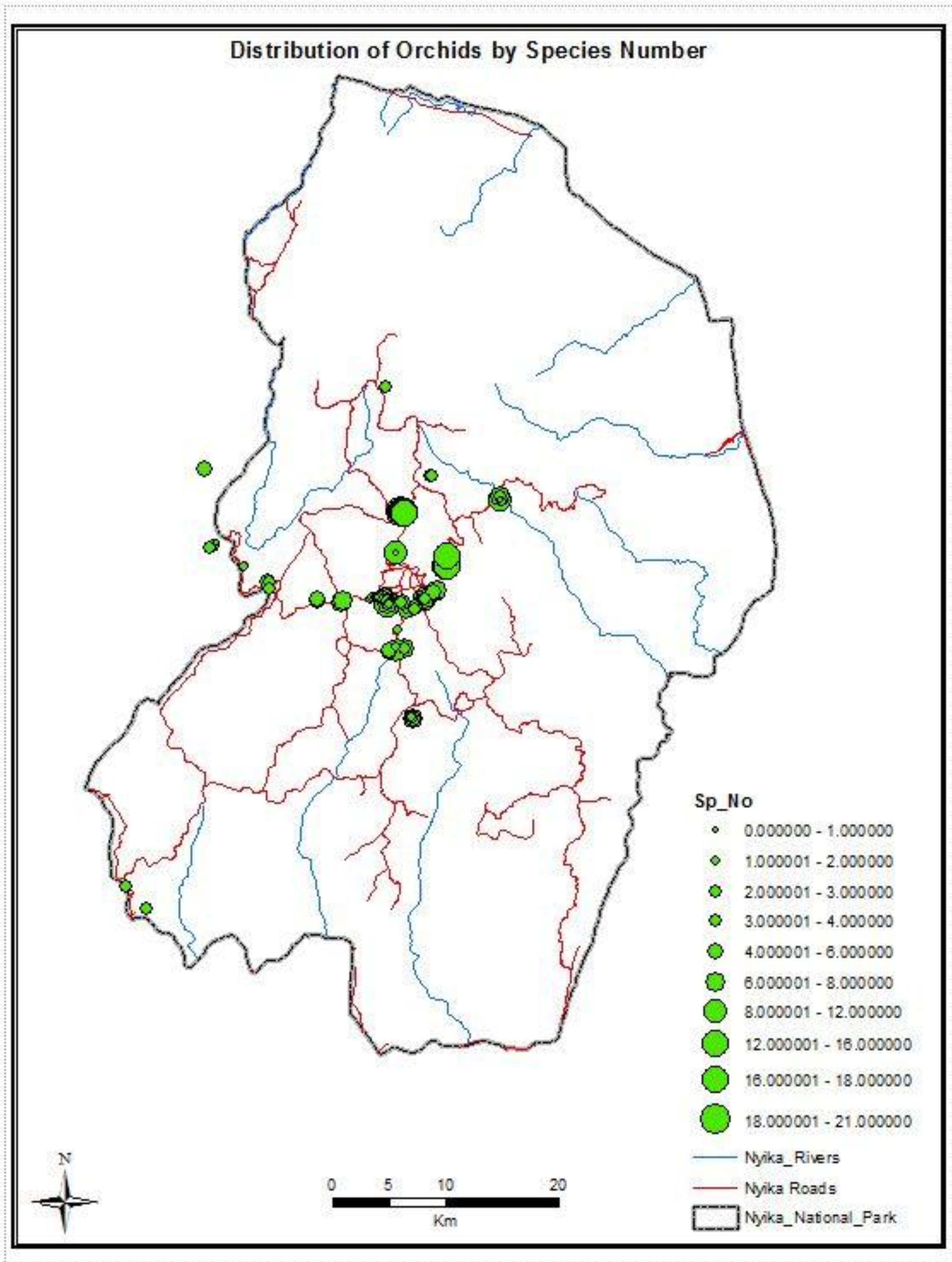


Figure 3.16: Hotspots for the edible orchid in the Nyika national park

3.2.6 Abundance of orchids with respect to vegetation types

Abundance of orchids (individual counts per hectare) in sampled vegetation types are presented in Figure 3.17. Kruskal-Wallis analysis on overall orchid abundances between vegetation types reveal high significant difference (H= 18.47; DF=4; P =0.001). The pine plantation recorded highest number of orchids per hectare (median= 3600) seconded by the montane evergreen-forest (median= 2360). While montane wetlands had median= 1760. The miombo woodland and the montane grasslands recorded the least in orchid abundances respectively (median= 390) and (median 1110) respectively. This result indicates that orchids were more numerous in the pine plantation than the rest of the vegetation types.

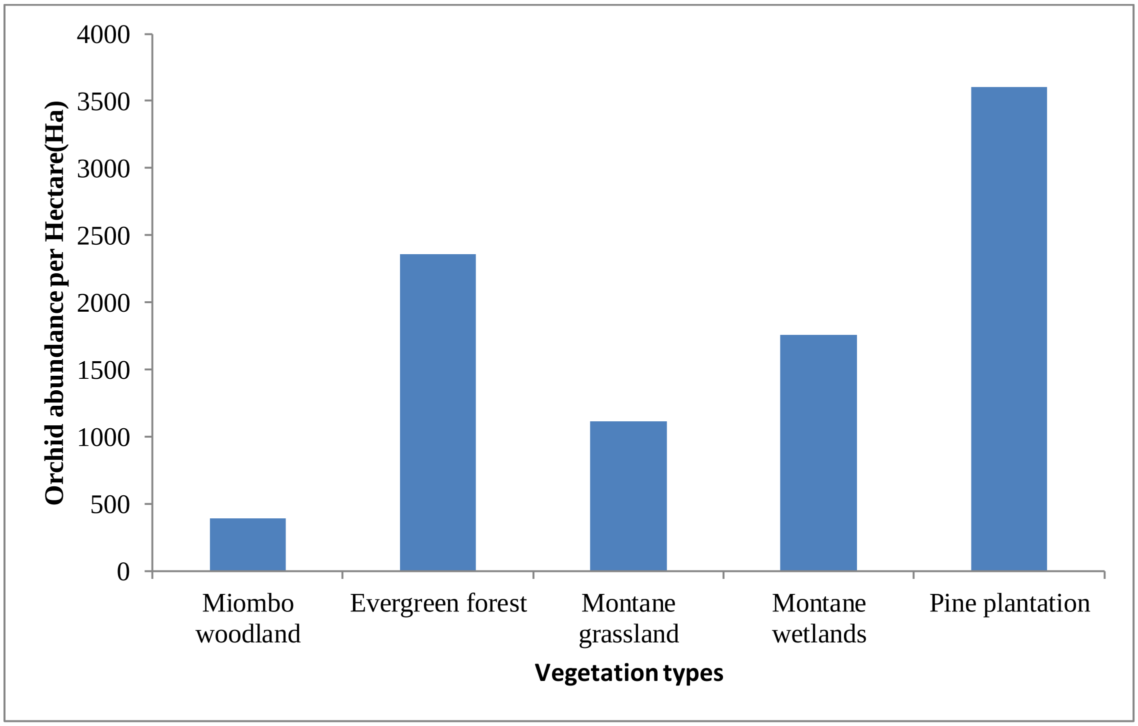


Figure 3.17: Edible orchid abundances with respect to vegetation types

3.2.7 Abundances of orchids in the study sites

The most abundant orchid species recorded in the study sites are presented in Figure 3.18 below. The most abundant species recorded were *Cynorkis kassneriana* (8230 plants per hectare) followed by *Satyrium antherstonei* (6810 plants per hectare), while the lowest (individual plants ≥700 per hectare) were Satyrium trinerve and Disa ukingensis respectively.

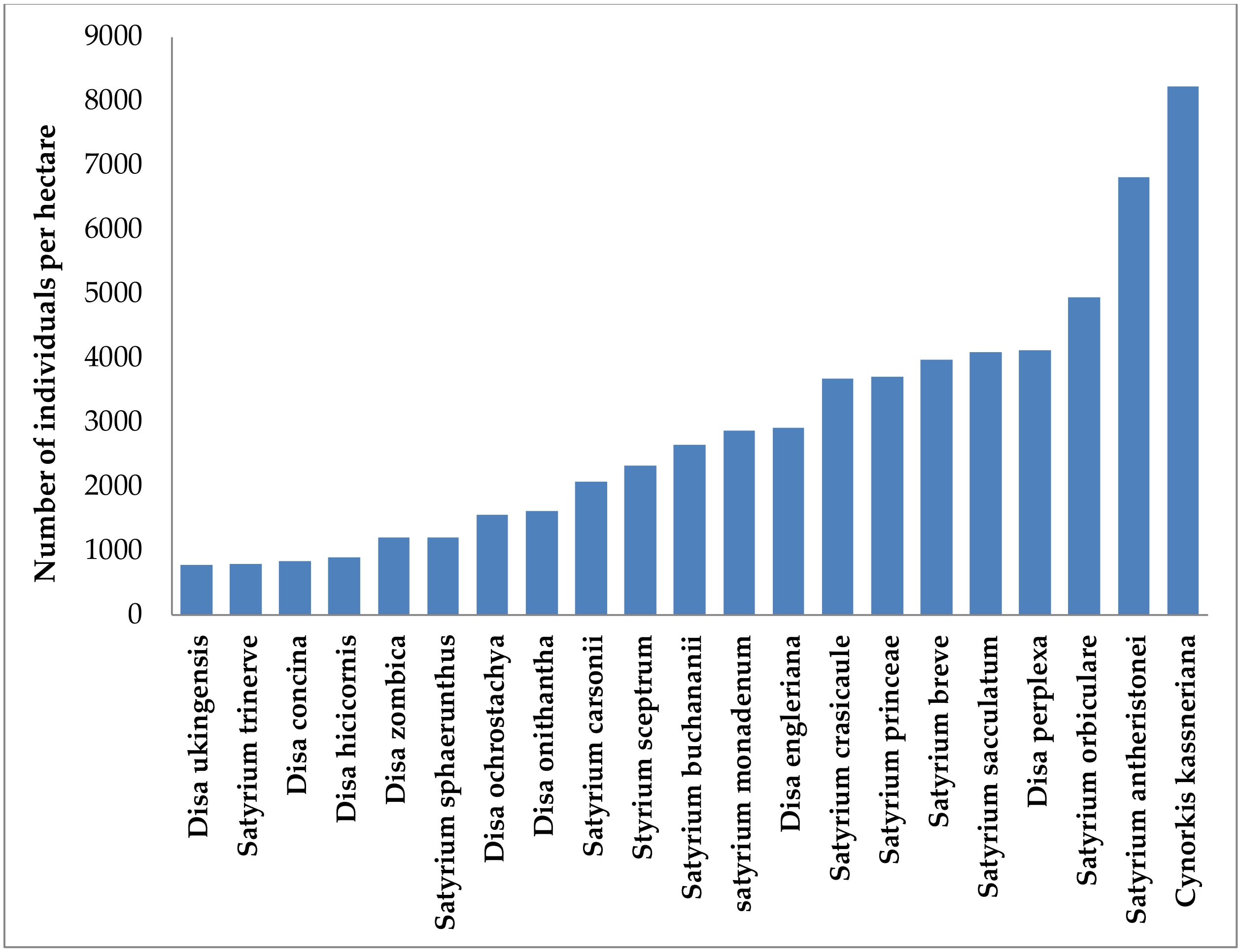


Figure 3.18: Top 20 abundant orchid species in the study sites

3.2.8 Relationships between orchid species richness and abundances with environmental variables

Pearson correlation analysis (r) of orchid species richness and abundances to basic soil properties (N,P,K and other associated environmental variables are shown in Table 3.5. There were significant positive relationships between availability of soil nitrogen (r= 0.85) and Iron (r=0.77) to the abundance of orchids in the study sites. Soil carbon, OM, K, P, Ca and soil pH were not significantly and linearly related to orchid abundance. In terms of species richness, significant positive relationships were observed between altitude and species richness (r=0.66).

Results of the CCA ordinations show that soil carbon (C), organic matter content (OM) Phosphorus (P) and Potassium were closely associated to each other among species (Figure 3.19). While marked and definite relationships were observed between soil carbon and richness (r=0.4) and organic matter and richness (r=0.37). These results indicate that availability of soil nitrogen and iron influence abundance of orchid. Similarly, a change in altitude, soil carbon and organic matter will positively influence orchid species richness in Nyika National Park.

Table 3.5: Relationship between environmental variables and orchid species abundance and richness

Soil property	Species abundance		Species richness	
	Correlation “r”	p-value	Correlation “r”	p-value
Altitude	0.454	0.220	0.66	0.050
pH	0.216	0.114	0.253	0.054
Carbon (C)	0.199	0.126	0.400	0.004
Organic Matter (OM)	0.233	0.105	0.374	0.006
Nitrogen (N)	0.847	0.030	0.367	0.008
Potassium (K)	0.482	0.109	0.118	0.214
Iron (Fe)	0.768	0.046	0.118	0.210
Phosphorus (P)	0.315	0.155	0.145	0.174
Calcium (Ca)	0.337	0.148	0.134	0.189

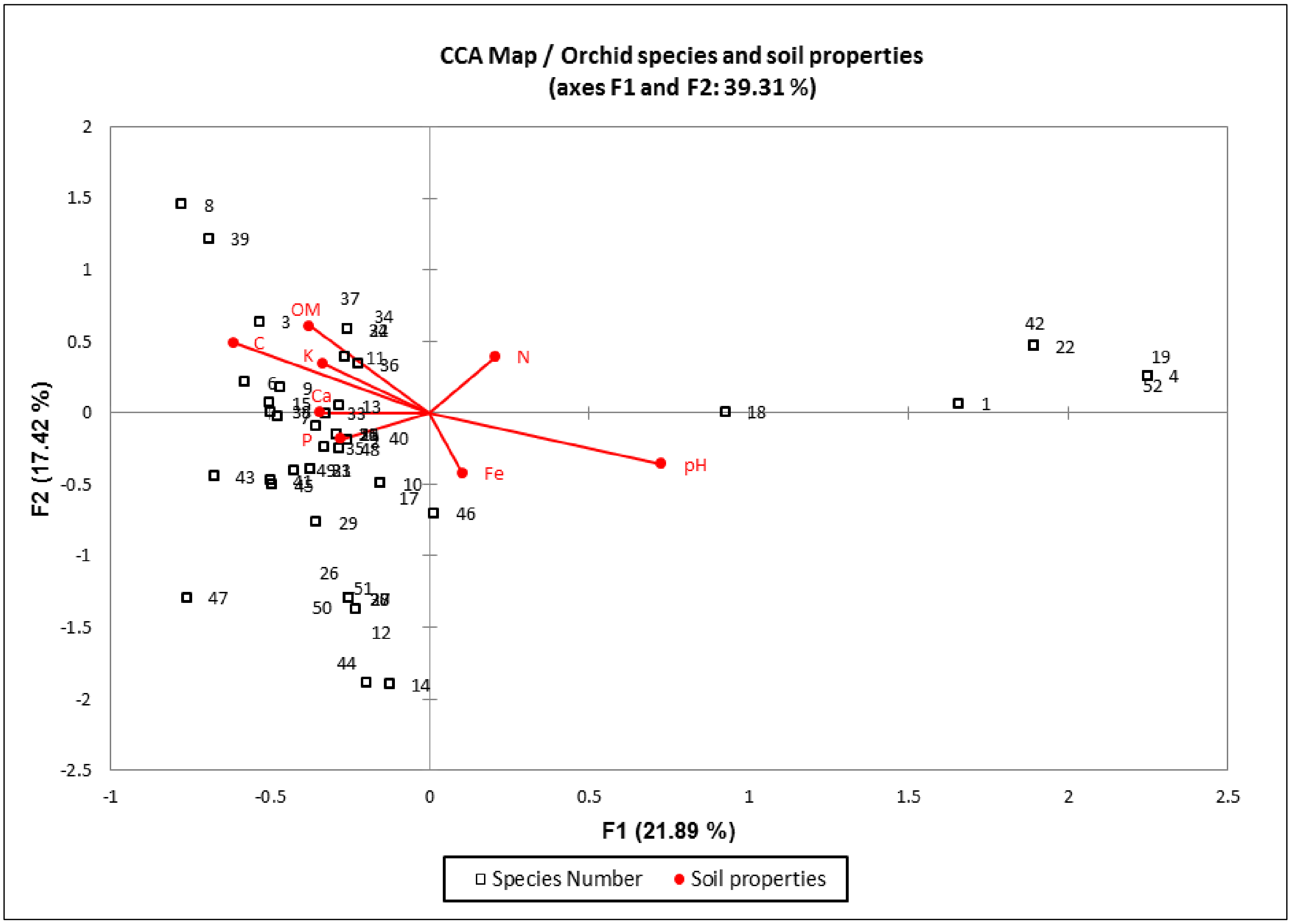


Figure 3.19: Canonical correspondence analysis of soil properties and orchid species in Nyika National Park

3.3 Morphological variations of the orchid tubers in Nyika National Park

3.3.1 Orchid stem height variations

The box and whisker plots (Figure 3.20) shows how character means varied between species. The measured character (stem height) revealed significant variations ($P<0.05$) in the sampled edible terrestrial orchids. A comparison of the average stem height values for the edible orchid species shows that stem length ranged from 19 to 72cm for flowering plants and 0.5 to 34 cm for non-flowering terrestrial orchid plants. *Satyrium sacullatum* and *S. sceptrum* were the tallest ranging from 29 to 50cm and 30 to 49cm respectively while *Satyrium obiculare* and *Disa zombica* were the least ranging from 1to 9 cm.

3.3.2 Orchid root collar diameter variations

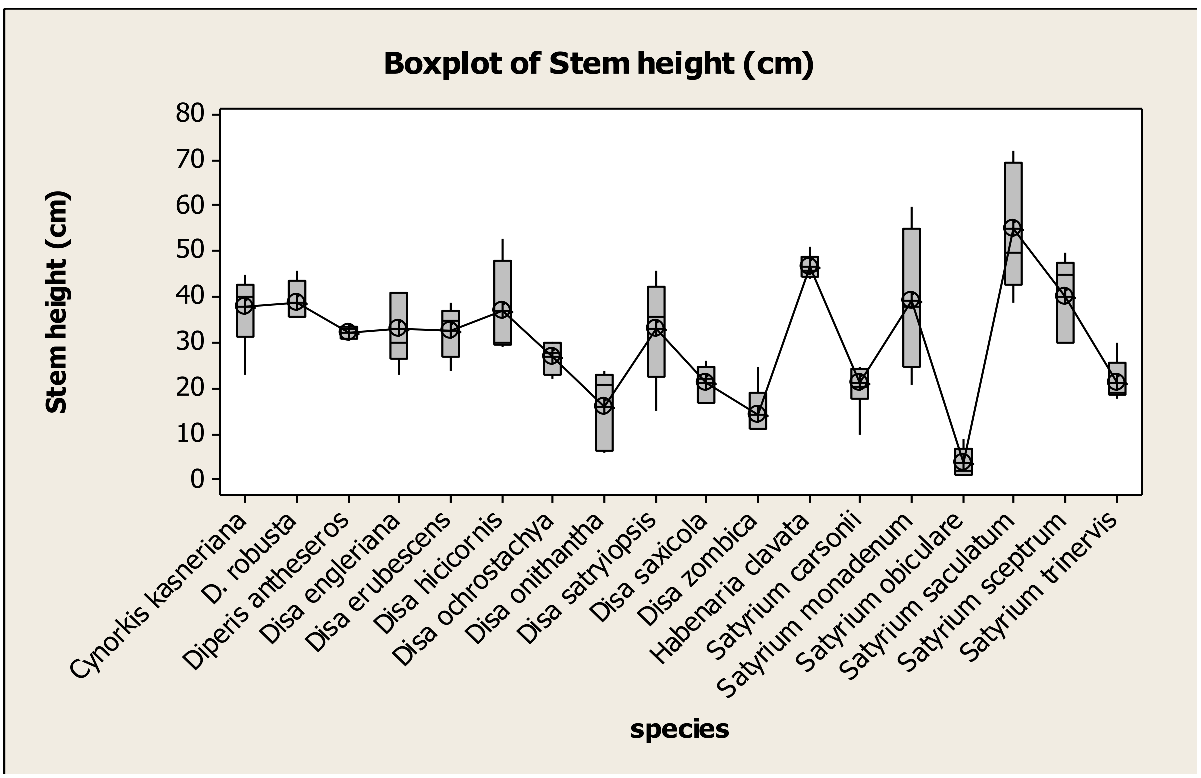


Figure 3.20: Edible orchids stem height in for the various species investigated.

3.3.3 Tuber morphological variations in the orchid species

1.0 Number of tubers

The average number of individual tubers recorded from each orchid species are presented in table 3.5. There were significant differences ($P \leq 0.05$) in number of tubers recorded among orchid species. Tubers recorded from individual orchid plants ranged between 1 to 6 (Table 3.5). The highest number of storage tubers (mean= 4) were recorded from *Brachycorythis pleistophylla* and *Cynorkis kassneriana*, while the lowest numbers (mean=1) were observed in *Disa robusta, D. onithantha, D. engleriana, Habenaria clavata, Satyrium monadenum* and *S. sceptrum*. However, remaining orchid species had two (2) underground storage tubers from an individual plant species (Table 3.5). These results indicate high variability in number of underground storage organs between orchid species.

2.0 Tuber weight

Results of tuber weights among the 21 orchid species are presented in table 3.5 below. There were significant differences ($P \leq 0.05$) in tuber weights among the edible orchid species investigated. The heaviest tubers were recorded from *Disa robusta* (46.2±3.18g) and *Disa ochrostachya* (34.63±5.54g). Intermediate tuber weights were found in *Brachycorythis pleistophylla* (30.92±12.82g), *Disa engleriana* (27.89±12.97g) and *Satyrium sceptrum* (26.7±12.97). Smaller weights were recorded from *Satyrium carsonii* (2.432 ±0.76g) and *Disa ukingensis* (1.8±0.41 g).

Table 3.5: Morphological variations of edible orchids

SPECIES	NUMBER OF REPLICATES	ROOT COLAR DIAMETER (mm)	NUMBER OF TUBERS	MEAN TUBER WEIGHT (g)
Disa robusta	15	7.4 (0.710)a	1	46.20 (3.18)a
Disa ochrostachya	15	1.240 (0.434)b	2	34.63 (5.54)ab
Brachycorythis pleistophylla	10	6.000 (1.225)abc	4	30.92 (12.82)b
Disa engleriana	15	4.000 (1.414)abcd	2	27.89(11.98)b
Satyrium sceptrum	15	4.40 (1.304)a	1	26.7 (12.97)bc
Satyrium obiculare	15	4.400 (0.894) abcd	2	12.32 (9.67)cd
Disa onithantha	15	4.900 (2.608)abc	1	11.68 (3.03)cd
Satyrium saculatum	15	6.400 (2.191)abc	2	11.404 (3.87)d
Disa satryiopsis	15	5.800 (2.775)abc	1	11.16 (4.77)d
Satyrium trinervis	15	5.200 (3.899)abc	2	9.638 (2.64)d
Satyrium sceptrum	15	4.400 2.510abc	2	8.068 (1.52)d
Disa hicicornis	15	5.400 (0.894)abcd	2	6.092 (4.18)d
*Disa erubescens**	15	3.000 (0.000) cd	2	5.940 (1.02)d
Satyrium monadenum	15	4.200 (1.095)abcd	1	5.312 (1.96)d
Cynorkis kasneriana	15	4.200 (0.837)abcd	4	3.424 (1.03)d
Diperis antheseros	15	3.200 (0.447)cd	2	3.234 (0.76)d
Habenaria clavata	15	3.400 (0.548)cd	1	2.826 (0.9)d
Disa zombica	15	3.600 (0.548)bcd	2	2.725 (1.16)d
*Disa stolzii**	15	5.000 (0.000)abc	2	2.720 (0.7)d
Satyrium carsonii	15	3.900 (0.738)bcd	2	2.432 (0.76)d
Disa ukingensis	15	4.240 (0.767)abcd	2	1.800 (0.41)d
GRAND MEAN		4.572	1.818	12.27
MINIMUM VALUE		1.00	1.0	1.02
MAXIMUM VALUE		12.00	6.0	56.00
P-VALUES		0.000	0.000	0.001

** Stems were dry before RCD measure*

3.0 Tuber length and width

The box and whisker plots (Figure 3.21) show how the character means (tuber length and tuber width) varied between the 21 different orchid species, as well as the amount of variations within each species. A comparison of the average values for each of the orchid species shows that tuber length ranged from 7.3 to 106 mm and tuber width ranged from 4.5 to 92.8 mm. Significant differences (P ≤ 0.05) were observed between the measured characters. *Brachycorythis pleistophylla* recorded the longest (103.2±9.63mm) tuber length followed by *Disa robusta* (63.8±5.02) and *S. sceptrum* (56.2±16.2 mm). The shortest tuber length was observed in *Disa ukingensis* (5.0±1.10) and *Satyrium carsonii* (16.2±6.99 mm) respectively. In terms of tuber width, D. robusta was the widest (40.9 ±3.31 mm) followed by *D. ochrostachya* (30.7 ±3.36 mm), while the least smaller diameter tubers was *B. pleistophylla* (1.2 ± 0.331) and *D. stolzii* (1.4± 1.141 mm) respectively.

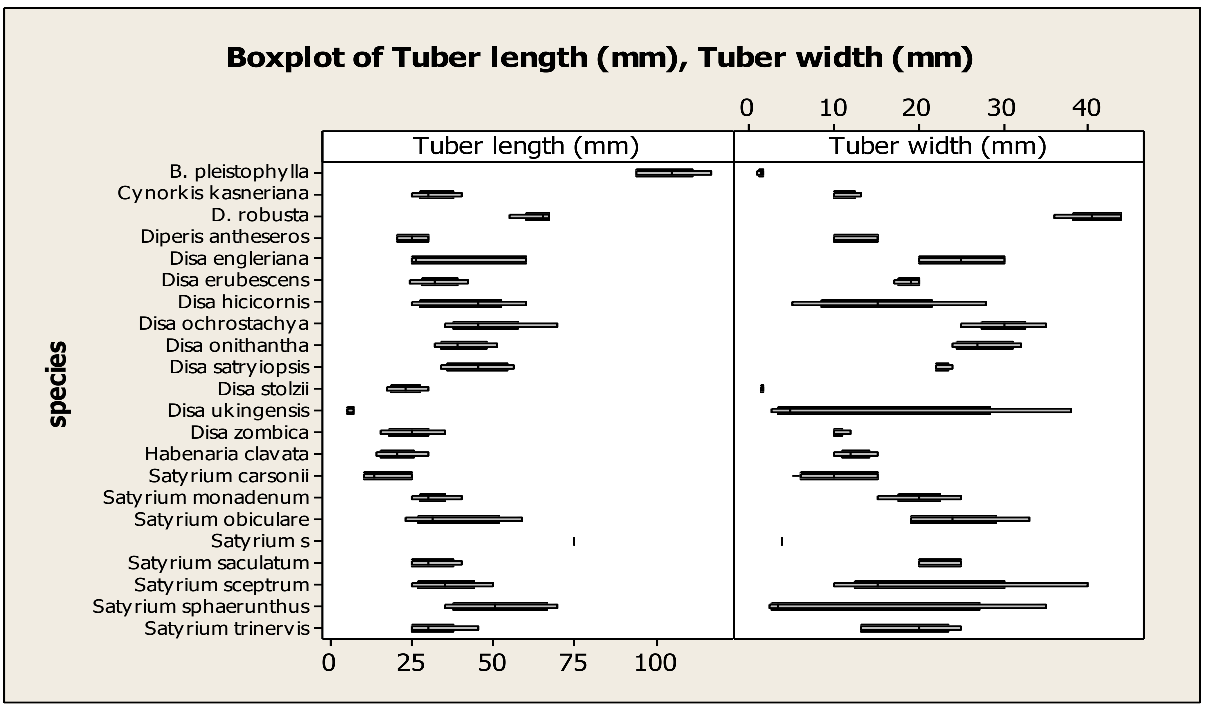


Figure 3.21: Box plot of mean tuber length (mm) and mean tuber width (mm) of the 21 orchids species

3.3.4 Diversity of tuber shapes

Thirteen (13) macro-morphological tuber-shapes were found among the 21 orchid species studied in the Nyika National Park (Figure 3.22).The tuber shapes found were elliptical, oblong, long-oblong, globose, compressed, ovoid, obovoid, cylindrical-billobed, elongated, and irregular shapes. The irregular shapes identified were arbitrary classified as heart-shaped, elephant-hooves and toothed-shape tubers (Figure 3.20). Tooth-shaped tubers were classed tooth-shaped1 (molar), tooth-shaped2 (canine).

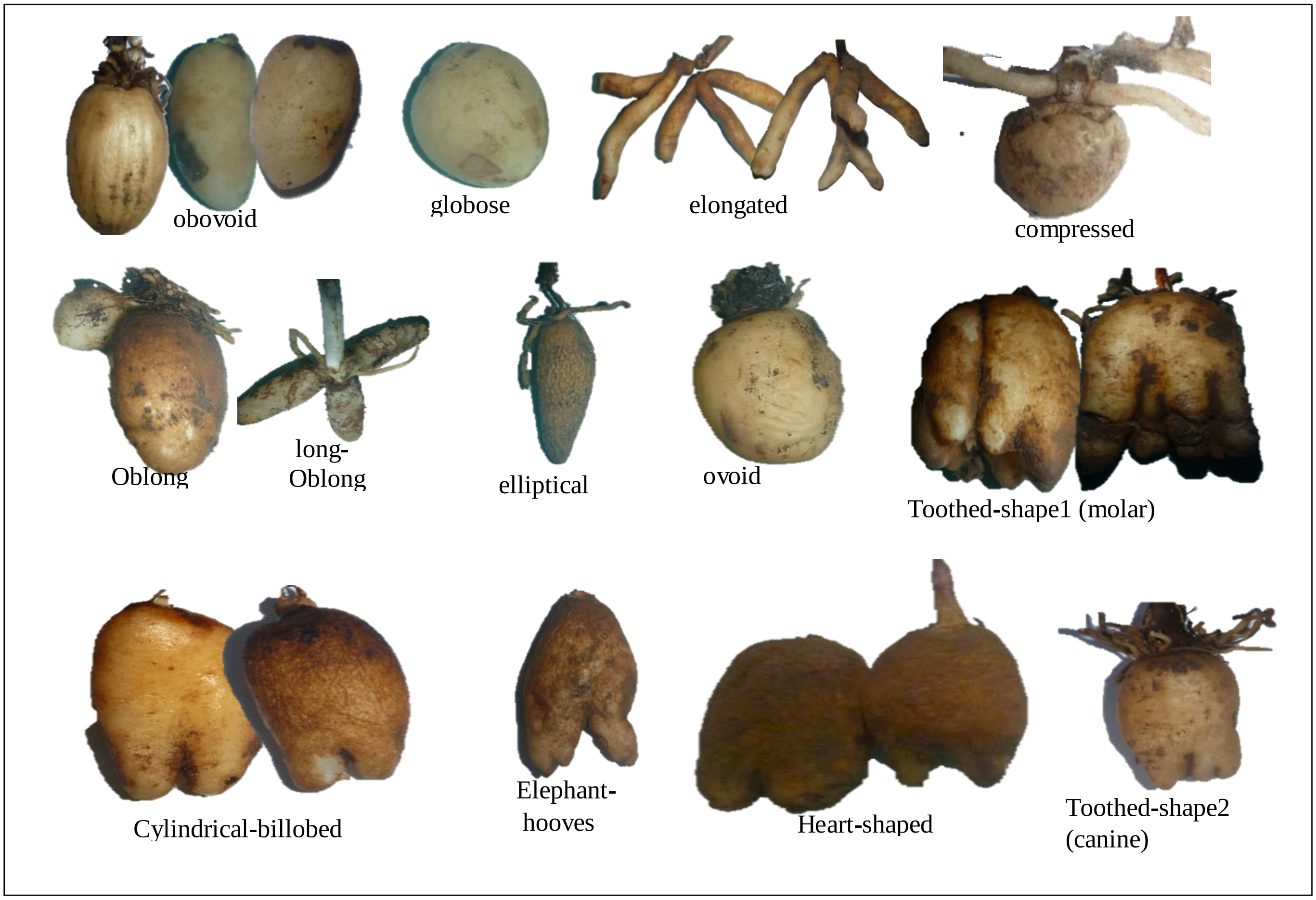


Figure 3.22: diversity of orchid tuber shapes in the study sites

3.3.5 Distribution of tuber shapes between species

The distributions of tuber shapes among the orchid species are shown in Principal Component Analysis (PCA) biplot (Figure 3.23). Results from the PCA biplot indicated that there were variations in tuber shape distributions between the orchid species (Eigen value =0.3779; Table 4.9). The oblong and obovoid tuber shapes revealed large positive contributions (0.71 and 0.15) to principal component axis (PC1) indicating high presence of the tuber shapes (Figure 3.23). While, the long-oblong and elliptic tuber shapes revealed large and positive variations (0.35 and 0.25) along PC2 axis (respectively). Results of the PCA biplot revealed that not all tuber shapes are closely associated to species. Some tuber shapes co-existed between species. While other shapes were not, but were species specific. For example, the oblong tuber shape co-existed between *Disa engleriana, Dispiris antheseros, Cynorkis kassneriana* and *Satyrium sacculatum* (Fig 3.23). While, obovoid shape co-existed between *Disa zombica, D. stolzii, D. onithantha and Habenaria clavata*. The species specific tuber shapes observed were, tooth shaped and the long elongated. Therefore, this kind of situation is not ideal for identification of orchids, and more efforts should be made to enlarge the basis for classification of edible orchids using tuber shapes.

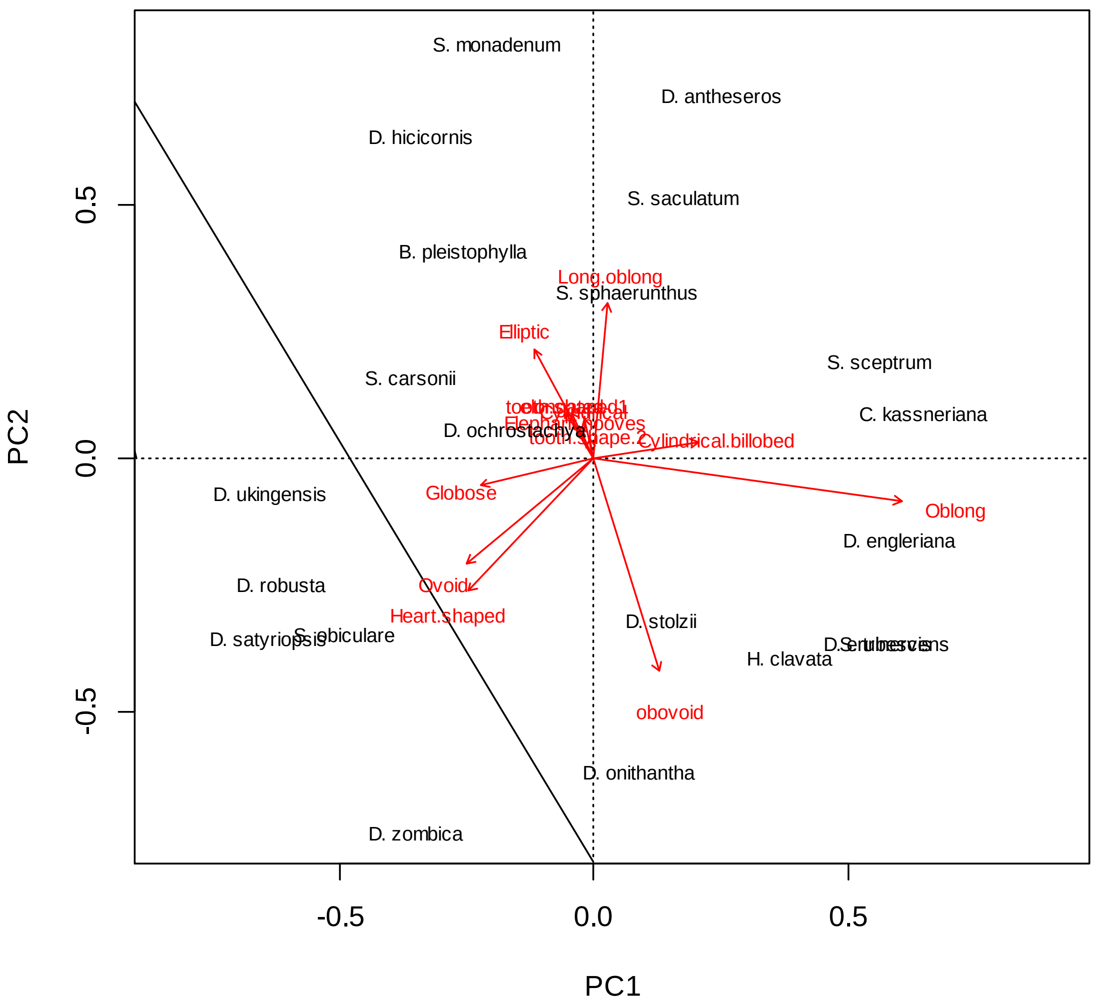


Figure 3.23: PCA Biplot of tuber shapes distributions between orchid species

Table 3.6: Eigenvalues and their contribution to the variance in Figure 3.21

	Principal Component (PC) axes						
	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	0.1699	0.1269	0.1109	0.09712	0.07389	0.06823	0.05614
Proportion Explained	0.2159	0.1612	0.1409	0.12338	0.09387	0.08667	0.07132
Cumulative Proportion	0.2159	0.3770	0.5179	0.64130	0.73516	0.82183	0.89315
Total inertia 0.781							

3.3.6 Frequency distribution of tuber shapes between orchid species

Tuber shapes were found to be distributed widely among the orchid species (Figure 3.24). The predominant tuber shape found was oblong (16.3%) followed by obovoid (14.9%), while compressed shape (0.99%) and the molar tooth-shape2 (2%) were least found in the study. No tuber shape was highly dominant over other shapes. Result from this study suggests that the edible orchid tubers shapes between species are not uniform, but vary between and within species.

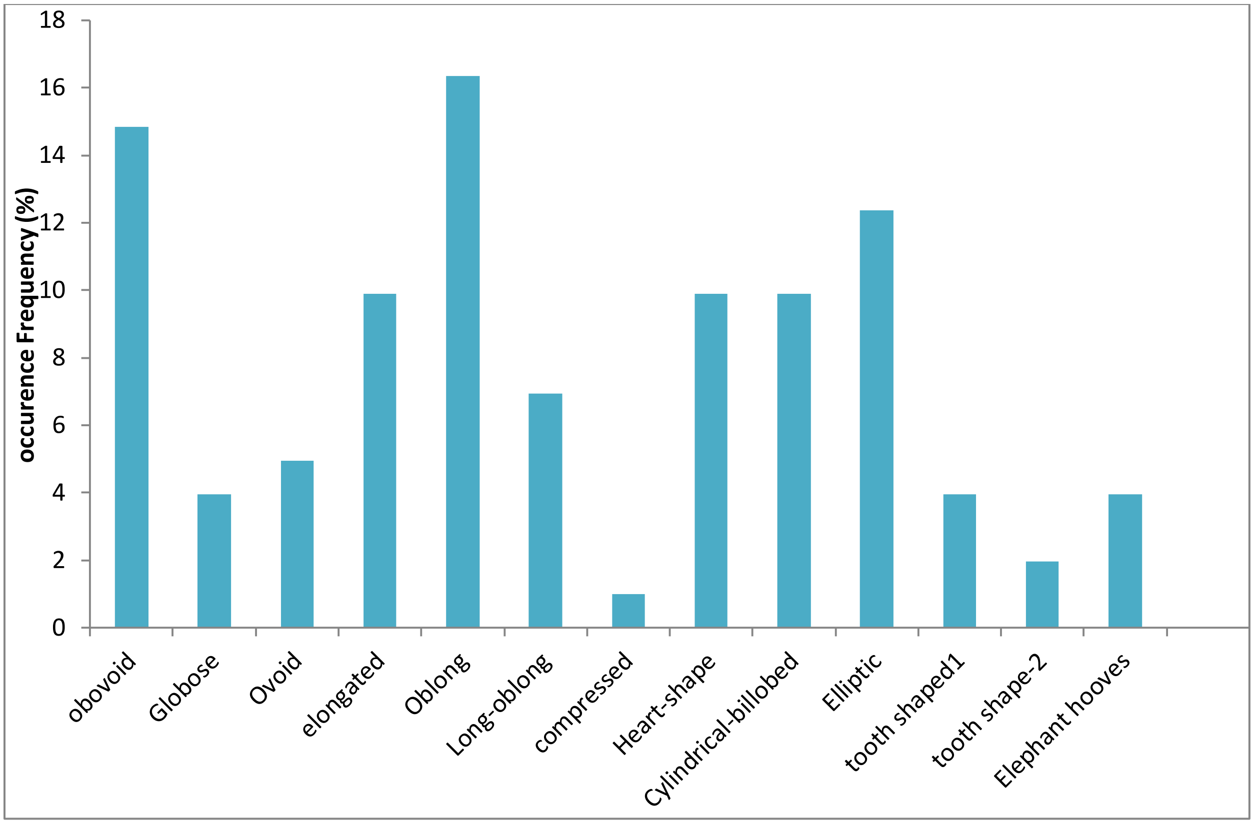


Figure 3.24: Frequency distribution of tuber shapes between orchid species

3.3.7 Diversity of orchid tuber colours

Figure 3.25 shows diversity of tuber skin colours between species investigated. Orchid tubers colours found were cream white, grey, light brown, and dark brown. In terms of proportions, 60% were brown, 20% light brown, 10% were dark brown. Disa robusta

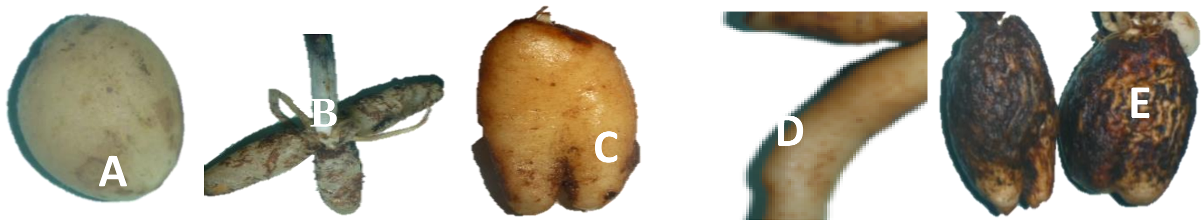


Figure 3.25: orchid tuber colours, A=cream white, B= grey, C=Light brown, D= brown D=Dark brown

3.3.8 Eye distributions

Orchid species studied revealed 0% eye distributions in all the tubers. This result may suggest that orchid tubers studied have no eyes.

3.3.9 Relationships between stem characters and tuber parameters

Results of the study shows significant positive relationships between tuber length and tuber width (r=85). Similarly, orchid tuber weights were positively correlated to tuber length (r= 0.59, $P \leq 0.05$) and tuber width (r=0.68) in the 21 species studied (Table 3.7). These results indicate that tuber length and tuber width are positively related to each other. Furthermore, tuber length and tuber width parameters are positively related to the mass of the tubers.

3.3.10 Relationship between tuber morphological characters

Results of the study shows that there were significant positive relationships between tuber length and tuber width (r=0.85). Similarly, orchid tuber weights were significantly correlated ($P \leq 0.05$) to tuber length (r= 0.59) and tuber width (r=0.68) studied species (Table 3.7). These results indicate that, tuber length and tuber width are positively related to each other. Furthermore, tuber length and tuber width parameters are positively related to the mass of the orchid tubers.

Table 3.7: Pearson's correlation coefficients between the stem and tuber morphological characters

	Tuber weight (g)	**RCD (mm)**	**Stem length (mm)**	**Tuber length (mm)**	**Tuber width (mm**
RCD (mm)	0.13* *0.198*				
Stem length (cm)	0.11 *0.310***	0.12 *0.239*			
Tuber length (mm)	**0.59** ***0.000***	0.15 *0.15*	**0.43** ***0.000***		
Tuber width (mm)	**0.68** ***0.000***	0.15 *0.161*	**0.39** ***0.000***	**0.85** ***0.000***	
Number of tubers	0.14 *0.190*	0.08 *0.434*	0.01 *0.912*	0.12 *0.251*	0.02 *0.838*

RCD= *Root collar diameter* * = *Pearson's correlation value (r)*
Bold value are significant at alpha 0.05 ** = *number in italics are probability values*

4.3 Seed collection of orchids for propagation/germination trial

A total of 18 orchid species and 1 other non-orchid endemic species were collected in-line with the MSB requirements for germination studies and long-term species conservation. Three herbarium specimens where collected and preparation in are place to send them to Kew for long term storage and research. No germination trials have been conducted on the seed samples yet. However, 12 edible species are being tested for propagation through tubers at the Forestry Research Institute of Malawi. Results indicate high response of orchid emergence.

Table 3.8: orchid species collected for germination and long term storage

NUMBER	GENUS	FAMILY
1	*Satyrium orbiculare Harv*	Ochidaceae
2	*Satyrium buchananii*	Ochidaceae
3	*Satyrium monodenium Schlt*	Ochidaceae
4	*Satyrium sacculatum (Rendle) Rolfe*	Ochidaceae
5	*Satyrium breve Rolfe*	Ochidaceae
6	*Satyrium sceptrum Schlt*	Ochidaceae
7	*Disa erubescens Rendle*	Ochidaceae
8	*Disa ornithantha Schlt*	Ochidaceae
9	*Disa satyriopsis Krzl*	Ochidaceae
10	*Disa hircicornis Reichb.F.*	Ochidaceae
11	*Satyrium sphaeranthum Schltr*	Ochidaceae
12	*Satyrium crassicaule Rendle*	Ochidaceae
13	*Eulophia odontoglossa Reichb. F.*	Ochidaceae
14	*Habenaria kyimbilae Schltr*	Ochidaceae
15	*Disa stolzii Schltr.*	Ochidaceae
16	*Brownlea parviflora Lindl.*	Ochidaceae
17	*Habenaria macrura Kraenzl.*	Ochidaceae
18	*Cyrtanthus breviflora Harv.*	Amaryllidaceae

4.0 DISCUSSION

4.1.0 Current management perception on trends of the edible orchids in Nyika National Park

Harvesting of edible orchids inside the National Park is affecting population structure of the targeted species. In areas where collectors frequent, orchid diggings are common. The illegal collection activities are seriously impacting on the flowering/shooting patterns of the orchids. According to the National Park manager Mr. P. Wadi, orchids are easily noticed of their existence when they flower. But in areas were harvesting is more intense, the flowering patterns of the orchids is compromised overtime indicating a reduction in orchid populations. He commented that it is also as good to intensify patrols and also increase staffing levels inside and outside the Nyika National Park.

4.2.0 Diversity, Distribution and abundance of orchids

4.2.1 Diversity of edible orchids in study sites and vegetation types

The fifty-four (54) terrestrial orchids investigated in the study represent 27% of the total orchid flora of the Nyika National Park (Burrows and Willis 2005). Eighty percent (80%) of the investigated terrestrial species (43) are recognized edible by surrounding communities (Table 3.4). The identified edible orchids belong to the genera Disa, Satyrium, Habenaria, Brachycorythis and Neobolusia. The number of edible orchids recorded in each genera from the study shows Disa (14), Satyrium (16), Habenaria (10), Brachycorythis (2) and Neobolusia (1). These results suggests that the edible orchid flora from the Nyika National Park is diverse and the species collected by surrounding communities has increased with 23 more species than previously observed by Kasulo *et al*. (2009) and Simkoko (2012) were almost 20 species were reported from only three species genera Disa, Satyrium and Habenaria. In the southern highlands of Tanzania, Davenport and Ndangalasi (2003) reported over 85 species as edible, and later Nyomora (2009) reported 14 edible orchids suggesting a decrease of species from the genera Disa, Satyrium and Habenaria. Results from the current study are in consistence with Hamisy (2007) and Bone (2016) who indicated community diversification of orchids being targeted for 'Chikanda trade' in Zambia as well as Tanzania to include other orchids genera such as Brachycorythis and Eulophia apart from the preferred Disa, Habenaria and Satyrium genera.

The dwindling species populations on customary land mainly from agriculture, settlements and trade has left orchid gatherers around the Nyika National Park with no option but to access resources inside the Park were diversity and abundance is assured. Therefore, the wider diversification of orchids being targeted for collections of tubers by local communities surrounding the National Park is attributed to increased pressure mainly for trade and traditional use. The high diversity of edible orchids collected by local communities from this study supports findings by Msekandiana and Mlangeni (2002), Kasulo *et al.* (2009) and Bone (2016) as well as Veldman *et al.* (2017). Owing to the high diversity of edible orchids currently being targeted for collection by communities, future changes in orchid species populations is imminent. The collection diversity of orchids by communities affirms to a higher number species requiring protection and closer monitoring now than before in Nyika National Park. Therefore, results from this study may act a base for future comparisons.

4.2.2 Patterns of orchid species richness in study sites and vegetation types

The edible orchid collection sites assessed fall within five (5) different vegetation types in the montane and sub-montane forests. The vegetation types recorded were the miombo woodlands in sub-montane forests, and the montane wetlands, montane grasslands, broadleaf-evergreen forests, and the exotic pine plantation in montane forests. Orchid species richness differed significantly ($P<0.05$) between vegetation types. However, no significant difference ($P>0.05$) of orchid's species richness were observed between collection sites. The montane wetlands and montane grassland vegetation types recorded orchid species richness way above the rest (Appendix table 1). While the pine plantation and the montane evergreen forests recorded the least. Results from this study suggest that the vegetation type has a greater influence on species richness than the study sites. These results are supported by Nyomora (2009) who reported that orchid species richness in typical montane grasslands have the highest orchid species richness than the miombo woodlands. In addition, the high species richness observed in montane wetlands and grasslands are consistent with Brundrett, (2014) who reported of high species richness in vegetation types with no overhead canopies (montane grasslands and wetlands) than those with overhead canopies which in this study are the pine plantation, miombo woodlands and the evergreen forests.

Furthermore, the low species richness of terrestrial orchids recorded in the pine plantation alone could be explained by the introduction of monocultures in the natural ecosystem. Normally, terrestrial orchids in natural habitants interact with the biotic and abiotic environments by mycorrhiza associations (Mello and Silva-Filhno 2002). Therefore, the introduction of monocultures and exotic plants species in natural ecosystem tend to reduce vital interactions between other plant species and the orchids, which in turn reduces mineral resource availability and subsequently affects the diversity and richness of orchids in the ecosystem (Mc Cormick *et al.*, 2014). Based on this observation, the low orchid species richness recorded in the pine plantation of the Nyika National Park could have resulted from the reduced mineral resource availability and allelochemicals which later affected soil mycorrhiza existence in the ecosystem necessary for both orchids' survival. In simple terms, orchid populations shifted from their natural habitat as conditions changed because of the introduction of exotic pine species in the natural ecosystem of the Nyika National Park. This result has a bearing on management implications of specific habitants (Sanchez *et al.*, 2016) inhabiting terrestrial orchids in the Nyika National Park.

4.2.3 Habitat preferences and associations between terrestrial orchids

Results indicate that no single orchid species was common in all the vegetation types (Appendix table 1and Table 4.1). However, some orchids were found to occupy two habitats in the montane wetlands and montane grasslands. These includes; *Disa stolzii*, *D. engleriana*, *D. ochrostachya*, *Neobolosia stolzii*, *D. robusta*, *Habenaria cornuta*, *H. filicornis*, *H. macrostele*, *Satyrium buchananii*, *S. breve*, *S. monadenum*, *S. orbiculare*, *and S. sacculatum* Similarly, *Cynorkis anacomptoides* was observed to occur both in the broadleaf evergreen forests and the montane wetlands.

Table 4.1 Summary of patterns of terrestrial orchid occurrences in vegetation types

Montane Grassland	Montane Wetlands	Pine plantation	Miombo woodland	Evergreen Forest
X	X			
	X			
		X		
			X	
				X

Most species were recorded in single vegetation types. For example, *Cynorkis kasneriana* nearly occupied the entire 570 hactare pine plantation alongside *Despiris antheceros* (Appendix table 1). Other species such as *Satyrium trinerve, S. sceptrum* and *S. sacculatum* were recorded in montane grasslands. *S. crassicaule* is confined to montane wetlands and stream/riverbanks, while *Disa zombica*, *S. carsonii* and *B. pleistophylla* were recorded in the miombo woodlands. These results are consistence with La Croix and La Croix (1991) who reported on commonality of *D. Robusta, Disa engleriana, and S. breve* in montane grasslands and wetlands at high elevation in Nyika National Park.

Frequently, groups of orchid species will be found associated together in one habitat, while other groups are associated in different vegetation types or sites. For example, the association of *Satyrium carsonii* and *Satyrium breve* is uncommon in the Nyika National Park. The association of *Satyrium breve*, *S. antherstonei* and *Disa engleriana* is common in montane wetlands or swampy grasslands. While in miombo woodlands, *Disa engleriana* is replaced by *Disa zombica* and *Satyrium breve* is replaced by *Satyrium carsonii*. These results are consistent with La Croix and La Croix (1991) and later La Croix (2011) who reported numerous terrestrial orchids' occurrence in bogs and montane grasslands on the Nyika plateau. Habitat specificity of the terrestrial orchids is ascribed to the wide spread availability of associated soil mycorrhiza in the vegetation types that supports germination and survival of orchids (McCormick 2014).

4.2.4 Abundance of orchids in study sites and vegetation types

Orchid species abundances with respect to vegetation types are presented in Figure 3.18. The pine plantation and the montane wetlands recorded highest number of orchids than the rest, while the miombo woodland recorded the least. The high abundances of terrestrial orchids recorded in the exotic pine plantation from low species richness per unit area observed are due to the changed environmental conditions that favour particular orchid species. These results are consistent with reports by Weller and Spatcher (1965) that habitat changes from natural vegetation to other vegetation types permits a measure of habitat preference in some plant and animal species. The high abundance of orchids recorded in the pine vegetation type is attributed to the wide spread availability of associated soil mycorrhiza (Brundrett *et al.*,2003; McCormick 2014) that tolerates the presence of exotic pine trees while enhancing germination and growth of orchid seeds in the changed ecological habitat. The observed orchid species in the vegetation type *(Cynorkis kassneriana* and *Despiris antheceros*) were the most tolerant of the changed environmental conditions and could have resulted in the utilization of a higher percentage of the bare ground for their proliferation and abundances. Additionally, the high abundance of orchids recorded in the montane wetlands is associated with high diversity of orchids in bogs. These results are consistent with Nyomora (2009) and Kreziou (2016) who reported on high abundances in montane grasslands and wetlands. While the low abundance of orchids observed in miombo woodlands could be explained by excessive pressure of collection from the surrounding local communities and supports finding of Nyomora (2009) and Simkoko (2012) unpublished report.

4.2.5 Distribution of orchids in relation to environmental variables

Distribution of orchids in relation to soil physiochemical properties

Canonical correlation analysis (CCA) (Figure 3.20) and Pearson's correlation analysis (Table 3.7) revealed that the distribution of orchids on the Nyika National Park is influenced by soil physiochemical properties and environmental variables. Soil physiochemical properties in this study revealed that orchid species richness is partially influenced by the presence of organic carbon, Organic matter content, and phosphorus. While orchid abundance of some species is positively correlated to increased soil nitrogen (r= 0.85) and Iron (r=0.77 in the study sites. These results coincide with Fonge *et al.* (2013) and McCormick and Jacquemyn (2013) who found that orchid species distribution in vegetation types are a result of environmental factors that includes soil physiochemical properties. Soil physiochemical properties influence availability of soil mycorrhizae necessary for transportation of mineral nutrients from the soil to the host plants and also between host plant species. Soil physiochemical properties such as an increase in soil carbon, organic matter content and iron are important factors that can be used to explain the distribution of terrestrial orchids in the Nyika National Park

Distribution of orchids in relation to altitude

Orchid collection sites were ranked based on elevational gradients across the range to determine species distribution and diversity across the range. All sites ranged between 1500m and 2350m. Species richness were recorded and analysed from each site. Species richness among orchid habitants across the altitudinal range revealed positive correlation of altitude to species richness and vice versa (Table 3.5). The diversity of edible orchids increased with an increase in altitude and vice-versa. High species richness was recorded at altitude between 2000 to 2400m above sea level and low species richness counts in sites below 1800m above sea level. Results from this study coincide with Bulafu *et al*. (2007) and Sugapriya (2011) who found out that altitude among other environmental variable investigated are important factors influencing distribution of terrestrial orchids. According to the authors, altitude influences temperature and moisture availability, such that lower altitudes have high temperatures and low moisture, and vice versa. The low species richness observed in lower altitudes (below 2000m.a.sl) supports finding by Mc Cormick *et al*. (2009), Reina- o Bertolini (2012) and Rodriguez *et al.* (2017) that orchid species richness in sites are due to the environmental differences between the sampled sites.

Plant species richness exhibits a unimodal response at some point along a large environmental gradient (Gauch and Whittaker 1972; Zhang *et al,*. 2015). Indeed, the unimodal curve has been generally accepted as fundamental response shape to environmental gradients, although many species may occupy the ends of the gradients. Species response curves may differ in shape, amplitude, width and optimum (Jongman, ter Braak and van Tongeren 1995; Oksanen and Minchin 2002, Toledo et al. 2012). In the Nyika National Park, the most notable of the differences between the altitudinal ranges in the sampled sites are changes in temperature and precipitation across the elevation gradient. Temperature and rainfall could be the main drivers of vegetation composition (Reina-Rodriguez *et al.* 2017) hence affect species composition. For example, the miombo woodlands at lower elevation is composed of plant species that are tall and deciduous (Burrows and Willis 2005). However, most edible terrestrial orchid species in the interior areas of the national park at high elevation inhabit vegetation types with no canopies and are more exposed to sunlight and wind than those in closed canopies (Rizzini 1979).

According La Croix and La Croix (1991), some orchid species of Malawi do have wide geographic ranges, but many of them are very restrictive in respect to the kind of environment they inhabit in nature. Thus, some preferred species such as *Disa ochrostachya, Disa hiscornis, Disa onithantha, Satyrium buchannaii, S. monadenum, Disa engleriana, Satyrium crassicaule and Disa satriopsis* amongst others are only found in habitants at high altitudes characterized by low temperatures in open montane grasslands and or wetlands. These species will unlikely cross environmental gradients to mid or lower altitudes (Powell & Powell 1987). In this study, orchids found at lower elevation includes; *Satyrium carsonii*, *Disa zombica* and *B. pleistophylla* and seem to be best adapted to slightly higher temperature environments (La Croix and La Croix (1991). This result suggest that the distribution of edible orchid species in the Nyika National Park is spread across all elevations, but restricted to only better adapted species with specific environmental requirements such as temperature, rainfall, vegetation type and other edaphic factors.

4.3.0 Tuber morphological variations between orchid species

4.3.1 Tuber weight variations among orchid species

Morphological variations of the edible orchids are presented in Table 3.5. Results have shown that weights of individual tubers vary significantly among the orchid species. *Disa robusta* and *D. ochrostachya* yield heavier tubers than any other orchid species observed in the study. This was followed in a range by *B. pleistophylla, D. engleriana* and *Satyrium sceptrum* orchid tubers. Variation in individual tuber weights observed in this study are consistent with reports by Govinden (2006) and Bressan et al. (2011) who reported on the differences existing between *Solanum tuberosum* species cultivars. Similarly, Amegbeto (2009) highlighted on *Discorea* species cultivars which are known to have large and extra-large tubers based on tuber weights. Extra-large tubers are reported to have better commercial value than smaller tubers (FAO, 2018). In Nyika National Park, with an exception of *B. pleistophylla*, overall, the top five heavier tubers are from montane wetlands and grasslands. Therefore, these results may give an indication as to why surrounding communities continue to target montane wetlands and grasslands in Nyika National Park for the bigger tubers that may attract commercial value. Heavier orchid tubers attract high monetary value than the smaller tubers on the market according to Simkoko (2009).The natural habitats therefore require special recognition as conservation areas. The presence of large variations between orchid tuber species implies possibilities to select from the natural population orchids with important traits for domestication and multiplication (Curuk *et al.*, 2016; Hardigan, *et al.,* 2017).

4.3.2 Variations in number of tubers

Results from the 21 orchids evaluated on the number of mature tubers per individual plant, 62% had two underground tubers, While 29% of the orchids investigated had a single tuber and 9% had averages of 4 more tubers per individual plant. The average number of tubers per individual plant was obtained maximum in *B. pleistophylla* and *C. kassneriana* with an average of 4 tubers (Table 3.5). These results are consistence with finding by Sugapriya (2012) who reported that dendrobium orchid cultivars vary in number of pseudobulbs, while Tutar and Kanbur (2013) reported that some orchids in natural environments produce only a single tuber, hence may risk extinction from continuous tuber harvests. In this study, variations observed in number of tubers between species demonstrate that under natural environment, increases in tuber yields can be achieved from orchids producing atleast two or more tubers (Table 3.5). The differences in number of tubers observed in the study are due to genetic and heritable characteristics existing between species (Hirut 2017). Orchid species having several tubers have advantages when compared to plant species with singular tubers as it comprise at least two or more tubers that are genetically identical of its copy and can satisfy the crucial needs in terms of usage of growing area. Therefore, the removal of the fresh tubers results in lethal destruction of the orchid plant populations. While orchid species producing a single tuber risk extinction from harvests. However, to eliminate disadvantages arising from the present new single-tuber producing species, studies to increase number of tubers in orchids, to obtain atleast 2-7 tubers from a single plant have been reported by Petrus and Bakker (2005) and Tutar and Kanbur (2013) in China and Japan respectively.

4.3.4 Diversity of tuber shapes

The centre of orchids diversity in Africa is Madagascar (Linder 2001), and within Malawi, centre of diversity lies in Nyika National Park (La Croix and La Croix, 1991; Burrows and Willis, 2003). The thirteen (13) macro-morphological tuber-shapes found among the 21 orchid species in the study implies existence of high diversity of tuber shapes among orchids. The tuber shapes found were elliptical, oblong, long-oblong, globose, compressed, ovoid, obovoid, cylindrical-billobed, elongated, and four irregular shapes (Figure 3.22). The irregular shapes were arbitrary classified together with communities as heart-shape, elephant-hooves and toothed-shape tubers. Tooth-shaped tubers were classed tooth-shaped1 (molar), tooth-shaped2 (canine).

The study found that *B. pleistophylla* (*Joyisi*) had elongated tuber shape characteristics (Figure 3.23). While *Satyrium carsonii* and *S. monadenum* (*Kabatica wa munyika*) had globose shapes Therefore, selection of species based on tuber shapes is relevant to such species. The irregular shapes were preponderant in *Disa robusta, D. ochrostachya*, *D. Zombica* and *D. engleriana*. The presence of irregular shapes in edible orchid tubers have been reported elsewhere by Kerr undated; Edens-Meier and Bernhardt (2014), Bone (2016), Gravendel

(2017). Principal Component Analysis shows that tuber shapes are not closely associated to species. Some tuber shapes co-existed between species. While other shapes were not. For example, the oblong tuber shape co-existed between *Disa engleriana, Dispiris antheseros, Cynorkis kassneriana* and *Satyrium sacculatum* (Fig 3.21). While, obovoid shapes co-existed between *D. zombica, D. stolzii, D. onithantha* and *Habenaria clavata*. Therefore, this kind of situation is not ideal for identification of orchids based on tuber shapes, and more efforts should be made to enlarge the basis for classification of edible orchids using tuber shapes.

The frequency of tuber shapes among the studied orchid species are shown in Figure 3.24. Tuber shapes that were common in the study were oblong (16.5%) followed by obovoid 15%. The compressed shapes and the tooth-shapes were least (1% and 2%) respectively. This result suggests that the edible orchid tubers shapes between species are not uniform, but vary between and within species. The morphological characteristics of terrestrial orchids feed constant discussions about the origin of orchids (Porembski and Barthlott, 1988; Robinson and Burns-Balogh, 1982). The evolution of this group of plants has been discussed for a long time, but even nowadays it is difficult to establish all the points of the process. The variety of morphological in orchids maintains the uncertainty about the primitive characteristics or derivates feature.

5.0 CONCLUSION

The distribution pattern of the edible orchids can be described as highly concentrated in specific vegetation types. Results from the study have shown that the montane wetlands and montane grasslands orchid's diversity and richness are higher than the rest. The edible orchids species are more common at higher elevation (upper plateau), while the lower altitude areas (below 1800 m.a.s.l) areas displayed low species richness and diversity. The distribution of the edible orchid species on the plateau is dependent on the geomorphology of individual habitants. The presence of high soil carbon in grasslands and montane wetland areas greatly influences the orchid species richness and diversity in the Nyika plateau. However, due to high richness and species diversity in the plateau grasslands and wetlands as opposed to the miombo woodlands which are closer to village communities, a large group of the rural poor surrounding the Nyika National Park shall continue to depend on the montane wetlands and grasslands to harvest orchid tubers for survival and nutrition.

Areas of high abundance which were only known to surrounding communities and specifically to orchid poachers have been identified and geo-referenced. The knowledge of the edible orchid spatial distribution will enhance more stringent habitats protection and monitoring of orchids.

In the same way, anthropogenic inputs in the Nyika wildlife management ecosystem such as establishment of the pine plantation and planting of other non-native species have helped to drive the increase in yield of wood products; but have shown to have a detrimental impact on both natural orchid ecosystems and other associated plants resulting in undesirable and costly outputs, such as the loss of the vital orchid species diversity and even other associated species in specific management units.

High variations observed in orchid tuber shapes, tuber length, tuber width, number of tubers per plant and tuber fresh weights between species affirms to the high levels of morphological differentiation that occur in terrestrial orchids. The presence of such between and within species variations in edible orchid tuber morphological characters provide an opportunity for further selection and improvements based on such characters for specific products and services of importance to communities. For example, orchid species with heavier tubers can have better selection advantage in terms of multiplication than the lighter tuber species.

6.0 RECOMMENDATIONS

-Campaign against illegal orchid collection activities should be intensified along boundaries and inside the Nyika national Park. Deliberate measures should be put in place especially along roads to start impounding excess orchid couriers. Other stakeholders and departments such as forestry and agriculture should also be involved. This perhaps may seem absurd to apprehend orchid gathers and transporters, but will in the long run have an impact in protecting the endemics of the Nyika National Park.

Monitoring of orchids fluxes in the identified collection arears should continue and also if possible other arears that were not visited can be included. i.e Baliro area

- Physiological/anatomical variations of the edible orchid tubers should also be investigated

-Germination studies and seed banking of orchid species of the Nyika National Park should be supported. Further studies should consider investigating molecular variations of the edible orchids and seed germinations specifically in species that have lower lower abundances.

-Understanding diversity of orchid associated soil mycorrhiza fungi orchid vegetation types can be one big area that may require special considerations.

- Understanding the orchid soil seed banks in respective vegetation types is one area

-Other studies should focus on distribution and diversity of epiphytic orchids in respective vegetation types.

7.0 CHALLENGES

1.0 Some identified collection sites were impassable due to bad slippery roads as it in the rainy season and potential access routes destroyed by poachers.


Figure: Survey team failing to proceed along Rumpi-Livingstonia rd; Burnt North Ruphi bridge by poachers

Appendices

Appendix photo 1: Collection team: Edible orchid survey team during the March, 2017 inventory: from left to right: Steven Mphamba (FRIM), Edwin Kathumba (NHBG); Mrs KK. Nyirenda; Mai Nya- Gamba (Gamba village, Kaperekezi), M. Namoto (Mzuzu University), Miss Olivia Chirwa, Isaac Jamali (FRIM) and Micheal Sisya (Chelinda camp)

Appendix photo 2: Collection team during the inventory

Appendix table 1: Orchids occurrence in Nyika National Park with respect to vegetation types

No.	Orchid species	Evergreen-forest	Miombo woodlands	Montane grassland	Montane wetland	Pine plantation
1	Brachycorythis pubescens	—	—	+	—	—
2	Brachycorythis pleistophylla	—	+	—	—	—
3	Brownlea parviflora	—	—	—	+	—
4	Cynorkis anacamptoides	+	—	—	+	—
5	Cynorkis kassneriana	—	—	—	—	+
6	Disa celata	—	—	—	+	—
7	Disa concina	—	—	—	+	—
8	Disa engleriana	—	—	+	+	—
9	Disa hicicornis	—	—	—	+	—
10	Disa ochrostachya	—	—	+	+	—
11	Disa onithantha	—	—	+	—	—
12	Disa perplexa	—	—	—	+	—
13	Disa robusta	—	—	+	+	—
14	Disa satryriopsis	—	—	—	+	—
15	Disa saxicola	—	—	—	+	—
16	Disa stolzii	—	—	+	+	—
17	Disa ukingensis	—	—	—	+	—
18	Disa welwischii	—	—	+	—	—
19	Disa zombica	—	+	—	—	—
20	Disperis antheceros	—	—	—	—	+
21	Eulophia coeloglosa	—	—	—	+	—
22	Eulophia milnii	—	—	—	+	—
23	Eulophia nutti	—	—	—	+	—

No.	Orchid species	Evergreen-forest	Miombo woodlands	Montane grassland	Montane wetland	Pine plantation
24	Eulophia sileense	—	—	+	—	—
25	Eulophia speciose	—	—	—	+	—
26	Eulophia thomsonii	—	—	—	+	—
27	Habenaria cornuta	—	—	+	+	—
28	Habenaria clavata	—	+	—	—	—
29	Habenaria dissoloides	—	—	—	+	—
30	Habenaria shirensis	—	—	—	+	—
31	Habenaria zambesiaca	—	—	—	+	—
32	Habenaria filicornis	—	—	+	+	—
33	Habenaria insolaris	—	—	+	—	—
34	Habenaria kymbilae	—	—	—	+	—
35	Habenaria macrostele	—	—	+	+	—
36	Habenaria praestans	—	—	—	+	—
37	Habenaria shimperana	—	—	+	+	—
38	Neobolosia stolzii	—	—	+	+	—
39	Reoperocharis beunettiana	—	—	—	+	—
40	Satyrium ambylosacos	—	—	—	+	—
41	Satyrium antheristonei	+	—	—	+	—
42	Satyrium breve	—	—	—	+	—
43	Satyrium buchananii	—	—	+	+	—
44	Satyrium carsonii	—	+	—	—	—
45	Satyrium chlorocorys	—	—	+	+	—
46	Satyrium crasicaule	—	—	+	—	—
47	Satyrium monadenum	—	—	+	+	—
48	Satyrium orbiculare	—	—	+	+	—

No.	Orchid species	Evergreen-forest	Miombo woodlands	Montane grassland	Montane wetland	Pine plantation
49	Satyrium princeae	—	—	+	+	—
50	Satyrium sacculatum	—	—	+	+	—
51	Satyrium sceptrum	—	—	—	+	—
52	Satyrium shirensis	—	—	—	+	—
53	Satyrium sphaerunthus	—	—	—	+	—
54	Satyrium trinerve	—	—	+	+	—
	Total present	2	4	25	41	2

Note: +=presence; — = absence

Table 1: Orchid Diversity and density (abundance of plants/Hectare)

Species	Site names														
	Chelinda airstrip	**British A. Base**	**Chelinda**	**East**	**Chelinda Dam3**	**Dembo**	**Kaperekezi**	**Kaulime**	**Manyeyezi forest**	**N. Rumphi bridge**	**Nganda area**	**North Rukuru R**	**Thazima**	**Vipiri**	**Zovochipolo**
S. sacculatum	0	200	0	180	576	680	0	20	0	0	0	336	0	0	0
Disa stolzii	0	0	0	40	64	0	0	165	0	0	0	0	0	0	0
Disa onithantha	0	0	0	0	644	0	0	0	0	0	0	0	0	0	0
Eulophia sileense	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0
S. buchananii	0	1093	0	0	364	0	0	0	0	0	0	40	0	0	0
S. orbiculare	0	767	0	516	12	0	0	0	0	0	0	992	0	0	0
S. chlorocorys	0	0	0	0	0	0	0	140	0	0	0	0	0	0	127
Disa concina	0	0	0	12	0	0	0	5	0	180	390	40	0	240	0
Satyrium princeae	0	760	0	0	0	0	0	55	0	0	0	0	0	0	1640
Disa engleriana	398	0	0	52	0	167	0	490	0	160	0	320	0	120	0
Neobolosia stolzii	0	0	0	0	24	213	0	0	0	0	0	0	0	0	0
Hebenaria insolaris	0	0	0	0	28	0	0	0	0	0	0	0	0	0	0
Reoperocharis beunettiana	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0
Disa perplexa	0	0	0	680	0	1613	0	0	0	0	0	0	0	0	0
Brownlea parviflora	0	0	0	0	0	40	0	0	0	0	0	28	0	0	0
satyrium monadenum	0	1280	0	0	0	167	0	0	0	0	0	280	0	0	0
Hebanaria filicornis	0	0	0	0	0	0	0	0	0	0	0	268	0	0	0
Disa hicicornis	0	0	0	108	0	107	0	0	0	0	0	0	0	920	0
Disa welwischii.	0	0	0	0	40	0	0	0	0	0	0	0	0	0	0
Satyrium antheristonei	435	0	0	212	0	280	0	0	4140	0	580	0	0	1120	0
Habanaria shimperana	0	0	0	0	140	93	0	0	0	0	0	40	0	0	0
Herbanaria praestans	0	0	0	0	0	260	0	0	0	0	0	0	0	0	0

Species	Site names														
	Chelinda airstrip	British A. Base	Chelinda	East	Chelinda Dam3	Dembo	Kaperekezi	Kaulime	Manyeyezi forest	N. Rumphi bridge	Nganda area	North Rukuru R	Thazima	Vipiri	Zovochipolo
Herbanaria macrostele	0	0	0	0	24	27	0	0	0	0	0	0	0	0	0
Herbanaria kymbilae	0	0	0	0	0	80	0	0	0	0	0	0	0	0	0
Disa zombica	0	107	0	0	0	147	300	0	0	0	0	80	640	0	0
Satyrium carsonii	0	0	0	0	0	0	1080	0	0	0	0	0	0	0	0
Disa ochrostachya	425	0	0	192	0	0	10	0	0	0	0	0	0	0	0
Cynorkis kassneriana	0	0	5487	0	0	0	0	0	0	0	0	0	0	0	0
Disperis antheceros	0	0	47	0	0	0	0	0	0	0	0	0	0	0	0
Satyrium trinerve	0	0	533	0	0	0	0	0	0	0	0	0	0	0	0
Eulophia nutti	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0
Eulophia speciose	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0
Brchycoryththis pubescens	0	0	400	0	0	0	450	0	0	160	0	0	460	0	0
Satyrium ambylosaccos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cynokis anacamptoides	18	0	0	225	0	0	0	0	120	0	10	8	0	0	0
Satyrium breve	495	0	0	1300	0	0	0	0	0	0	550	64	0	0	0
Disa celata	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0
Disa robusta	0	0	0	25	0	0	0	0	0	60	0	208	0	0	0
Disa saxicola	0	0	0	15	0	30	0	0	0	280	0	0	0	0	0
Disa ukingensis	0	0	0	390	0	0	0	0	0	0	0	0	0	0	0
Eulophia coeloglosa	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Eulophia milnii	0	0	0	35	0	0	0	0	0	0	0	0	0	0	0
Eulophia thomsonii	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
Brachycorythis pleistophylla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Satyrium crasicaule	0	0	0	0	0	0	0	0	0	0	0	1280	0	0	0

Species	Site names														
	Chelinda airstrip	**British A. Base**	**Chelinda**	**East**	**Chelinda Dam3**	**Dembo**	**Kaperekezi**	**Kaulime**	**Manyeyezi forest**	**N. Rumphi bridge**	**Nganda area**	**North Rukuru R**	**Thazima**	**Vipiri**	**Zovochipolo**
Disa satryriopsis	0	0	0	80	0	30	0	0	0	0	0	0	0	0	0
Habenaria zambesiaca	35	0	0	0	0	0	0	0	0	0	0	68	0	0	0
Satyrium ambylosacos	120	0	0	0	0	0	0	0	0	0	0	24	0	0	0
Habenaria disolloides	0	0	0	0	0	0	0	0	0	0	0	144	0	0	0
Habenaria shirensis	0	0	0	0	0	0	0	0	0	0	0	88	0	0	0
Satyrium shirensis	0	0	0	0	0	0	0	0	0	0	0	128	0	0	0
Satyrium sphaerunthus	0	0	0	0	0	0	0	0	0	0	0	480	0	0	0
Habenaria cornuta	0	0	0	0	0	0	0	0	0	0	0	120	0	0	0
Styrium sceptrum	600	0	0	0	0	0	0	0	0	0	0	448	0	0	0
Mean density per Area	**2526**	**4207**	**6467**	**4112**	**1920**	**3987**	**1860**	**875**	**4260**	**840**	**1530**	**5484**	**1100**	**2400**	**1767**
Species richness															

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