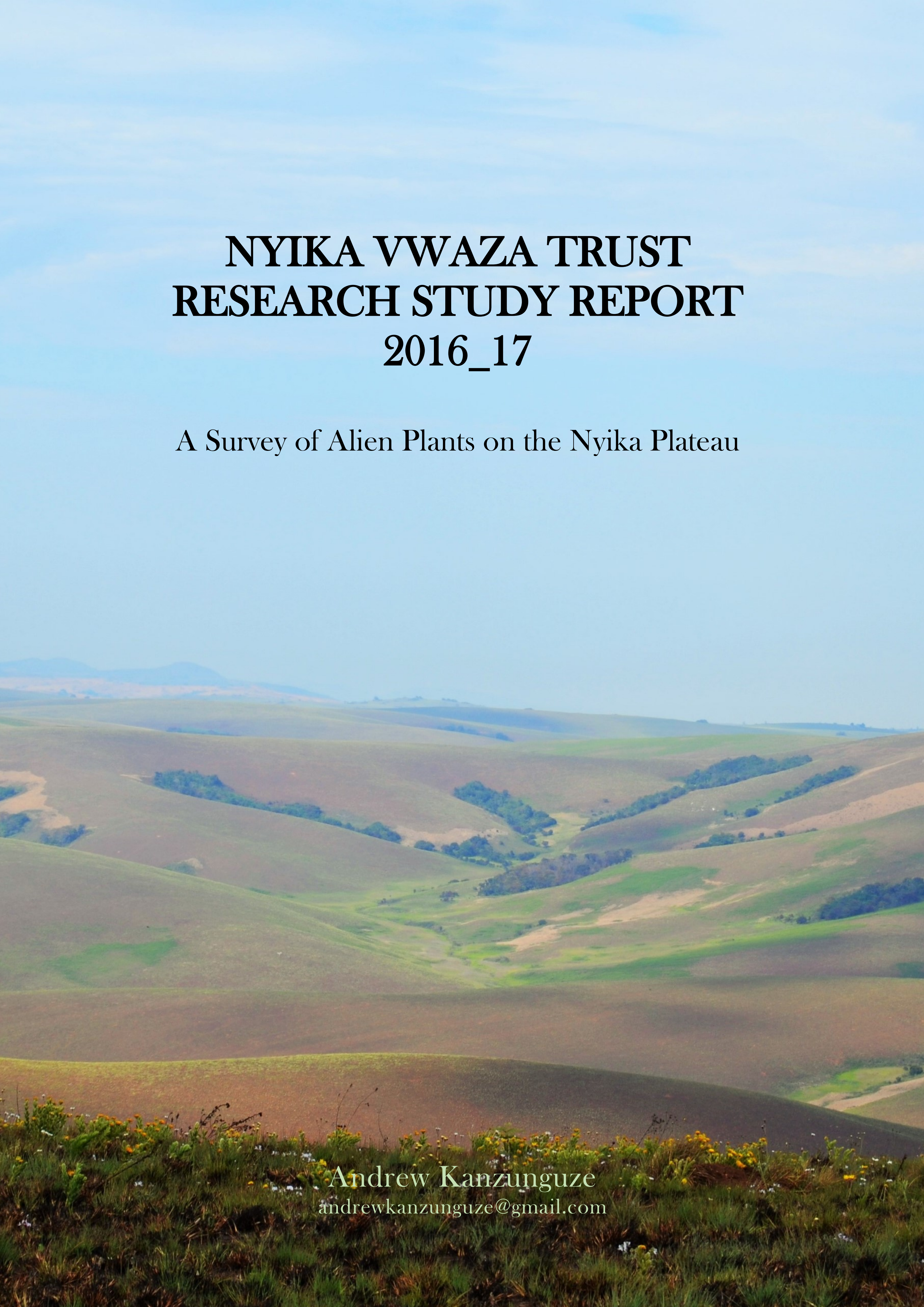


NYIKA VWAZA TRUST RESEARCH STUDY REPORT 2016_17

A Survey of Alien Plants on the Nyika Plateau

Andrew Kanzunguze
andrewkanzunguze@gmail.com

ABSTRACT

Alien plants have become a cause for concern because of the challenges they present to wildlife management and biodiversity conservation in protected areas globally. Despite the increasing attention by both government and international stakeholders in the management and control of invasive species on the Nyika Plateau, it was noted that the current range of alien plants is unknown, let alone their impacts on the plateaus' overall ecosystem structure and functioning. As a first step in filling this gap and for the purpose of improving invasive species management on the Nyika plateau, a survey was conducted aimed at determining the abundance and geographic extent of four alien plants namely Black Wattle (*Acacia mearnsii*), Mexican Pine (*Pinus patula*), Himalayan Raspberry (*Rubus ellipticus*) and three species of Gum (*Eucalyptus maidenii*, *Eucalyptus bridgesiana* and *Eucalyptus saligna*) on the plateau. It was carried out for three weeks in the month of October (2016) guided by questions on the current (1) extent and abundance, (2) spatial distribution, and (3) vegetation structure of the target alien plant populations on the Nyika plateau. Data was collected from belt transects along riverine systems as well as from plots laid in areas with high anthropogenic activity, using basic GIS techniques and forest inventory methods respectively. The findings revealed that *P. patula* and *R. ellipticus* are distributed away from Chelinda camp, whereas the different species of Eucalyptus and *A. mearnsii* are only present where they were first introduced. *R. ellipticus* was more abundant in the south eastern direction, whereas *P. patula* revealed no definitive pattern. As yet, it is difficult to conclude regarding both the spatial pattern and abundance of the alien species on the whole plateau without surveying the area further away from Chelinda camp. Nonetheless, studies can be conducted to understand the influence of management practices on alien-invasive species proliferation, as well as the underlying factors rendering the plateau susceptible to plant invasions.

ACKNOWLEDGEMENTS

First and foremost, I would like to acknowledge the Nyika-Vwaza (UK) Trust for deeming survey work on invasive species in Nyika National Park as worth financing. Their assistance is sincerely appreciated. Secondly, I recognize the supervision of Mr. P. Simkoko, as well as the valuable critique of Mr. S. Sichinga during the survey work. Thirdly, many thanks to Mr. G. Z. Nxumayo (the Northern Division Manager), Mr. J. Mabeti (Chelinda Camp Manager) and entire management in the Department of National Parks and Wildlife for advice and support in logistics that made the field work successful, and my stay at the camp a pleasant one. Finally, special thanks to Mr. M. Siska and the rest of the team that assisted during the crucial phases of data collection, entry and analysis.

Contents

LIST OF FIGURE AND TABLES

1 INTRODUCTION

1.1 Background for the Survey

From as early as 1950, alien plants of the *Pinus, Eucalyptus, Acacia* and *Rubus* genera were introduced on the Nyika plateau, apart from being introduced elsewhere also in Malawi (Dorward, 1990). Until after abandonment of the associated projects for which most of these species were planted, observations in regard to their spread on the plateau became a growing concern (The Nyika-Vwaza Trust, 2010). Such that whilst *Acacia mearnsii* was the most vigorously counteracted (The Nyika-Vwaza Trust, 2005), attempts were also made at controlling *Pinus patula* and the different *Rubus* and *Eucalyptus* species (The Nyika-Vwaza Trust, 2006, The Nyika-Vwaza Trust, 2011). Although this is reported to have happened, the current extent, abundance, spatial distribution and even the impacts these plants have had on the plateau's overall ecosystem structure and functioning is unknown. For instance, following the introduction of these alien species, other native plants such as *Hagenia abyssinica* and *Pteridium aquilinum* (bracken fern) have spread tremendously on the plateau, to the extent that joint efforts from international stakeholders under the Nyika Trans-Frontier Conservation Area (TFCA) Project supported the control of bracken fern on the plateau for fear of the negative implications it is known to have on wildlife and floral diversity (Nxumayo, 2013). Yet it is still unclear what other processes (whether positive or negative) have been/ are at play on the plateau.

Richardson and Pysek (2012) argue that alien plants go through different stages along an Introduction-Naturalization-Invasion continuum before becoming problematic invasive, and that different factors determine a plants' movement along this continuum. Such factors include the period since initial introduction (Williamson et al., 2009; de Albuquerque et al., 2011), continual introduction of other alien species in the same habitat (Hierro et al., 2005; Pysek et al., 2009), dispersal traits and mechanisms of the alien species (Hamilton et al., 2005; Kuster et al., 2008; van Kleunen et al., 2010), genetic superiority of the alien plant over native plants (Pandit et al., 2011), the frequency, intensity and extent of ecological disturbances in the invaded habitat (Chytry et al., 2008a,b; Leishman and Thomson, 2005), as well as different aspects of climate change as precipitation and temperature (Lambdon et al., 2008; Thuiller et al., 2005). Recent studies have demonstrated the importance of determining abundances and spatial distribution of alien plants in different habitats as integral to understanding the position of alien plants along this continuum i.e. whether they have become invasive or not as to require either immediate control interventions or further monitoring and research aimed at defining relevant management intervention (Foxcroft et al., 2013). Within this school of thought, this survey aimed at providing baseline information on the (1) current extent and abundance, (2) spatial distribution and (3) vegetative characteristics of alien plant species on the Nyika plateau. This is in the hope of assisting park authorities and all other stakeholders in developing relevant alien plant management interventions, whilst also providing a platform for further research on alien plants and their impacts on the Nyika plateau.

1.2 Target Species

The species that were prioritized for the survey were *Pinus patula, Rubus ellipticus, Acacia mearnsii* and different species of *Eucalyptus*. This brief section presents a summary of the species mainly based on content from CABI's Invasive Species Compendium (ISC), iSPOT database, and the online Encyclopaedia of Life (EOL).

1.2.1 Pinus patula (Mexican Weeping Pine)

P. patula is a medium-size tree (usually to 20 m tall) native to eastern Mexico. It is the most important pine species in southern and East Africa (Kenya, Malawi, Mozambique, Zambia, Zimbabwe, South Africa, Swaziland, Tanzania and Uganda) and is commercially planted in South America (Colombia, southern Brazil, Argentina) and, to a limited extent, in Asia (Nepal and India). According to CABI, the major problem of *P. patula* is its aggressiveness and weediness. Introduced *P. patula* has been found to be associated with invasion events in Hawaii (USA), South Africa, Zimbabwe, Botswana, Malawi (Haysom and Murphy, 2003), Madagascar and New Zealand (Richardson and Rejmánek, 2004). It is an invasive species of both fire-climax grasslands and woodland in exotic situations where climatic conditions are close to those found in its natural range. It flowers as early as 2 years with female flowers appearing first and male flowers appearing in the fourth year, and begins producing viable seeds and cones at 5 years. Seed production is most prolific by the eighth to the tenth-year.

In the mid-1900s, several *Pinus* species were introduced in all regions of Malawi (Venkatesh and Kananji, 1985a, b). On the Nyika plateau, *P. patula* was introduced between 1952 and 1957 for a potential pulp plantation at Chelinda. Besides the main *P. patula* plantation, another 12 trial quarter acre (0.1 hectare) plots of four pine species were also planted in 1954/5, and removed later around 1980. Although these were not visited during the current study, they would merit looking at in any further study on invasive plants and also when looking at how sites recover from being under pine plantations. A map from 1956 is attached giving the location of ten of the twelve plots. Consequently, the main *P. patula* plantation was left intact to serve other domestic purposes for the staff at Chelinda as well as the lodges (Dorward, 1990).

1.2.2 Acacia mearnsii (Black wattle)

A. mearnsii is a vigorous, nitrogen fixing species that has precocious and prolific seed production, with a high density and accumulation of long-lived seeds in the soil, and a variety of potential dispersal mechanisms including water, mammals and possibly birds. It causes a number of mainly environmental problems and is hard to control because of its ability to form root suckers. *A. mearnsii* is a highly invasive species, and listed as one of the World's 100 Worst Invaders (GISD, 2016). It is known to be invasive in California, South Africa, USA, Zimbabwe, Kenya, Tanzania, Uganda, Jamaica, Brazil and New Zealand, has shown a tendency to invade and cause concerns in other countries, e.g. in India, and is widely naturalized elsewhere where it may become invasive in the future. It was introduced on the Nyika plateau within the same period as *Pinus patula* (i.e. between 1950 and 1960).

1.2.3 Eucalyptus (Gum species)

Some of the reported gum species on the Nyika plateau are *Eucalyptus saligna, Eucalyptus maidenii* and *Eucalyptus bridgesiana* according to Siska, M (personal communication, 16 October, 2016)*.* Generally, there are many species in the genus Eucalyptus which is mostly native to Australia and very few other in areas of New Guinea and Indonesia. Species from this genus have attracted much attention from horticuluralists, global development researchers and environmentalists because of its desirable traits such as being fast-growing, producing oil that can be used for cleaning and as a natural insecticide, and even their ability of draining swamps and thereby reducing the risk of Malaria. The invasiveness of most species in the Eucalyptus genus have not been as worrisome as compared to the aforementioned species, even though it has its impacts that may/may not be a cause for concern depending on the ecosystem where it occurs. Despite its introductions for commercial purposes in Malawi and other countries like South Africa and Ethiopia, reports on its negative impacts on bird species have been little reported. Gum species were introduced on the Nyika plateau almost within the same period as the Acacia and Pinus species.

1.2.4 Rubus ellipticus (Himalayan Raspberry)

R. ellipticus is a thorny shrub which has been most thoroughly documented on the island of Hawaii since its escape from cultivation in 1961, where it has become established in mid-elevation forest and pastureland, and formed tall, dense thickets. The seeds of *R. ellipticus* remain sufficiently viable following passage through the digestive systems of birds and mammals to readily germinate in pastureland and undisturbed forest sites where they are deposited. The species is reported to also spread by suckers, and re-sprouts vigorously after fires. Its ability to colonize undisturbed native forests and displace native species is cause for alarm especially among resource managers of Hawaii Volcanoes National Park and other natural reserves of Hawaii comprised of highly ecologically sensitive systems. On a global scale, *R. ellipticus* has been listed as one of the world's 100 worst invasive alien species (Lower et al., 2000), and is a prohibited species in South Africa.

In Malawi, the species is reported to have been introduced on Mulanje mountain and the Zomba plateau. Neither the reasons for its introduction in Malawi, nor how it spread beyond its original points of introduction are clear. On the Nyika plateau, other Rubus species apart from *R. ellipticus* have been identified, including the exotic and invasive *Rubus niveus* and other native Rubus species such as *Rubus chapmanianus, Rubus apetalus, Rubus pinnatus* as well as *Rubus rigidus* (Burrows and Willis, 2005). Whilst this is so, other databases have reported differently on the identity of the different Rubus species on the Nyika plateau. For instance, whilst CABI clearly report of the presence of *Rubus niveus*, *Rubus rosifolius* and *Rubus ellipticus* generally in Malawi, other databases such as the EOL have referred to Rubus observations on the plateau as either of the species *chapmanianus, apetalus, pinnatus, rigidus,* or *niveus.* Observations uploaded on iSPOT have also expressed the challenge in identifying different Rubus observations with the known species occurring on the plateau (Figure 1). The appearance of *R. ellipticus* is quiet distinctive in comparison to the other reported native Rubus species on the plateau as to call for ill identification. However, identification amongst the native Rubus species (including the alien invasive *R. niveus*) on the plateau is not as easy and may have been confused during the survey.

Figure 1: Rubus species observed on 11th January, 2012 in Nyika National Park. (From iSPOT Nature)

1.3 The Baseline Survey

We started by conducting a baseline survey around Chelinda Camp accompanied by Mr. M. Siska (Research Officer at Chelinda Camp) and Mr. S. Sichinga for the purpose of defining boundaries within which the survey was going to be conducted, so as to avoid duplicating work with Mr. S. Sichinga who was to be conducting a study on the ecological impacts of pine removal at Chelinda in the near future. One of the objectives for his study is to determine the impacts that removing pine has had on invasive species. First, we visited Dam 2 (Figure 1a), then went through the pine plantation to the airstrip (Figure 1b) and concluded the baseline survey at the Campsite (Figure 1c), where it was agreed that I was going to focus on the areas outside Chelinda pine plantation (Figure 1b).

Figure 2: The baseline survey in review (a-d).

Whilst conducting the baseline survey, the research officer at the camp advised that *Eucalyptus* and *Acacia* species were very localized on the plateau (Figure 3). To confirm this, the baseline survey was extended to where gum species were initially planted by communities living on the outskirts of the park before the boundaries were expanded (Zieglar, 1993). Consequently, the advice was true and I decided to focus more on *Pinus patula* and the different *Rubus* species during the rest of the survey.

Figure 3: Old plot of *Acacia mearnsii* (a-b) and Eucalyptus stand west of Chelinda pine plantation (c-e)

As we had extended the baseline survey, it was noted that the northeast, east and northwest directions from Chelinda pine plantation have very dense, dense and less dense forest patches in that order, with an array of fairly steep hills rolling continuously towards Nganda peak in the north. The forest patches in the south are not as dense, and they have more open canopies as well as moderately sloped hills. Then, I also determined to collect data mainly along valleys (and also roads) in a 10 square kilometre grid, with Chelinda Pine plantation as the centre, towards the northern, southern, eastern and western directions.

Figure 4: The northern side of Chelinda Pine plantation

Figure 5: The southern side of Chelinda Pine Plantation.

Figure 6: The eastern side of Chelinda Pine Plantation

Figure 7: The western side of Chelinda Pine Plantation

2 METHODOLOGY

2.1 Study site and setting

The survey was carried out between the 13th October, 2016 and 1st November, 2016 on the Nyika Plateau.

2.2 Survey Design and Sampling

Data was primarily collected using belt transects established along riverine systems/valleys and key roads. Valleys were sampled in a 100 square kilometre grid (Chelinda camp inclusive), whereas roads were surveyed around Chelinda Camp in the same grid extending up to Nganda in the north as well as Zambia Guest House to the east. Data from ecologically active centres (hereafter referred to as hotspots) were collected using 20 square meter plots at Lake Kaulime and the Airstrip.

2.3 Data collection

Along all transects, GPS coordinates were collected for spot observations, together with descriptive data of the surrounding flora in areas where there were significantly large populations (>20 individuals) of the target species. At hotspots, $20m^2$ plots were used to collect count data of target species with a description of associated flora. All data were recorded and stored temporarily on data collection forms.

2.4 Data analysis

Data were used to determine the abundance of key target alien species in the sampled area, and their distribution were reflected by maps produced using Quantum GIS 2.2.

Figure 8: Laying plots (a-c) and identifying valleys to be used as transects in the field (d)

3 RESULTS

3.1 Key Findings from Riverine systems

Table 1: Coordinates for transects covered along riverine systems in UTM zone 36, WGS 84.

Transect number	Start coordinate (x, y, z)				End coordinate (x, y, z)		
	Easting	Northing	Altitude		Easting	Northing	Altitude
1	588664	8836288	2361		589630	8836048	2264
2	589630	8836048	2264		589263	8835391	2272
3	589263	8835391	2272		589677	8834942	2323
4	589638	8834816	2323		589189	8834865	2283
5	588915	8835179	2282		588441	8835729	2331
6	589105	8834670	2280		589533	8834191	2299
7	590027	8834203	2331		589250	8833155	2333
8	588559	8833332	2340		588231	8834460	2294
9	588567	8833891	2320		588584	8834456	2292
10	588893	8833865	2323		588779	8834460	2288
11	587670	8835145	2345		887074	8836080	2279
12	587074	8836080	2279		584671	8836142	2194
13	584671	8836142	2194		583947	8836152	2157
14	583497	8836152	2157		587144	8833038	2349
15	586648	8831669	2346		583786	8833543	2196
16	583786	8833543	2196		583984	8831574	2309
17	584038	8831218	2295		585093	8831806	2272
18	585093	8831806	2272		586420	8830988	2348
19	587984	8827183	2270		588656	8827228	2258
20	588656	8827228	2258		588695	8827200	2258
21	587535	8829625	2269		583592	8830016	2360
22	583637	8829340	2357		587897	8827208	2262
23	590539	8831421	2300		591455	8833702	2245
24	591455	8833702	2245		591991	8833253	2329
25	591945	8832351	2340		592258	8832704	2237
26	592258	8832704	2237		592493	8831183	2263
27	592493	8831183	2263		590891	8831119	2337
28	590596	8830904	2359		591715	8828507	2252
29	591715	8828507	2252		591999	8827612	2296
30	591999	8827612	2296		591831	8827507	2311
31	591380	8827140	2340		589973	8828913	2327

NB: Coordinate units are in Universal Transverse Mercator (UTM) zone 36, based on the World Geodetic System of 1984 (WGS 84).

Table 2: Approximate abundance of *P. patula*, *R. ellipticus* and *R. chapmanii* along transects from riverine systems.

TRANSECT Number	Species Observations Times		
	P. patula	**R. ellipticus**	**R. chapmanii**
1	0	0	2a
2	1a	0	1a
3	0	1a	3a
4	2a	4b	0
5	0	2a	3a
6	0	0	1a
7	6b	1a	5b
8	3b	2a	2a
9	1a	0	2a
10	0	0	2a
11	2a	0	5b
12	0	1a	3a
13	0	0	6c
14	3a	1a	8d
15	3a	0	5a
16	3b	0	2a
17	2a	1a	0
18	2b	0	1a
19	0	1a	3b
20	2a	2a	4a
21	8f	0	5a
22	5a	2b	2a
23	5a	1a	4c
24	0	1c	1b
25	0	0	4a
26	0	2a	0
27	2a	1a	2a
28	4b	3f	1a
29	2a	3f	0
30	1a	2e	0
31	1a	7f	4b

NB: Species observation per transect, where an integer represents the number of points along the transect when species observations were made, and a letter represents the range for total number of species counts per point along the transect. The integers represent abundances as follows; a<20, b=21-40, c=41-60, d=61-80, e=81-100, f>100.

Having collated all the data in the Microsoft Office Excel database, a map was produced showing the distribution pattern of *Pinus patula* and *Rubus ellipticus* in the surveyed area (Figure 9). It was noted that *R. ellipticus* was more densely present in the south-eastern direction from Chelinda camp, occurring in clusters of up to ≥100 species continuously along valleys (Table 2), close to forest patches (at least up to 100m away). *P. patula* though seemingly more frequent in the western side of the plantation, showed no clear-cut specificity in terms of direction from the camp.

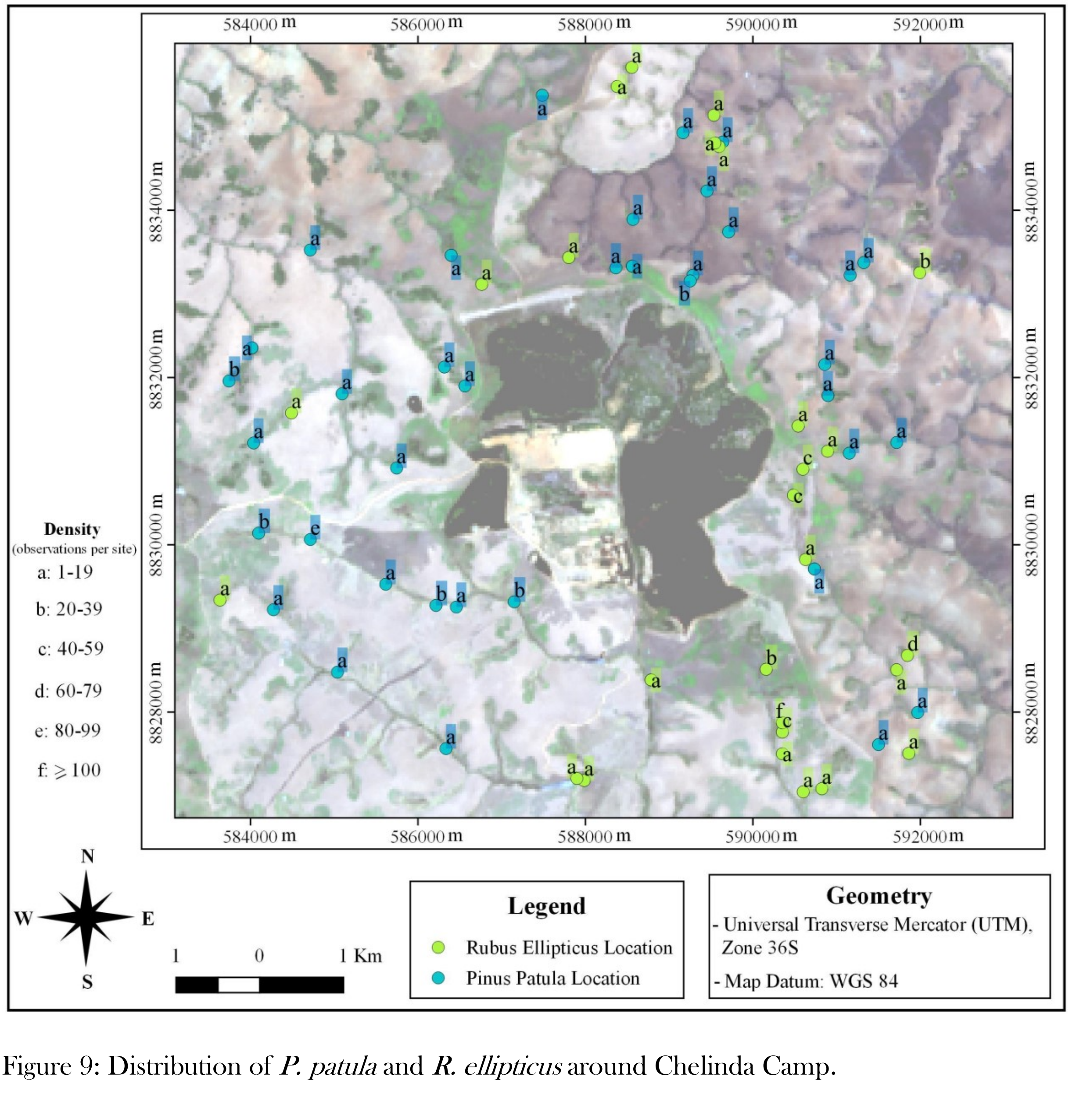


Figure 9: Distribution of *P. patula* and *R. ellipticus* around Chelinda Camp.

3.2 Key Findings from Hotspots

Table 3: Summarized findings for *P. patula, R. ellipticus* and *R. chapmanii* at hotspots

HOTSPOT	Plot number	Plot Coordinates (x, y, z)			Species Count			Other observed species
					P. patula	R. ellipticus	R. chapmanii	
Airstrip	1	588030	8832957	2317	29	0	0	*Helichrysum splendidum, Buddleja salvifolia, Pteridium aquilinum*
	2	587981	8832843	2368	28	0	0	*Helichrysum splendidum, Buddleja salvifolia, Stoebe kilimanjarica, Hypericum revolutum and Pteridium aquilinum*
	3	587595	8832876	2369	31	0	0	*Hypericum revolutum and Helichrysum splendidum*
	4	587233	8832823	2366	0	34	0	*Myrica salicifolia, Erica benguelensis, Helichrysum splendidum and Pteridium aquilinum*
	5	587138	8832801	2365	0	>100	17	
	6	587024	8832750	2356	0	32	27	*Pteridium aquilinum, Hypericum revolutum, Helichrysum splendidum and Stoebe kilimanjarica*
	7	586751	8832701	2367	35	14	4	*Stoebe kilimanjarica, Helichrysum splendidum and Hypericum revolutum species*
	8	586583	8832621	2366	3	>100	0	*Pteridium aquilinum and Helichrysum splendidum*
	9	586891	8832821	2365	5	68	0	*Pteridium aquilinum, Helichrysum splendidum, Hypericum revolutum, Buddleja salvifolia and Stoebe kilimanjarica*
	10	587080	8832885	2366	0	28	0	*Helichrysum splendidum, Hypericum revolutum, Pteridium aquilinum* and *Stoebe kilimanjarica*
Lake Kaulime	1	583136	8830185	2364	21	0	4	*Helichrysum splendidum, Hypericum revolutum, Pteridium aquilinum and Buddleja salvifolia*
	2	583206	8830268	2360	7	0	3	*Helichrysum splendidum, Hypericum revolutum* and *Buddleja salvifolia species*
	3	583298	8830338	2355	0	0	12	*Helichrysum splendidum, Hypericum revolutum,* and *Grass species*
	4	583375	8830255	2364	13	16	0	*Helichrysum splendidum, Hypericum revolutum* and *Buddleja salvifolia species*
	5	583193	8830172	2369	20	0	27	*Helichrysum splendidum, Hypericum revolutum, Pteridium aquilinum* and *Buddleja salvifolia*
	6	583134	8830187	2371	18	0	0	*Helichrysum splendidum, Hypericum revolutum, Pteridium aquilinum* and *Buddleja salvifolia*
	7	583493	8830283	2371	9	0	0	*Helichrysum splendidum, Hypericum revolutum, Pteridium aquilinum* and *Buddleja salvifolia*
	8	583521	8830424	2371	15	0	0	*Helichrysum splendidum, Hypericum revolutum, Pteridium aquilinum, Buddleja salvifolia* and *Artemisia afra*
	9	583702	8830434	2375	18	0	0	*Pteridium aquilinum, Hypericum revolutum, Buddleja salvifolia, Helichrysum splendidum, Stoebe kilimanjarica* and *Hagenia abyssinica*

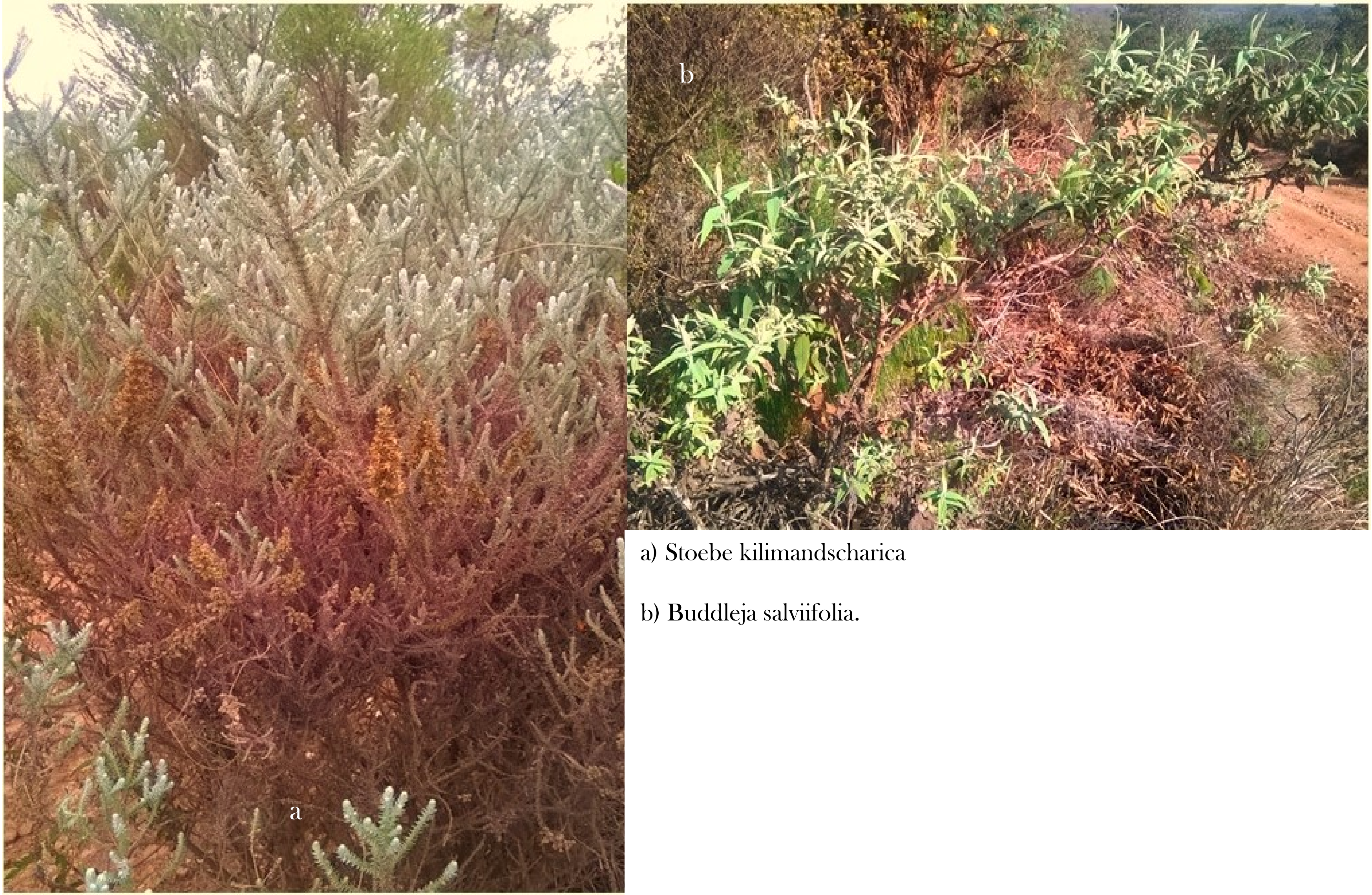
With respect to table 3, the mean height of *P. patula* species was 2.7±0.67 at the Airstrip, and 4.5±0.85 at Lake Kaulime. There were more *R. ellipticus* stands at the Airstrip than at Lake Kaulime which suggests a relationship between *R. ellipticus* proliferation and frequency of disturbance, since clearing is usually done at the Airstrip than at Lake Kaulime. *R. chapmanii* showed no differences in occurrence at both sites as to suggest any pattern. *Helichryum splendidum*, *Hypericum revolutum* and *Pteridium aquilinum* (Figure 10) were present in almost 80% of all sampled plots, *Buddleja salvifolia* and *Stoebe kilimanjarica* (Figure 11) were present in almost 50% of all sampled plots, whereas *Erica benguelensis*, *Artemisia afra*, *Hagenia abyssinica* and *Myrica salicifolia* were present in not more than 20% of all sampled plots (Figure 12).

a) Hypericum revolutum.

b) Pteridium aquilinum (bracken fern).

c) Helichrysum splendidum.

Figure 10: Other species most dominant (approximately 80%) in hotspots.



a) Stoebe kilimandscharica

b) Buddleja salviifolia.

Figure 11: : Other species fairly dominant (approximately 50%) in hotspots.

a) Hagenia abyssinica. b) Artemisia afra.

c) Myrica salicifolia. d) Erica benguelensis.

Figure 12: : Species least dominant (approximately 20%) in hotspots.

4 DISCUSSION

During the survey, it was observed that *R. ellipticus* was very common around forest patches at the mouths of valleys and tributaries, especially those patches containing a mixture of *Pinus patula, Myrica salicifolia* as well as *Hagenia abyssinica* (Figure 13). There was not an instance where *R. ellipticus* was observed on the grassland away from the patches, except where dense thickets of *Hypericum, Helichrysum, Pteridium* and other shrubs were present (Figure 14).

Whilst passing through Chikangawa plantations in Viphya on my way to Lilongwe on the 27th November as well as on the 18th December, I noticed a lot of *R. ellipticus* along the roadsides and on the borders of pine stands. Since pine species were planted on both the Nyika and Viphya plateaus during the same period in the mid-1900s (Dorward, 1990), and fires are similarly common on the both the Viphya and the Nyika plateaus, I suspect *P. patula* as well as fires play a role on the proliferation of *R. ellipticus* species in one way or another.

Figure 13: *Rubus ellipticus* in and on the edges of forest patches (a-d)

Figure 14: *Rubus ellipticus* away from forest patches (a-d).

As for *P. patula,* multiple observations were more frequent closer to the pine plantation than further away, and these were mostly juveniles with heights commonly in the range of 2 to 7 meters (Figure 15). The species was sparsely distributed further from the plantation along valleys, and present at different points in not more than 3 observations per kilometre (probably an illustration of dispersal from the plantation by water) (Figure 16). Mature trees were also present close to the camp, and only in dense patches away from the plantations with heights in the range of 15 to 25 meters. Unlike *R. ellipticus* however*, P. patula* showed no particular pattern with respect to direction from the camp.

Figure 15: *P. patula* observations closer to the pine plantation (a-d)

Figure 16: *P. patula* observations along valleys far from the pine plantation (a-d).

A ubiquitous version of *R. ellipticus* was the other species we identified as *R. chapmanii* with reference to the Photographic Guide to Wildflowers of Malawi (Bauman, 2005). Not usually beyond 2 meters in height, the species showed no specific spatial preference in terms of direction from the camp, let alone unique specificity to surrounding flora. It was observed alongside animal tracks with or without abundance of shrubs and grasses, main roads, valleys, close to forest patches and even amongst bracken fern patches (Figure 17). Such that if this species was really introduced on the plateau (I say this doubtfully because the information on this is proving hard to come by), I guess there is enough cause for worry that it may cause problems in the near future.

Figure 17: Observations of *Rubus chapmanii* (a-h)

It is almost unimaginable that *Hagenia abyssinica* which was mainly planted as a verge species for *P. patula* during pine introductions on the plateau (Dorward, 1990) because it is now present as far as Nganda to the north, around Lake Kaulime and towards Zambia Guest House in the west. The same astonishment applies for *Pteridium aquilinum* which has rapidly spread and formed vast patches within the last decade (Nxumayo, 2013). Although both *H. abyssinica* and *P. aquilinum* are said to be native to the plateau, their current spread needs further enquiry. It cannot be wholly ruled out that the introduced species have not influenced their range expansion which could be homogenizing the plateaus' floral diversity. Notwithstanding this though, I'd speculate that not only earlier plant introductions on the plateau, but also their subsequent removal and other ecological disturbances (such as the current fire regime and construction projects) have been rendering the Nyika plateau more susceptible to plant invasions.

As Richardson and Pysek (2012) postulated regarding the movement of alien plants along an Introduction-Naturalization-Invasion continuum, the factors that may be rendering the Nyika ecosystem more susceptible to plant invasions need to be intensively investigated, especially with regard to residence time, propagule pressure and the current fire regime. The history of introduction for most alien species, except for *Pinus patula, Acacia mearnsii and Eucalyptus* species which can be traced to the 1950's, is substantially unknown. It is not clear on how exactly the different varieties of *Rubus* found their way into the Nyika ecosystem, except only as Edwards (1985) confirms the introduction of *R. ellipticus* on Mulanje Mountain in Malawi, and Burrows and Willis (2005) confirm its introduction on the Zomba plateau. Although this is so, a clear understanding of the introduction pathway and even reasons for introduction assist in both monitoring and control of alien-invasive plants in protected areas (Pysek et al., 2011; Pysek et al., 2015). There could just be need for clarity on *Rubus ellipticus* introduction on the plateau.

Whilst it is common knowledge amongst plants scientists that fires play a vital role in influencing the structure of plant communities and alien-invasive species in particular (Alba et al., 2015), the role that fire has had on the proliferation of these alien plants and other flora on the plateau is unclear. Most invasive species are characterized with resilience to fires and often take the opportunity to thrive where the fire regime (i.e. type, frequency, intensity, severity, size, spatial complexity and seasonality) is poorly implemented (Brooks and Lusk, 2008). In the case of the Nyika ecosystem, it seems there is more to be understood regarding the impacts of fire in conserving and managing the plateaus' plant diversity. Factoring in other climatic conditions such as precipitation levels and temperature which influence a fire regime, we may just be close to defining the position of the Department of National Parks and Wildlife (DNPW) on invasive species management in Nyika National Park.

5 CONCLUSION AND RECOMMENDATIONS

The survey has revealed that *Acacia mearnsii* and different varieties of *Eucalyptus* are only present on the sites where they were first planted and not spreading in any direction from Chelinda camp on the plateau. *Rubus ellipticus* and *Pinus patula* however, have shown spread in all directions from the camp. Although *R. ellipticus* seemed confined around forest patches or close to where pines are present, there is need to establish the kind of relationship and dispersal mechanisms for *R. ellipticus* on the plateau, whilst continuing the survey work to areas further away from Chelinda camp so as to develop a more definitive pattern of spread for both *R. ellipticus* and *P. patula.*

In view of this, it is recommended that the survey work continue on the plateau, and further investigations be carried out to explain (1) the introduction pathways for the alien species on the plateau, (2) the dispersal mechanisms of alien-invasive plants on the plateau, (3) the role of fire and other disturbances on proliferation of alien-invasive species, and also (4) the influence of alien species on the range expansion of other native species such as *Pteridium aquilinum.* This is before the impacts of alien-invasive species on the Nyika Plateau can be clearly outlined without mere extrapolation from studies elsewhere.

6 REFERENCES

Alba, C., Skalova, H., McGregor, F. K., D'Antonio, C. and Pysek, P. (2015). Native and exotic plant species respond differently to wildfire and prescribed fire as revealed by meta-analysis. **Journal of Vegetation Science,** 26, pp.102-113.

Baumann, G. (2005) **Photographic Guide to Wildflowers of Malawi**. Wildlife Environmental Society of Malawi.

Brooks, M. and Lusk, M. (2008) **Fire Management and Invasive Plants: A Handbook.** United States Fish and Wildlife Service**,** Arlington Virginia, 27pp.

Burrows, J. W. and and Willis, C. K. (eds) 2005. *Plants of the Nyika Plateau: an account of the vegetation of the Nyika National Parks of Malawi and Zambia.* Southern African Botaincal Diversity Network Report No. 31. SABONET, Pretoria.

Chytry, M., Jarosık, V., Pysek, P., Hajek, O., Knollova, I., Tichy, L. and Danihelka, J. (2008a) Separating habitat invasibility by alien plants from the actual level of invasion. **Ecology,** 89, pp.1541–1553.

Chytry, M., Maskell, L.C., Pino, J., Pysek, P., Vila, M., Font, X. and Smart, S.M. (2008b) Habitat invasions by alien plants: a quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. **Journal of Applied Ecology,** 45, pp.448–458.

de Albuquerque F. S., Castro-Diez, P., Rueda, M., Hawkins, B.A. and Rodriguez, M.A. (2011) Relationships of climate, residence time, and biogeographical origin with the range sizes and species richness patterns of exotic plants in Great Britain. **Plant Ecology,** 212, pp.1901–1911.

Dorward, F. S. (1990) The Chelinda Pine Plantations. In: Dorward, R. and Dorward, F. eds. **The Nyika Experience: Reminiscences of Malawi's First National Park**. The Wildlife Society of Malawi, pp.14-26.

Edwards, I. (1985) Conservation of plants on Mulanje Mountain, Malawi. **Oryx**, 19, pp.89-90.

Foxcroft, C. L., Richardson, M. D., Pysek, P., and Genovesi, P. (2013) Invasive Alien Plants in Protected Areas: Threats, Opportunities, and the Way Forward. In: Llewellyn. C.F., Petr, P., Richardson, M.D. and Genovesi, P. eds. **Plant Invasions in Protected Areas:**

Patterns, Problems and Challenges, Invading Nature. Springer Series in Invasion Ecology 7, pp.621-639.

Global Invasive Species Database (2016). Downloaded from http://www.iucngisd.org/gisd/100_worst.php on 14-12-2016

Hamilton, M. A., Murray, B. R., Cadotte, M. W., Hose, G. C., Baker, A. C., Harris, C. J. and Licari, D. (2005) Life-history correlates of plant invasiveness at regional and continental scales. **Ecology Letters,** 8, pp.1066–1074.

Haysom, K. A. and Murphy, S. T. (2003) **The Status of Invasiveness of forest tree species outside their natural habitat: a global review and discussion paper**. Forest Health and Biosecurity Working Paper FBS/3E. Forestry Department. FAO, Rome (Unpublished).

Hierro, J. L., Maron, J. L. and Callaway, R. M. (2005) A biogeographical approach to plant invasions: the importance of studying exotics in their introduced and native range. **Journal of Ecology** 93, pp.5–15.

Kuster, E. C., Kuhn, I., Bruelheide, H. and Klotz, S. (2008) Trait interactions help explain plant invasion success in the German flora. **Journal of Ecology,** 96, pp.860–868.

Lambdon, P. W., Pysek, P., Basnou, C., Hejda, M., Arianoutsou, M., Essl, F., Jarosık, V., Pergl, J., Winter, M., Anastasiu, P., *et al* (2008) Alien flora of Europe: species diversity, temporal trends, geographical patterns and research needs. **Preslia,** 80, pp.101–149.

Leishman, M. R. and Thomson, V. P. (2005) Experimental evidence for the effects of additional water, nutrients and physical disturbance on invasive plants in low fertility Hawkesbury Sandstone soils, Sydney, Australia. **Journal of Ecology,** 93, pp.38–49.

Lowe, S., Browne, M., Boudjelas, S. and De Poorter, M. (2000) **100 of The World's Worst Invasive Alien Species: A selection from the global invasive species database**. The Invasive Species Specialist Group (ISSG), a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), 12pp. New Zealand.

Nxumayo, G. Z. (2013) **The Sustainable Management of the Nyika Trans-Frontier Conservation Area Project: Bracken Fern Management Guideline.** Department of National Parks and Wildlife (Northern Division), Malawi (Unpublished).

Pandit, M. K., Pocock, M. J. O. and Kunin, W. E. (2011) Ploidy influences rarity and invasiveness in plants. **Journal of Ecology,** 99, pp.1108–1115.

Pysek, P., Krivanek, M. and Jarosık, V. (2009) Planting intensity, residence time, and species traits determine invasion success of alien woody species. **Ecology,** 90, pp.2734–2744.

Pysek, P., Jarosik, V. and Pergl, J. (2011) Alien Plants Introduced by Different Pathways Differ in Invasion Success: Unintentional Introductions as a Threat to Natural Areas. **PLoS ONE,** 6(9): e24890. Doi:10.1371/journal.pone.0024890.

Pysek, P., Manceur, M. A., Alba, C., McGregor, F. K., Pergl, J., Stajerova, K., Chytry, M., Danihelka, J., Kartesz, J., Klimesova, J., Lucanova, M., Moravcova, L., Nishino, M., Sadlo, J., Suda, J., Tichy, L. and Kuhn, I. (2015). Naturalization of central European plants in North America: species traits, habitats, propagule pressure, residence time. **Ecology**, 96(3), pp.762-774.

Richardson, M. D. and Pysek, P. (2012) Naturalization of Introduced Plants: Ecological Drivers of Biogeographical Patterns. **New Phytologist**, 196, pp.383-396.

Richardson, M. D. and Rejmánek, M. (2004) Conifers as invasive aliens: a global survey and predictive framework. **Diversity and Distributions**, 10, pp.321-331.

Siska, M. (2016) **Survey of Alien Plants on the Nyika Plateau.** Interviewed by: Andrew Kanzunguze, 24 October.

The Nyika-Vwaza Trust, (2005) **Exotic Species Control Programme**. Trust News, 1(1), p2.

The Nyika-Vwaza Trust, (2006) **Eradicating Exotics.** Nyika-Vwaza News, 3, p6.

The Nyika-Vwaza Trust, (2010) **From Seedlings – Pine Trees Grow!** Nyika-Vwaza News, 10, pp.6-7.

The Nyika-Vwaza Trust, (2011) **News from the field: Invasives.** Nyika Vwaza News, 13, p6.

Thuiller, W., Richardson, M. D., Pysek, P., Midgley, G. F., Hughes, G. O. and Rouget, M. (2005) Niche-based modelling as a tool for predicting the risk of alien plant invasions at a global scale. **Global Change Biology,** 11, pp.2234–2250.

van Kleunen, M., Weber, E. and Fischer, M. (2010) A meta-analysis of trait differences between invasive and non-invasive plant species. **Ecology Letters**, 13, pp.235–245.

Venkatesh, S. C. and Kananji, B. (1985a) Provenance Research in Malawi. **South African Forestry Journal**, 135(1), pp.65-67.

Venkatesh, S. C. and Kananji, B. (1985b) The Status of Tree Breeding in Malawi. **South African Forestry Journal**, 135(1), pp.61-64.

Williamson, M., Dehnen-Schmutz, K., Kuhn, I., Hill, M., Klotz, S., Milbau, A., Stout, J. and Pysek, P. (2009) The distribution of range sizes of native and alien plants in four European countries and the effects of residence time. **Diversity and Distributions,** 15, pp.158–166.

Zieglar, A. P. (1993) Nyika National Park March 1978 to November 1983. In: Dorward, R. and Dorward, F. eds. **The Nyika Experience: Reminiscences of Malawi's First National Park.** The Wildlife Society of Malawi, pp.57-70.

7 APPENDICES

7.1 Appendix 1: Data Collection Forms

Plot Category: Hotspot

Plot Number: _______

Hotspot name: _____________________

Hotspot Coordinate: ________________

____

Species	Count (age)		Total Count	Average Height (m)	Average Diameter (cm)	Coordinates (x, y)	
	Juvenile	Mature				Top-Right	Bottom-Left
Rubus							
Acacia							
Pine							
Eucalyptus							

Other Description (Vegetation health status, surrounding flora and fauna, prevailing terrain features).

____

____

____

____

____

____

____

____

____

____

____

Track Category: Road **Spot Number:** _______

Track #: _______ **Start Coordinate:** ______________ **End Coordinate:** ____________

______________ ____________

Species	Age		Total Count	Average Height (m)	Average Diameter (cm)	Coordinates (x, y)
	Juvenile	Mature				
Rubus						
Acacia						
Pine						
Eucalyptus						

Other Description (Vegetation health status, surrounding flora and fauna, prevailing terrain features).

____
____
____
____
____
____
____

____
____
____
____
____
____
____

Track Category: Riverine System **Spot Number:** _______

Track #: _______ **Start Coordinate:** ______________ **End Coordinate:** ____________

______________ ____________

Species	Age		Total Count	Average Height (m)	Average Diameter (cm)	Coordinates (x, y)
	Juvenile	Mature				
Rubus						
Acacia						
Pine						
Eucalyptus						

Other Description (Vegetation health status, surrounding flora and fauna, prevailing terrain features).

____

____

____

____

____

____

____

____

____

____

____

____

____

____

7.2 Appendix 2: Map of old pine trial plots on the Nyika

The following sketch maps of the Nyika plateau were drawn in 1956 and obtained from Professor Andrew Dorward who has the original copy. The first map is the original captured version (Figure 18) whereas the second map (Figure 19) has 10 of the 12 trial plots highlighted in red. Map date and scale are highlighted on the bottom right quadrat of the third map (Figure 20).

Figure 18: Nyika sketch map, 1956.

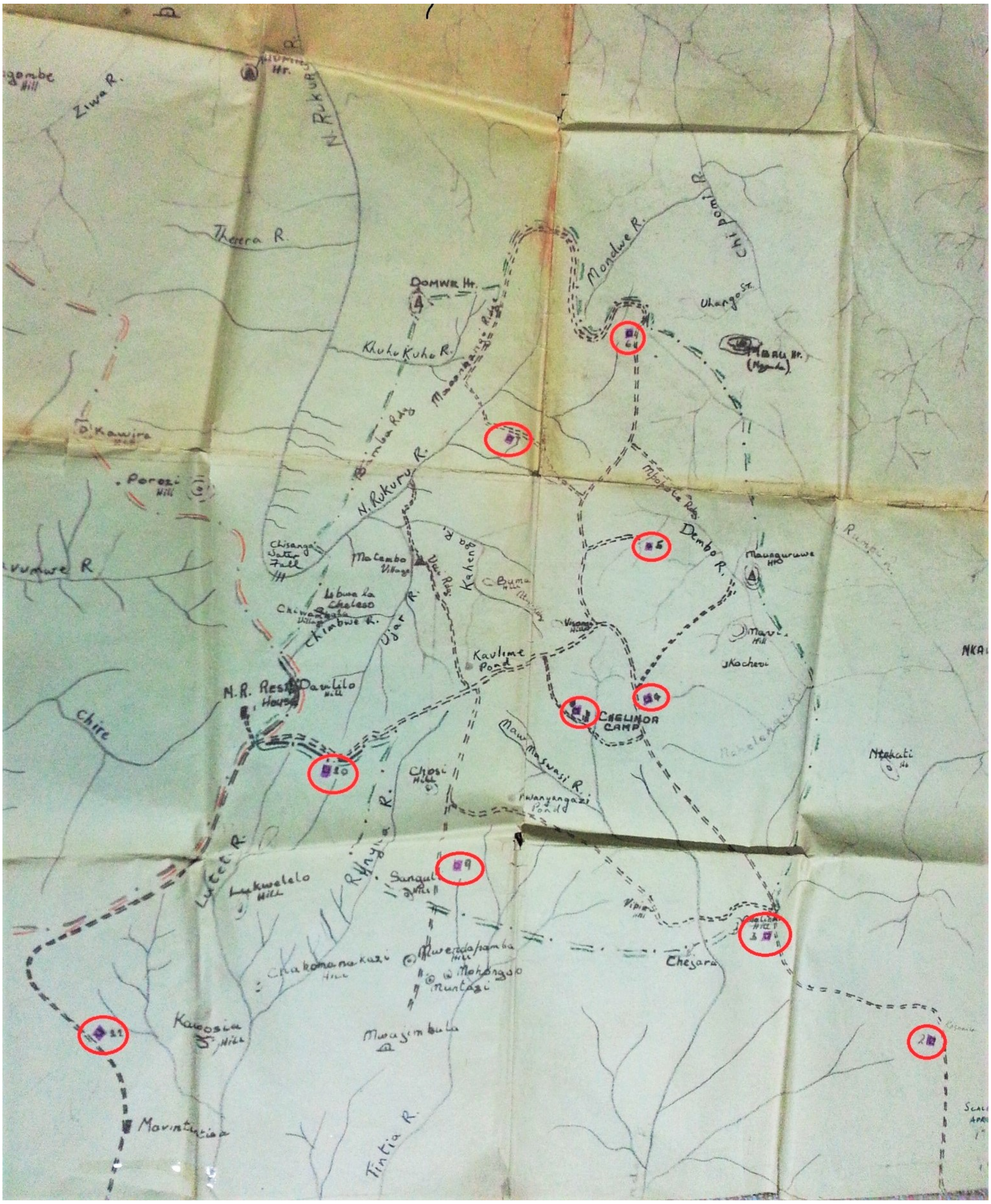


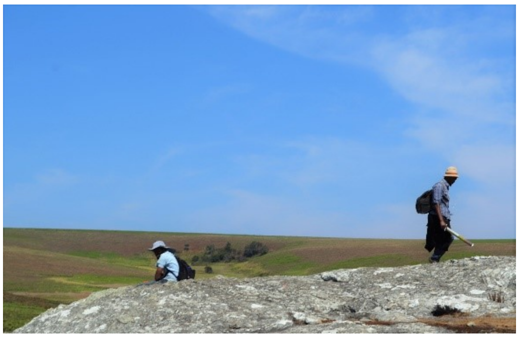
Figure 19: Nyika sketch map, 1956. Trial sites are circled in red.

Figure 20: Nyika sketch map, 1956. Scale and date in selective focus on the bottom right quadrat.

7.3 Appendix 2: The team

Figure 21: Mr. KK, Mr. Masina, Mr. Katondo, Mr. Sichinga, Mr. Siska and Myself [above(a): left to right]

7.4 Appendix 3: Highlights from the survey




GOD
BREAKS
CHAINS
NOT

7.5 Appendix 4: Upon orchids

Whilst collecting data in the eastern direction from Chelinda Camp, we came across two valleys wherein was an abundance of orchids beautifully arrayed. The following pictures show the highlights, where figures **a** to **d** were taken at the first site, and figures **e** to **g** were taken at the second site.