Final Evaluation Report

Your Details	
Full Name	Christine Rose Coppinger
Project Title	Understanding Pollinator Diversity and Ecology, and the Impacts of Wild Honeybee Exploitation in Subtropical Africa
Application ID	23606-1
Grant Amount	£5,000
Email Address	christine@remoteafrica.com
Date of this Report	30th June 2019

1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
To document plant-pollinator networks		■		This work was planned to be part of a long-term study which is still in progress however preliminary data has been collected which was the original goal of the Rufford project. Good progress has been made and the preliminary findings have been very instructive and will effectively inform research going forward. See Appendix 1.
Pollen library		■		Pollen samples are being continually collected to contribute to a pollen reference library for the area. This will help to inform indigenous honeybee resource use and to identify the forest species are that are important for honey production (an important forest product). At least 50 pollen samples have been collected from priority species and these are yet to be photographed and catalogued.
Assess nesting biology		■		Preliminary data has been collected that will set the foundation for future research as originally planned.
Review of traditional and modern methods of wild honeybee exploitation			■	The available information on traditional and modern beekeeping and other forms of honeybee exploitation has been reviewed. See Appendix 1 attached.
Socio-economic interviews to assess impacts of beekeeping and traditional practices		■		Over 570 household interviews have been conducted so far as part of the socio-economic survey. This socio-economic data will help to inform future planned focus group discussions with key informants in the area such as representatives from the Forestry Department and Nature's Nectar (honey industry representatives) See Appendix 1 for more information.

Field surveys to assess impacts of traditional beekeeping				Preliminary surveys have been conducted but further data collection and data analysis still needs to take place. Socio-economic data has provided rough estimates of the likely impacts of traditional beekeeping in the area (see Appendix 1).
Field surveys to assess impacts of traditional honey hunting				Preliminary surveys have been conducted but further data collection and data analysis still needs to take place. Socio-economic data has been collected on the number of active honey hunters present in the area and so data on honey hunting activities recorded during land surveys will indicate the level of impact expected by known densities of honey hunters.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled.

The amount of travel initially proposed was impossible to accomplish due to time constraints and there being one principle investigator carrying out the research. This resulted in the data collection being focussed in only the North-Western Province of Zambia and the study sites in the Eastern Provinces were excluded from the study for the present time. Other time constraint factors resulted in the project being extended beyond the initial year planned for the proposed activities. This was partially due to the delays in receiving permits for the research which were not foreseen.

3. Briefly describe the three most important outcomes of your project.

a) A review of traditional and modern beekeeping and honey hunting in Zambia was completed as part of this project which reviewed the available sources with information on these topics. This has helped to inform the development of an appropriate socio-economic survey that can collect information in the North-Western Province of Zambia that can help to provide an updated picture of beekeeping and honey hunting practices in the area. This information will eventually feed into beekeeping development and conservation projects to help to inform more effective development and conservation action.

b) Preliminary socio-economic findings from the data that has been analysed so far is enlightening in terms of livelihood activities that rural subsistence farmers in the area are engaged in and the relative importance of these for sustaining households. It has shown that beekeeping is a relatively important economic activity for a significant proportion of sampled households and also that traditional beekeeping using bark hives is likely having significant impacts on forests. These findings will help to inform future planned focus group discussions on forest use relating to important forest products what actions will be most effective in promoting forest conservation.

c) Data from an experiment on the effect of time of day on plant-pollinator interactions for two selected species has helped to get an idea of the insect community in the area and the factors that may affect effective research on plant-pollinator networks. Time of day effects on floral visitor communities have rarely been looked at and this forms an important first step to quantifying and studying the plant-pollinator communities in the area further in the future.

d) The preliminary research conducted during this project enabled scholarship funding to be secured and the expansion of the research project into a 4-year long PhD study. This has exponentially increased the impact that the research will have

4. Briefly describe the involvement of local communities and how they have benefitted from the project.

Local communities have been involved through the socio-economic survey which collected information on rural livelihoods in the area. This information will eventually feed into rural beekeeping and conservation projects to promote more effective action in rural development projects. Community members were also employed as field assistants to help in the collection of socio-economic data and this exposure to research and training in data collection methods is hoped to benefit these community members in future.

5. Are there any plans to continue this work?

This work has enabled scholarship funding to be secured to extend the study into a 4-year PhD study, supported by the Irish Research Council. The primary researcher is now enrolled at University College Dublin.

6. How do you plan to share the results of your work with others?

The results of the study will be published in peer-reviewed articles when research on these topics has been completed. The results will also be presented at conferences whenever possible. Technical reports will be distributed to project partners (the beekeeping industry and the Ministry of Lands and Natural Resources) on completion of the study to make the research findings of this study more accessible to partners.

7. Timescale: Over what period was the grant used? How does this compare to the anticipated or actual length of the project?

The grant was used over a period of approximately 18 months which is about 6 months longer than the anticipated length of the project. This was due to the delay in securing permits for the research from the relevant Zambian Government departments.

8. Budget: Provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used. It is important that you retain the management accounts and all paid invoices relating to the project for at least 2 years as these may be required for inspection at our discretion.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Travel	1670	813	-857	There were savings made on travel expenses as the proposal included fieldwork in two very distant study areas. Time and logistical constraints prevented work being possible in the Eastern Province field area and so travel expenses were less than expected. In kind support secured from project partners (Trident Foundation) has also contributed to savings in this budget line.
Per diems/ subsistence allowance, primary fieldworker	2064	2075	-11	Per diems were used effectively to conduct the field work and assistant training that was planned for the project.
Per diem's field assistants/ field monitors	1016	707	-309	Budget was set aside for game scout escort fees which in the end were not required. This accounts for the savings in this budget line.
Equipment	250	855	+605	Equipment expenses were higher than expected primarily because of the unanticipated necessity of expensive ropes and safety equipment for conducting floral observations in trees safely. Other insect sample storage equipment such as Eppendorf's and tubes were also more expensive than anticipated.
TOTAL	**5000**	**4450**	**-550**	**Unused funds returned to RF**

9. Looking ahead, what do you feel are the important next steps?

The support provided by the project has enabled scholarship funding to be secured to continue the research initiated through this project. It has also allowed preliminary data to be collected which will inform the future PhD research and a major goal of this research will be to identify practical and tangible solutions to the environmental and socio-ecological problems identified. Focus group discussions will be an important next step in gathering the data needed to further define these socio-ecological problems, and the socio-economic data collected so far through household interviews will be important for informing the structure and focus of these focus group discussions. In the long term, prioritising conservation action and promoting more sustainable forest use and identifying mechanisms for community protected forests to achieve forest conservation goals while also providing for the needs of rural communities will be important outcomes of the research.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

The Rufford Foundation logo was used on the tablets that were used to record data for the household surveys. Some of the work carried out during the project was presented at the SCAPE (Scandinavian Association of Pollination Ecologists) conference held in Ireland in October 2018 and the Rufford Foundation were acknowledged as part of this oral presentation. Some of the work completed through the project was also showcased at the Rufford Conference in Malawi in July 2019 through an oral presentation and Rufford was acknowledged as the primary funder of the research presented.

11. Please provide a full list of all the members of your team and briefly what was their role in the project.

Christine Coppinger – principle investigator
Christine was the principle investigator of the project who developed and drove the project activities and research.

Fred Chiyanga – field assistant
Fred assisted Christine in aspects of the project, mainly the socio-economic survey, and helped with household surveys. Fred also helped in the training of additional field helpers.

Clever Kaloza – field assistant
Clever assisted with carrying out household interviews for the socio-economic survey.

Kairal Kasaji – field assistant
Kairal assisted with carrying out household interviews for the socio-economic survey.

Appendix 1: Understanding Pollinator Diversity and Ecology, and the Impacts of Wild Honeybee Exploitation in Subtropical Africa

Christine R Coppinger

September 2019

Report prepared for the Rufford Foundation

This report is made possible by the support of the Rufford Foundation. The contents are the responsibility of Christine Coppinger and do not necessarily reflect the views of the Rufford Foundation.

The Rufford Foundation

www.rufford.org @ruffordgrants

Contents

1 Introduction

This report is the final report for Christine Coppinger's Rufford project, "Understanding Pollinator Diversity and Ecology, and the Impacts of Wild Honeybee Exploitation in Subtropical Africa" (project number 23606-1) which accompanies the Final Project Evaluation Report for this project. The primary purpose of the project was to collect data on forest product exploitation (including honey from indigenous honeybees) and plant-pollinator relationships in the North-Western Province of Zambia in the areas surrounding West Lunga National Park, to create an understanding of rural forest uses and the sustainability of forest use. The duration of the project was approximately 1.7 years and the support provided by the Rufford Foundation for this work has enabled a long-term PhD study to be initiated that will explore the topics investigated in more detail in the coming four years.

1.1 Biophysical and Socio-Economic Context

In order to understand the study area, it is important to understand its biophysical context (i.e. the biotic and abiotic factors) and the socio-economic factors that influence forest utilisation and the availability of forest products. The following sections summarise these aspects.

1.1.1 Study Area

The study area for the project is shown on the map in Figure 1. All research was conducted within Chizela Chiefdom in Mufumbwe District of the North-Western Province of Zambia.

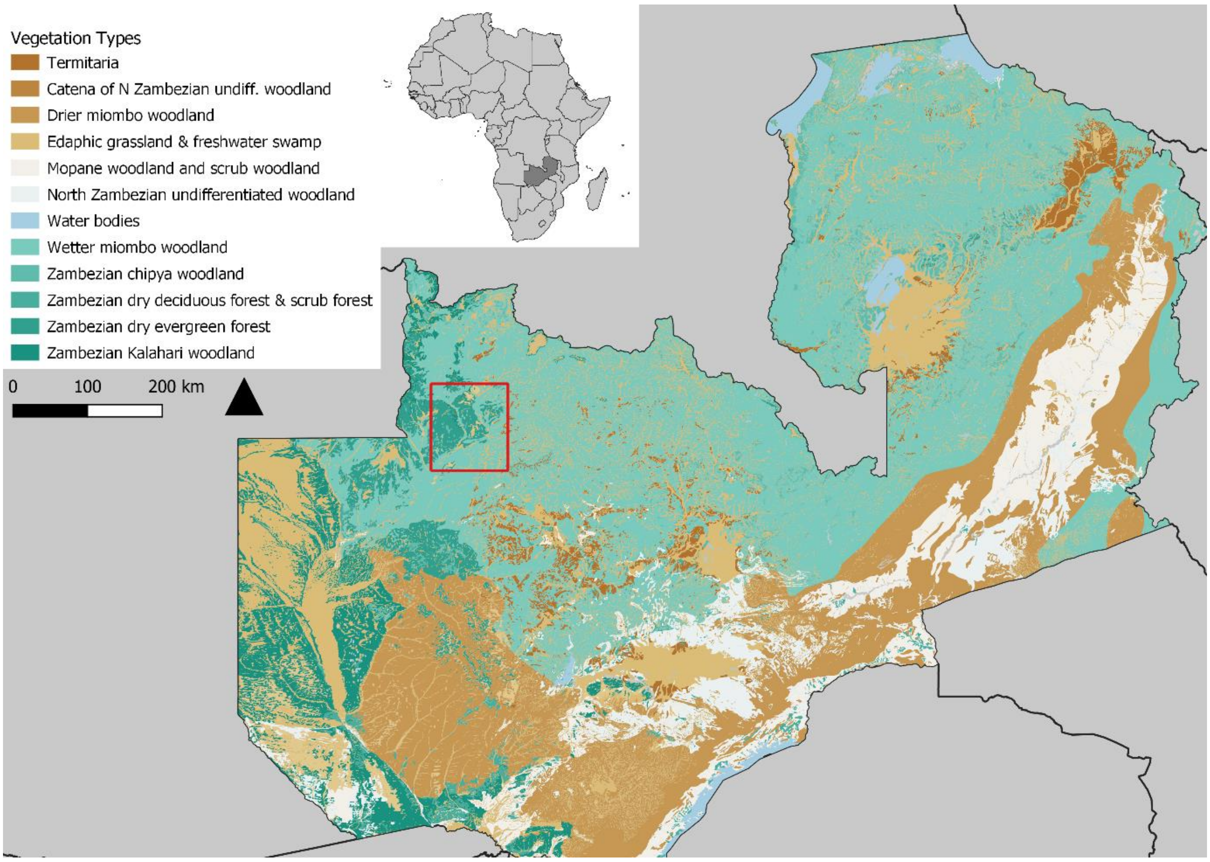

Figure 1: The predominant vegetation types of Zambia, with only the types dominant in the study area (shown by the red rectangle) listed in the legend. Vegetation data sourced from van Breugel et al. (2015).

1.1.2 Dry evergreen Cryptosepalum forest

The miombo ecoregion is particularly species rich with an estimated 8,500 species of higher plants , 54% of these being endemic to the region (Chirwa, Syampungani and Geldenhuys, 2008). The study area falls within the miombo ecoregion which spans 9 countries: Zambia, Angola, DRC, Tanzania, Malawi, Mozambique, Zimbabwe, South Africa and Botswana (Chirwa, Syampungani and Geldenhuys, 2008). Within this ecoregion there are a number of vegetation types with the dominant vegetation types within the study area being wetter miombo and Zambezian dry evergreen forest which is in places dominated by *Cryptosepalum* (Timberlake and Chidumayo, 2011). Detailed vegetation accounts are described by Fanshawe (2010).

Figure 2: A typical healthy Zambezian dry evergreen forest, here dominated by *Cryptosepalum* and *Parinari curatellifolia*.

1.1.3 Socio-economic context

The North-Western Province of Zambia was historically a very poor province (Crehan and Von Oppen, 1988) with a relatively sparse population (Mickels-Kokwe, 2006). The majority of the population consists of rural subsistence farmers who have very low monetary incomes (Mickels-Kokwe, 2006) and who supplement their livelihoods by various means, including foraging for forest products such as honey and through traditional beekeeping (Fischer, 1993). Various beekeeping projects have stimulated the development of the beekeeping industry in the study area (Mickels-Kokwe, 2006) and this is detailed further in section 2.

2 Review of traditional and modern beekeeping and honey hunting

An exhaustive review of existing information on beekeeping and honey hunting in Zambia was conducted. A short summary of other important forest products known from Zambia and from the project area is also included in this section which helps to give a more complete picture of the importance of forests for rural livelihoods in Zambia.

Forest products have been widely recognised as being an important component in rural livelihoods (Mickels-Kokwe, 2006; Chirwa, Syampungani and Geldenhuys, 2008; Jumbe, Bwalya and Husselman, 2008). In Zambia, woodlands contribute 20.6% of total household income and provide a wide range of products and services to rural communities (Jumbe, Bwalya and Husselman, 2008). The western honeybee, *Apis mellifera scutellata*, native to Zambia, provides one of the most valuable and widely exploited forest products of the region – honey (Mickels-Kokwe, 2006).

2.1 Beekeeping and honey hunting

The urgent need to conserve the western honeybee *Apis mellifera* and the imperilled status of the species throughout much its native range, has been highlighted (Dietemann *et al.*, 2009; Eardley, Gikungu and Schwarz, 2009; Jaffé *et al.*, 2009; Requier *et al.*, 2019). However, little work has been done to assess the conservation concerns and needs of the western honeybee within their native range (Anguilet *et al.*, 2015), despite their importance for supporting a highly valuable honey and wax trade which also contributes to livelihoods development (IPBES, 2016). In rural Zambia income from honey sales can contribute significantly to household income where many people survive on less than 1 USD a day and honey can account for 20-25% of total annual income (Mickels-Kokwe, 2006). Beekeeping projects have been promoted in Zambia by rural development programmes for many years and in the North-Western Province of Zambia, the German Technical Cooperation Agency (GTZ) Integrated Rural Development Project (IRDP) focussed on developing the honey sector in Kabompo District since the early 80's (Simukoko, 2008). Although this particular project was successful with the support of the GTZ, sources report that once this support ended the community did not have the capacity to continue running the project (Crehan and Von Oppen, 1988) and access to the honey market for rural beekeepers became problematic (Simukoko, 2008).

Bee product exports from Zambia are recorded as early as the 1890s but no statistics are available prior to 1964 after which Zambia reportedly exported on average 7.3 tonnes of beeswax annually between 1964 and 2002 (Mickels-Kokwe, 2006). Honey exports from Zambia only became significant after 1990 and by 2003 the total estimated production of honey in Zambia was at 1,500 metric tonnes with 250 MT exported to Europe and by 2004, more than 400 MT of honey was being exported (Mickels-Kokwe, 2006). Until 2001, North-Western Bee Products' (NWBP), which had been set up to take over the honey-buying functions of the GTZ IRDP project, were the major exporters of Zambian honey, but after 2001 Forest Fruits Zambia contributed significantly to exports (Mickels-Kokwe, 2006). Currently there are several honey buyers in Zambia, many of which buy the bulk of their honey from the North-Western Province of Zambia, considered to be the "honey pot" of the country (Simukoko, 2008). These businesses include among others, Forest Fruits (which produces Zambezi Gold), Ubuchi, Nature's Nectar and Bee Sweet. These businesses primarily export the honey (to South Africa or Europe) to service an insatiable global honey demand. According to Mickels-

Kokwe (2006) 100% of honey exports and 90-95% of domestic production originated from the North-Western Province of Zambia at the time.

Although the honey industry (Forest Fruits and others) provide access to global markets for rural beekeepers, in many cases investments back into rural beekeepers and the indigenous miombo woodlands from which the vital nectar flows originate is lacking. Mickels-Kokwe (2006) highlights several constraints that limit the potential of the bee products industry in Zambia with deforestation being a major threat. Policies are also not supportive of beekeepers and much of the success of the bee products sector is thanks to private sector or NGO projects (Mickels-Kokwe, 2006). Many honey businesses buy their honey directly from rural beekeepers that are still using traditional bark hives. Others (e.g. Nature's Nectar) couple this approach with sourcing modern top bar hives made from pine through donor funding and then engage target communities in beekeeping training and forest conservation initiatives to contribute more actively to community development and the protection of forest resources that are vital for providing nectar flows. This business model which combines the needs of a viable business with rural development seems to be a more sustainable approach in terms of impactful and sustainable rural development, financial and long-term sustainability ensured by building viable businesses around rural development while simultaneously promoting the conservation of the forest resources that are vital for ensuring honey production.

Published information from Zambia on the actual traditional and modern beekeeping methods or of harvesting methods from wild honeybee hives is scarce or lacking. A few publications that resulted from the GTZ work in Kabompo District provide the best idea of what traditional methods may have involved. A Zambian beekeeping handbook developed by Clauss and Clauss (1991) illustrates the beekeeping options available to rural beekeepers including the use of calabash hives, bark hives, clay pots and the more modern top bar hives. Bark hives appear to be the more traditional hive type that was historically used by beekeepers as these are the methods that persist in areas where no "project" exists to support beekeepers. Clauss and Clauss (1991) report that this hive type was widely used and popular in the Western and North Western Provinces of Zambia and was also used in the neighbouring regions of Angola and Southern DRC (formerly Zaire). While Clauss and Clauss (1991) recommend maintaining and learning from the vast indigenous knowledge of experienced traditional bark beekeepers they also caution against the use of bark hives which are destructive for forests and are not sustainable in light of increasing population pressure. Indeed, a beekeeping report from the region estimated that roughly 273,000 trees are reportedly felled annually in the North-Western Province for the construction of traditional bark hives (Clauss, 1992).

Log hives are reportedly used by traditional beekeepers in Tanzania (Ntenga, G. M and Mugongo, 1991) and earlier written records of bee-hives by David Livingstone in 1845 describe log and bark hives that were used Lunda tribespeople on the upper Zambezi River in the North-Western Province of Zambia (Mickels-Kokwe, 2006). Beekeeping appears to be part of the traditions of the people of this area of Zambia as even today traditional beekeeping is common among the Lunda and Luvale tribespeople of Mwinilunga and Kabompo Districts (Mickels-Kokwe, 2006). Other materials are reportedly used in traditional hive construction (logs, calabashes, pots) and the main consistent design of a "traditional" hive is its cylindrical shape (Mickels-Kokwe, 2006). Hives are also traditionally suspended high up in trees in order to more easily attract swarms which generally fly relatively high and also to deter pests such as honey badgers, red ants and to escape fire (Mickels-Kokwe, 2006).

Another report from the Tanganyika region of East Africa described the process of making bark hives, which generally involves removing a ring of bark from a standing tree of the preferred tree species (usually *Julbernardia* or *Brachystegia*) which, unfortunately, are the same tree species that provide the main nectar flows on which the majority of the honey industry in the miombo region depends (Smith, 1966). Often only a single hive is constructed from one tree as this is easier than removing a number of bark rings from one tree, resulting in more tree death than is strictly necessary. The lifespan of these bark hives was reportedly only between three and five years. Smith (1966) estimated that there were approximately 2,000,000 bark hives and the same number of log hives in Tanganyika at that time, and based on a hive lifespan of 3-5 years, it was calculated that roughly 500,000 trees were killed each year. Additionally, when considered other rural uses for bark, it was assumed that this figure should be doubled.

Very little information exists on traditional honey hunting practices in Zambia. A recent publication that resulted from the support provided by this Rufford project forms the first published information on honey hunting in Zambia. In this publication, Coppinger *et al.* (2019) report tree felling, branch removal and hive cavity excavation as methods employed by honey hunters to harvest honey from wild indigenous *Apis mellifera scutellata* colonies in the Eastern and Lusaka Provinces of Zambia. Re-occupation rates of hives that had formerly been poached was also found to be very low – 0% in the miombo habitat and 10% in the mopane habitat. Fire is also used by honey hunters to subdue the bees (Clauss, 1992; Fischer, 1993) and sometimes also to burn down the tree or to burn out the hive cavity often resulting in damaging forest fires (personal observation). In Tanzania, honey hunting is reportedly carried out at night often by people who are themselves beekeepers (Ntenga, G. M and Mugongo, 1991). This is possibly due to the fact that the honey hunting reported for this study was being conducted within a national park due to the lack of intact forest areas not under protection. The socio-economic survey that has been supported by the Rufford Foundation as part of this project is currently gathering data on traditional honey hunting methods and some of the preliminary results from this study are presented in section 4.

Globally and regionally, information does exist on honey hunting and it appears that this ancient practice existed from as early as 12,000 years ago and was practiced by Neolithic humans (Roffet-Salque *et al.*, 2015). One study does report that an estimated 150 trees per square mile were felled annually by honey hunters in Zambian forest reserves in the Copperbelt, an area where population densities were high at the time (Smith, 1966). Kajobe and Roubik (2006) document honey hunting impacts in Bwindi Impenetrable National Park in Uganda where they found almost all cases of human and chimpanzee predation on bee nests resulted in destruction of the nest including the brood. Crane (1999) also provided a comprehensive review on beekeeping and honey hunting in Africa and globally. Honey hunting is described as an opportunistic practice whereas beekeeping is more a "way-of-life" practiced by those families that have developed their skills over generations (Fischer, 1993). Both practices are however generally supplementary activities that serve to support a multi-faceted strategy to ensure food security for rural families living subsistence lifestyles (Fischer, 1993) with a significant number of people engaged in these activities: an estimated 20,000 beekeepers and 6,000 honey hunters in Zambia (Mickels-Kokwe, 2006). Generally, honey hunting results in the death of the colony harvested (Hussein, 2001) as does traditional beekeeping in some cases when traditional fixed comb hives are used and when brood is also harvested or when harvesting is carried out at night (Smith, 1953). Mickels-Kokwe (2006), in his case study on the Zambian honey industry, points out that deforestation unlinked to bark hive production is the main threat to the beekeeping potential of the country, further highlighting the need to reduce pressure on forests in any way possible if the honey producing potential of the country is to be realised. This indicates that traditional bark hive beekeeping and honey hunting practices, which may have been sustainable before substantial population growth, are likely now causing damage both to the forest resources the provide the nectar flows needed for honey production and for honey bee colonies whose genetic diversity and abundance may be negatively impacted by exploitative practices that result in the death of whole colonies. If practices are altered slightly, there is great potential for beekeeping and beekeepers to help in conserving important forest landscapes.

2.2 Fruits as non-timber forest products

The potential of fruit products from a number of tree species native to the miombo region to become valuable commodities and thus improve livelihoods in the miombo ecoregion has been recognised widely (Akinnifesi *et al.*, 2002, 2006, 2008; Ham, 2006; Chirwa, Syampungani and Geldenhuys, 2008; Jumbe, Bwalya and Husselman, 2008; Jamnadass *et al.*, 2011). A number of constraints preventing smallholder involvement in fruit production in sub-Saharan Africa were highlighted by Jamnadass *et al.* (2011) and which included a lack of access to appropriate cultivars (which do not yet exist), poor farm management and post-harvest practices and weak marketing systems. It has also been recognised that while some products such as oils (e.g. marula nut oil) may have commercial value as a traded commodity, rural communities have little value for these products locally and do not have access to the relevant markets (Ham, 2006). While some of the fruits that are particularly important to rural communities are from exotic trees such as the mango (Ham, 2006), many indigenous fruits and food resources have been recognised as being highly important, especially in times of famine and food shortages (Malaisse and Parent, 1985; Akinnifesi *et al.*, 2006, 2008; Chirwa, Syampungani and Geldenhuys, 2008). Malaisse and Parent (1985) comprehensively list fruit producing species that are important for rural communities in the Zambezian woodland area.

Indigenous fruit and other food products harvested from indigenous forests (Figure 3) provide important nutrients, vitamins and minerals to supplement generally poor rural diets (Akinnifesi *et al.*, 2006; Chirwa, Syampungani and Geldenhuys, 2008) and additionally, these forest food products provide food security and some supplementary income for marginalised demographic groups such as women, children and the aged (Akinnifesi *et al.*, 2006). In Zambia, Jumbe, Bwalya and Husselman (2008) found that dry forests contribute significantly to rural livelihoods with forest products contributing 20.6% to total household income on average in the form of subsistence and cash income. The most important forest products found by this study included mainly wood products such as charcoal and firewood which were found to provide 70% of the country's energy needs. Non-wood forest products that were important included more than ten leafy vegetable species, 25 mushroom types and 35 edible species of caterpillars. The poverty mitigation functions provided by forests that other studies have reported were also found to be true in Zambia (Jumbe, Bwalya and Husselman, 2008). Similar to the honey industry, the major threat to the provision of food and fruit products from forests is deforestation and shifting cultivation (Akinnifesi *et al.*, 2006; Chirwa, Syampungani and Geldenhuys, 2008; Jumbe, Bwalya and Husselman, 2008).

A comprehensive review by Akinnifesi *et al.* (2008) on important fruit trees in the region found that several indigenous Zambian tree species' fruit were important for rural communities who recommended them for domestication. This resource and other field guides and publications were used to develop the below table (Table 1) identifying the most important indigenous trees for providing the forest products reviewed in this section (including honey, hive materials, fruit and other edible forest products) in the Mufumbwe District where the Rufford Project (project number 23606-1) was based.

Figure 3: Image depicting some of the common forest products harvested from the forest in the study area. These include: A-B) honey, either from wild colonies or through traditional beekeeping; C) fruit from indigenous forest trees; D-G) edible caterpillars.

Table 1: Indigenous tree species identified as providing important forest products in the study area in Mufumbwe District of Zambia's North-Western Province. Sources from which the information was obtained is indicated by superscripts and are listed below the table.

Tree species	Fruit	Honey (nectar)	Timber	Building/ materials	Hive construction	Medicinal	Charcoal	Edible caterpillar host tree	Mushrooms (Ectomycorrhizal association)
Mobola plum, *Parinari curatellifolia*	x[1, 2, 5]	x[3]		x[1, 2]	x[2]	x[1]			
Mukungu, *Cryptosepalum exfoliatum pseudotaxis*		x[2, 3]			x[2]				
Woodland waterberry, *Syzygium guinense guinense*	x[1]	x[1, 3]							
Waterberry, *Syzygium guinense barotsense*	x[2]	x[3]							
Musamba, *Brachystegia longifolia*		x[1, 2, 3]				x[1]		x[1]	
Mupuchi, *Brachystegia spiciformis*		x[2, 3]			x[1]				
Musobo, Brachystegia floribunda		x[3]					x[1]		
Muselele, *Brachystegia bussei*				x[2]					
Mutondo, *Julbernardia paniculata*		x[1, 2, 3]		x[1, 2]		x[1, 2]	x[2, 3]	x[2]	
Mutobo, *Isoberlinia angolensis*		x[1, 2]		x[2]		x[2]		x[1, 2]	
Musuku, *Uapaca kirkiana*	x[1]	x[1, 2]		x[1]					x[1]
Bush orange/ Katonga, *Strychnos cocculoides*	x[5]								
Monkey orange/ Munkulunkulu, *Strychnos pungens*	x[5]								
Mufuka, *Marquesia macroura*		x[3, 4]			x[2]				x[1]
Chikuku, *Phyllocosmos lemaireanus*		x[3]		x[2]		x[2]			

[1] (Smith and Allen, 2004), [2] (Storrs, 1995), [3] (Clauss and Clauss, 1991), [4] (Trapnell, 2001), [5] (Akinnifesi *et al.*, 2008)

3 Socio-economic survey on beekeeping, honey hunting and forest use

A total of 574 respondents were interviewed during the socio-economic surveys undertaken within the Chizela Chiefdom since the start of the project. This report is based on the first 72 surveys for which exploratory analysis has been done. Further data cleaning and analysis still needs to be done on the more recent socio-economic data before these can be presented. More recent surveys also collected data on opinions relating to pollinators and forests, but these data still need to analysed. The rough geographic coverage of the entire survey thus far is approximately 400km^2. The aim of the survey was to investigate the importance of forests and pollination services to rural subsistence farming communities, relative to other livelihood activities. All surveys were conducted within Mufumbwe District in the area south of West Lunga National Park.

Households were categorised into “household types” based on their predominant livelihood activities. Farming is by far the most common type of household. Beekeeping is the second most common type of household (Figure 4).

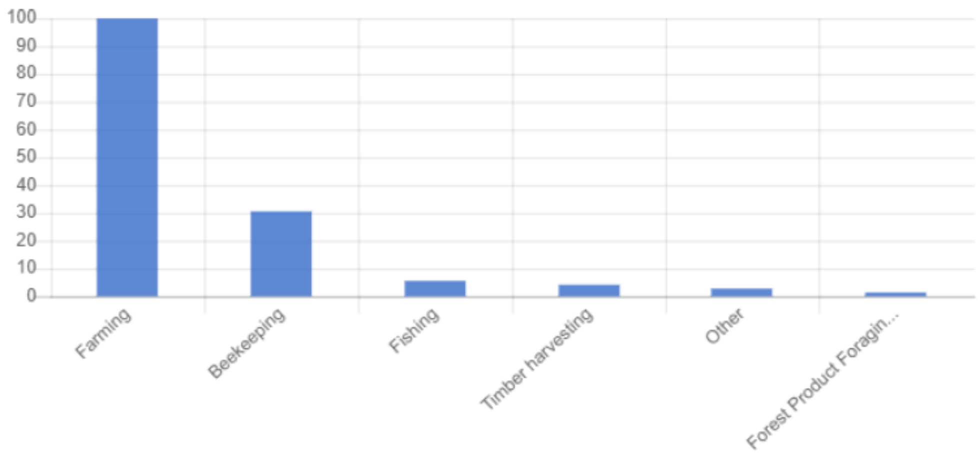

Figure 4:The types of households encountered during the socio-economic survey

In terms of income generation, farming by far the most important with beekeeping in second. Caterpillars and mushrooms were also relatively important (Figure 5):

- On average, households make ZMK 295.83 per year from beekeeping (stdev: 660.57)
- On average, households make ZMK 39.40 per year from wild honey harvest (stdev: 155.63)
- On average, households make ZMK 111.10 per year from forest products (stdev: 265.47)
- On average, households make ZMK 2157.64 per year from farming and livestock (stdev: 1858.02)
- On average, households make ZMK 3185.44 per year in total (stdev: 3105.56)

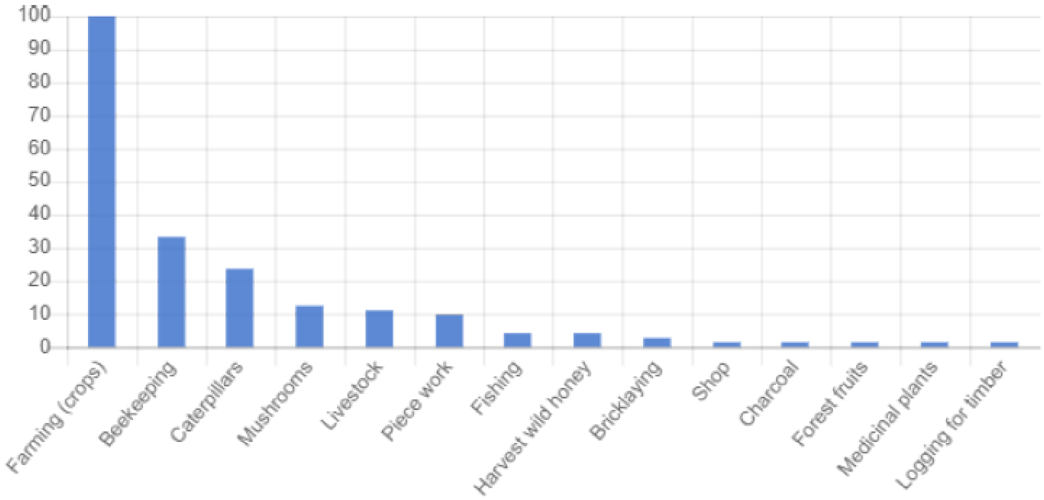

Figure 5: Livelihood activities for income generation practiced by interviewed households

Farming was an important source of income for 100% of the households interviewed whereas beekeeping was only important for the income generation of 24% of households (Table 2).

Table 2: Table showing the most important seasonal activities of traditional beekeepers and wild honey harvesters, the seasonal burning practices and seasonal changes forest product collection activities.

Top 3 Most important sources of income for the Household (%)			
	Farming (100%)	Beekeeping (24%)	Piece work (19%)
Top 3 beekeeping and wild honey harvesting activities each month			
January	Making hives (15)	Checking hives (4)	None (3)
February	Making hives (14)	None (5)	Hanging hives (5)
March	Hanging hives (13)	None (5)	Checking hives (3)
April	Checking hives (9)	Hanging hives (8)	None (3)
May	Harvesting honey (9)	Checking hives (6)	Hanging hives (5)
June	Harvesting honey (13)	None (6)	Wild harvest (3)
July	None (9)	Harvesting honey (8)	Hanging hives (6)
August	None (6)	Hanging hives (6)	Harvesting honey (6)
September	None (7)	Checking hives (6)	Hanging hives (5)
October	Harvesting honey (9)	Checking hives (7)	Wild harvest (4)
November	Harvesting honey (12)	None (7)	Checking hives (3)
December	Harvesting honey (12)	None (7)	Checking hives (3)
Top 3 burning activities each month			
January	Not burning (72)		
February	Not burning (71)	Burning around hives (1)	
March	Not burning (72)		
April	Not burning (70)	Burning around hives (1)	Burning the forest (1)
May	Not burning (66)	Burning around hives (5)	Burning the forest (1)
June	Not burning (56)	Burning the forest (11)	Burning the fields (7)
July	Not burning (48)	Burning the forest (20)	Burning the fields (12)
August	Burning the forest (41)	Burning the fields (35)	Not burning (26)

September	Burning the fields (57)	Burning the forest (48)	Not burning (12)
October	Burning the fields (60)	Burning the forest (44)	Not burning (9)
November	Not burning (65)	Burning the fields (7)	Burning the forest (4)
December	Not burning (70)	Burning the forest (2)	Burning the fields (2)
Top 3 forest products collected each month			
January	Firewood (42)	Mushrooms (26)	Honey (24)
February	Firewood (42)	Mushrooms (27)	Honey (24)
March	Caterpillars (51)	Firewood (41)	Honey (24)
April	Caterpillars (44)	Firewood (40)	Honey (22)
May	Firewood (41)	Caterpillars (37)	Honey (24)
June	Firewood (40)	Honey (24)	None (21)
July	Firewood (41)	None (23)	Honey (21)
August	Firewood (40)	None (22)	Honey (19)
September	Firewood (36)	None (22)	Honey (18)
October	Firewood (40)	Honey (21)	Mufungo fruit (18)
November	Firewood (40)	Honey (20)	Mufungo fruit (19)
December	Firewood (37)	Honey (23)	Mufungo fruit (21)

3.1.1 Beekeeping

As much as 24% of households reported that beekeeping was an important income generating activity (Table 2). This equates to 22 beekeeping households of the 72 households included in this preliminary analysis which is relatively high. All these beekeepers reported that they used bark beehives (i.e. they employed traditional beekeeping practices) and the average number of beehives per beekeeper was 45. If one assumes that one bark hive is made per tree and given the reported average lifespan of barks hives of 5.2 years (stdev. 2.4), this equates to approximately 8.7 trees felled per beekeeper per year to construct bark hives and 191 trees felled annually by the 22 beekeepers interviewed in this initial survey. Beehives were situated between 2 and 15km from the homestead. The seasonal activities of beekeepers seemed to variable between different beekeepers but most beekeepers reportedly harvest their honey in the months of June, November and December (Table 2). Most beekeepers are engaged in some activity in every month of the year whether it is making hives, hanging hives, harvesting honey or checking hives (Table 2).

Table 2 shows that burning the area around beehives was also a common practice among beekeepers and this activity was practiced all year round.

3.1.2 Honey hunting

The total number of respondents who engaged in harvest of honey from wild honeybee colonies (i.e. honey hunting) was 10 which is roughly 14% of the respondents. This is a relatively high number for a supposedly opportunistic activity (Fischer, 1993). Honey hunters that their typical practices involved either cutting a hole around the cavity of the bee nest to extract honey (10 respondents) or felling the tree (9 respondents). Very few reported being stopped from harvesting wild honey, even when this was being done in a closed or restricted area. The seasonality data does not seem to show a clear seasonal pattern of honey hunting activity which would be consistent with the theory that this is an opportunistic activity.

3.1.3 Forest product use

Honey, caterpillars and mushrooms seem to be the most important forest products in terms of things that have a good market value and are collected for income generation (Figure 5) and are also sought after for home consumption (Figure 6). Firewood is also extremely important and is collected by most households. Fuel products harvested from forests were also found to be important by other studies (Jumbe, Bwalya and Husselman, 2008).

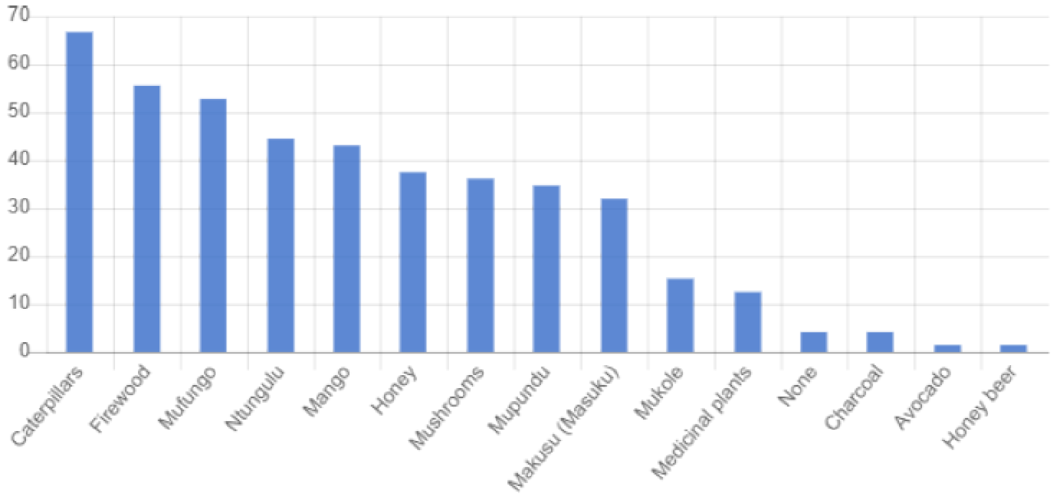

Figure 6: Types of forest products most important for households (for consumption and/or for sale)

Seasonal changes in availability of the various forest products are reflected in the seasonal changes in collection of these products (Table 2). This data shows that firewood is collected year-round by all households but that the majority of the other forest products are only available in their specific season e.g. mushrooms are collected during the rainy season in January and February, caterpillars from March to May etc. The availability of these resources has implications for how important they are for households and how much they can contribute to food security and a supplementary income. The successional availability of different resources at different times is likely important for households in that they always have something available to them. Honey is commonly collected throughout the year and Mufungo fruit are the only fruit that were within the top three most collected forest products.

4 Plant-pollinator networks

A time of day experiment was conducted on the waterberry *Syzygium guinense barotsense* in which the theory that time of day and the duration and number of floral observations conducted would have an impact on the resulting floral visitation rates by visiting insects and also the diversity of insect flower visitors. The experiment was repeated on Mutondo *Julbernardia paniculata* trees and preliminary floral visitor data has been collected for a number of other tree species but these data have not yet been analyzed and just the *S. g. barotsense* data are presented here. This experiment will help to determine the minimum duration of observation periods and the minimum number of observations needed to ensure that data comprehensively capture all floral visitors. The findings of this study will help in developing protocols for establishing future planned plant-insect visitation network experiments.

4.1 Methods and study area

Floral observations were conducted over three weeks in November 2018 on flowers of waterberry trees in the vicinity of the Jivundu Department of National Parks and Wildlife, across the Kabompo River of the southern boundary of the West Lunga National Park in the North-Western Province of Zambia (lat: -13.10007619, long: 24.69418904). This area falls within a relatively well protected area of forest with relatively low anthropogenic impacts when compared to surrounding communal areas. Waterberry trees grow abundantly on the banks of the Kabompo River and other rivers in Zambia and are widely regarded as an important floral resource, especially for indigenous honey bees *Apis mellifera scutellata*. This tree species is restricted to river banks and does not grow outside of the riparian zone.

Each observation was conducted in a different tree and flowers were reached for observations by climbing the tree. Roughly the same numbers of flowers were observed during each observation and the observer was situated within 1.5m of the observed flowers. All floral visitors to these flowers were recorded and visiting insects that could not be identified on sight were collected when possible. Where species level identifications were not possible, insect visitors were identified to genus or family level. Observation periods of 30 minutes were conducted, within three different day-time slots: 1) 6:00 to 10:00; 2) 10:00 to 14:00; 3) 14:00 to 18:00.

4.2 Results

A total of 43, 30-minute observations were conducted: 14 observations were conducted in time slot 1 (6:00 – 10:00), 15 in time slot 2 (10:00 – 14:00) and 14 in time slot 3 (14:00 – 18:00). The temperatures within each time slot ranged as follows: 6:00 -10:00: 17-29°C; 10:00 – 14:00: 23 - 33°C; 14:00 – 18:00: 29 -35°C.

4.2.1 Species accumulation curves

When the whole 30 minute observation period was used in analysis, a total of 27 taxa were observed visiting waterberry flowers with the full complement of taxa being observed by the 36th observation period (Figure 7). When only the first 15 minutes of each observation period are used a total of 21 taxa were observed visiting waterberry flowers with all 21 taxa being observed by the 35th observation period.

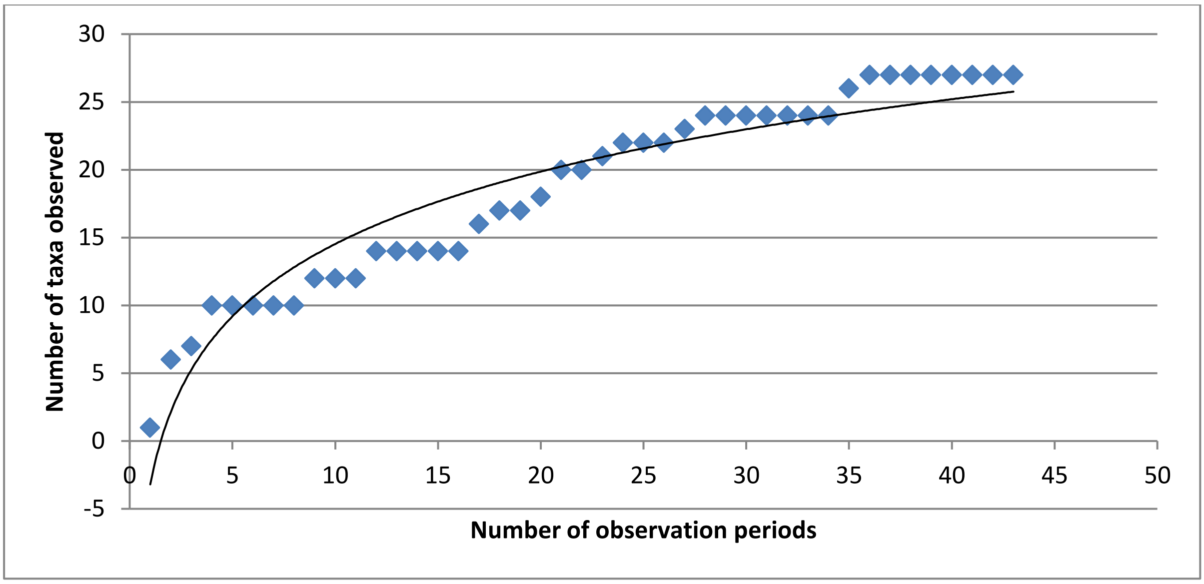

Figure 7: Graph showing the species accumulation with 30 minute floral observation periods with a logarithmic curve fitted to the points.

When incidental taxa were removed and only more common floral visitors seen within the 30 minute observation periods were included (i.e. Apidae, Anthophoridae, Halictidae, Tachanidae, Callophoridae, Syrphidae, Sphecidea), resulting in a total of 9 taxa observed, the full complement of taxa were observed by the 21st observation period (Figure 8). This indicates that a minimum of 21 floral observations are need to observe the full complement of floral visitors for *S. g. barotsense* when incidental floral visitors are not considered.

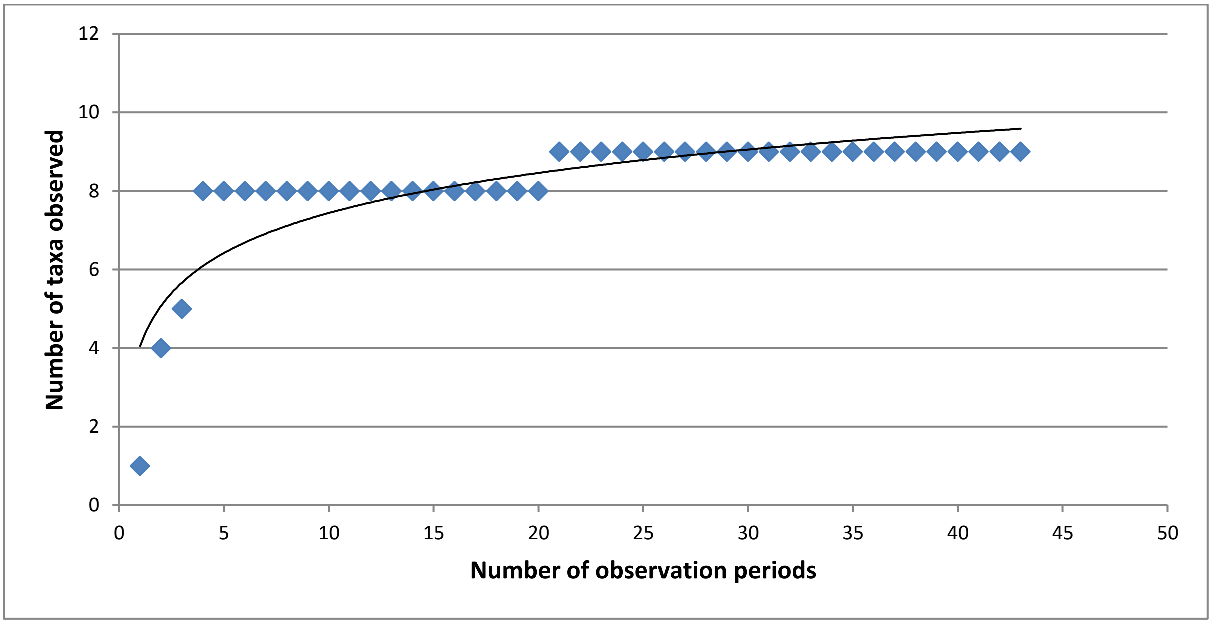

Figure 8: Graph showing the species accumulation with 30 minute floral observation periods and incidental species removed with a logarithmic curve fitted to the points.

4.2.2 Activity rate and visitation rate

When activity rate was calculated for each insect category or taxon (number of flower visits per minute throughout the 30-minute observation period), honeybees were the most frequent flower visitor across all time slots (Figure 9). Honeybee activity rate was greatest in the afternoon time slot, 14:00 to 18:00.

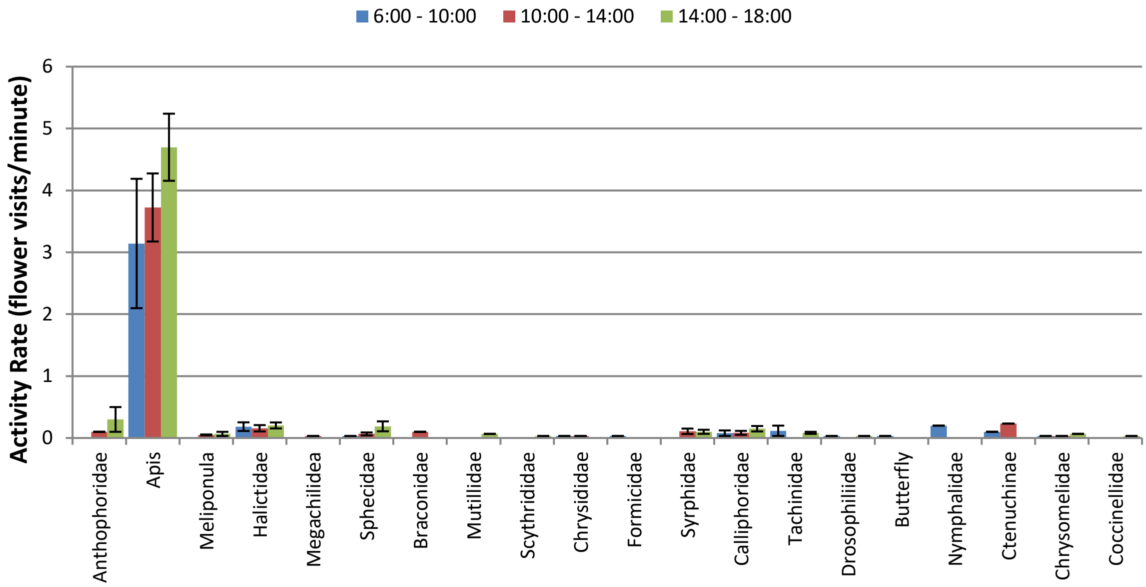

Figure 9: Activity Rate (number of floral visits per minute) graphed for each taxon observed within each time slot (6:00 – 10:00; 10:00 – 14:00; 14:00 -18:00).

When visitation rate was calculated (floral visits/minute/total flowers observed) for each insect category/ taxon, visitation rates were highest for honeybees across all time slots, and greatest in the afternoon time slot, 14:00 to 18:00 (Figure 10).

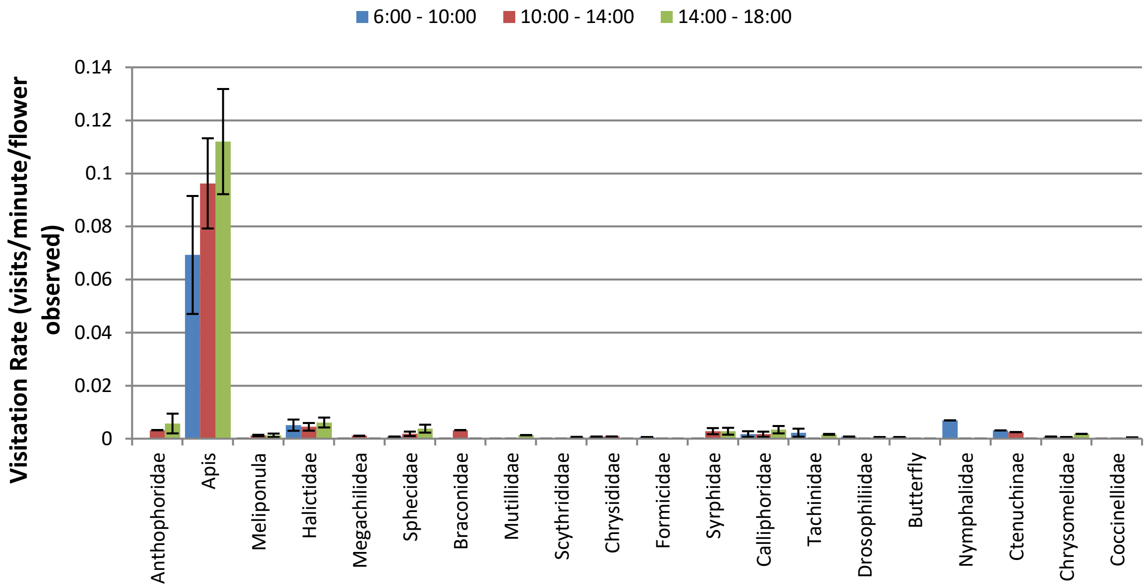

Figure 10: Visitation Rate (number of visits per minute divided by the total number of flowers observed), graphed for each taxon observed within each time slot (6:00 – 10:00; 10:00 – 14:00; 14:00 -18:00).

4.3 Conclusions

These results show that to comprehensively observe all flower visitors (but not considering incidental visitor species) to waterberry tree flowers, a minimum of 21 floral observations of 30 minute duration are needed. The results also show that honeybees were the most frequent flower visitor across all time slots and that honeybee activity rate was greatest in the afternoon time slot, 14:00 to 18:00. Visitation rates were also highest of honeybees across all time slots and was greatest in the afternoon time slot. Whether this is to do with the nectar flow dynamics of waterberries or the general activity patterns of honeybees was not determined. These findings will be helpful for structuring future experiments on plant-pollinator networks.

5 References

Akinnifesi, F. K. *et al.* (2002) 'Domesticating priority for miombo indigenous fruit trees as a promising livelihood option for small-holder farmers in southern Africa', in *XXVI International Horticultural Congress: Citrus and Other Subtropical and Tropical Fruit Crops: Issues, Advances and Opportunities*, pp. 15–30.

Akinnifesi, F. K. *et al.* (2006) 'Towards the development of miombo fruit trees as commercial tree crops in southern Africa', *Forests, Trees and Livelihoods*, 16(1), pp. 103–121.

Akinnifesi, F. K. *et al.* (2008) *Indigenous fruit trees in the tropics: domestication, utilization and commercialization*. Edited by F. K. Akinnifesi et al. CAB International.

Anguilet, E. C. F. *et al.* (2015) 'Meliponini and Apini in Africa (Apidae: Apinae): a review on the challenges and stakes bound to their diversity and their distribution', *Biotechnology, Agronomy, Society and Environment*, 19(4), pp. 382–391.

van Breugel, P. *et al.* (2015) *Potential natural vegetation map of Eastern Africa (Burundi, Ethiopia, Kenya, Malawi, Rwanda, Tanzania, Uganda and Zambia). Version 2.0. Forest and Landscape (Denmark) and World Agroforestry Centre (ICRAF).* Available at: http://vegetationmap4africa.org/.

Chirwa, P., Syampungani, S. and Geldenhuys, C. (2008) 'The ecology and management of the Miombo woodlands for sustainable livelihoods in southern Africa: the case for non-timber forest products', *Southern Forests*, 70(3), pp. 237–245. doi: 10.2989/SF.2008.70.3.7.668.

Clauss, B. (1992) *Bees and beekeeping in the North Western Province of Zambia*.

Clauss, B. and Clauss, R. (1991) *Zambian beekeeping handbook*.

Coppinger, C. R. *et al.* (2019) 'Insights into the impacts of rural honey hunting in Zambia', *African Journal of Ecology*, 00, pp. 1–5. doi: 10.1111/aje.12632.

Crane, E. E. (1999) *The world history of beekeeping and honey hunting*. New York, USA: Routledge.

Crehan, K. and Von Oppen, A. (1988) 'Understanding of "development": an arena of struggle. The story of a development project in Zambia', *Sociologia Ruralis*, 28(2–3), pp. 113–145. doi: 10.1111/j.1467-9523.1988.tb01034.x.

Dietemann, V. *et al.* (2009) 'Is there a need for conservation of honeybees in Africa?', *Apidologie*, 40, pp. 285–295. doi: 10.1051/apido/2009013.

Eardley, C. D., Gikungu, M. and Schwarz, M. P. (2009) 'Bee conservation in Sub-Saharan Africa and Madagascar: diversity, status and threats', *Apidologie*, 40, pp. 355–366. doi: 10.1051/apido/2009016.

Fanshawe, D. B. (2010) *Vegetation descriptions of the upper Zambezi districts of Zambia*. Bulawayo, Zimbabwe.

Fischer, F. U. (1993) *Beekeeping in the subsistence economy of the miombo savanna woodlands of south-central Africa., Network Paper - Rural Development Forestry Network. Three Views from Africa.* doi: 10.1177/030913339802200306.

GRZ Ministry of National Development Planning (2017) *Seventh National Development Plan*.

Ham, C. (2006) *Zimbabwe, Zambia, Malawi and Tanzania: priority fruit species and products for tree domestication and commercialisation*.

Hussein, M. H. (2001) 'Beekeeping in Africa: I. North, east, north-east and west African countries', in *Proceedings of the 37th International Apiculture Congress*, p. 28.

IPBES (2016) *Summary for policymakers of the assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on pollinators, pollination and food production*, *UNEP/GRID Europe*. Edited by S. G. Potts et al. Bonn, Germany: Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. doi: 10.1371/journal.pone.0090102.

Jaffé, R. *et al.* (2009) 'Estimating the density of honeybee colonies across their natural range to fill the gap in pollinator decline censuses', *Conservation Biology*, 24(2), pp. 583–593. doi: 10.1111/j.1523-1739.2009.01331.x.

Jamnadass, R. H. *et al.* (2011) 'Improving livelihoods and nutrition in sub-Saharan Africa through the promotion of indigenous and exotic fruit production in smallholders ' agroforestry systems: a review', *International Forestry Review*, 13(3), pp. 338–354.

Jumbe, C. B. L., Bwalya, S. M. and Husselman, M. (2008) *Contribution of dry forests to rural livelihoods and the national economy in Zambia*, *XIII World Forestry Congress*.

Kajobe, R. and Roubik, D. W. (2006) 'Honey-making bee colony abundance and predation by apes and humans in a uganda forest reserve', *Biotropica*, 38(2), pp. 210–218. doi: 10.1111/j.1744-7429.2006.00126.x.

Malaisse, F. and Parent, G. (1985) 'Edible wild vegetable products in the zambezian woodland area: a nutritional and ecological approach', *Ecology of Food and Nutrition*, 18(1), pp. 43–82. doi: 10.1080/03670244.1985.9990913.

Mickels-Kokwe, G. (2006) *Small-scale woodland-based enterprises with outstanding economic potential: the case of honey in Zambia*. Bogor Barat, Indonesia: Center for International Forestry Research (CIFOR).

Ntenga, G. M and Mugongo, B. . . (1991) *Honey hunters and beekeepers: a study of traditional beekeeping in Babati District, Tanzania., Swedish University of Agricultural Sciences, International Rural Development Centre.*

Requier, F. *et al.* (2019) 'The conservation of native honey bees is crucial', *Trends in Ecology & Evolution*. Elsevier Ltd, 34(9), pp. 789–798. doi: 10.1016/j.tree.2019.04.008.

Roffet-Salque, M. *et al.* (2015) ‘Widespread exploitation of the honeybee by early Neolithic farmers’, *Nature*. Nature Publishing Group, 527, pp. 226–230. doi: 10.1038/nature18451.

Simukoko, M. (2008) *Soul of the forest: honey value chain development in Zambia*.

Smith, F. G. (1953) ‘Beekeeping in the tropics’, *Bee World*, 34(12), pp. 233–245. doi: 10.1080/0005772X.1953.11094829.

Smith, F. G. (1966) ‘Beekeeping as a forest industry’, *East African Agricultural and Forestry Journal*, 31(3), pp. 349–355. doi: 10.1080/00128325.1966.11662064.

Smith, P. and Allen, Q. (2004) *Field guide to the trees and shrubs of the miombo woodlands*. Surrey, UK: Royal Botanic Gardens, Kew.

Storrs, A. E. G. (1995) *Know your trees: some common trees found in Zambia*. Regional Soil Conservation Unit (RSCU).

Timberlake, J. and Chidumayo, E. (2011) *Miombo ecoregion vision report*.

Trapnell, C. G. (2001) *Ecological survey of Zambia: the traverse records of C.G. Trapnell 1932-43*. Edited by P. P. Smith. Royal Botanic Gardens, Kew.