EFFECTS OF LAND USE ON HYMENOPTERA DIVERSITY:

A CASE STUDY IN SOUTHERN UNGUJA

By

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Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Masters of Science in Biodiversity Conservation of the University of Dodoma.

The University of Dodoma

October, 2013

CERTIFICATION

The undersigned certifies that she has read and hereby recommends for acceptance by the University of Dodoma dissertation entitled "***Effects of Land Use on Hymenoptera Diversity"*** in fulfilment of the requirements for the degree of Master of Science in Biodiversity Conservation of the University of Dodoma.

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I **Mansour Said Nassor** do here by declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other University or other academic institution for a similar degree award.

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ACKNOWLEDGEMENT

First, my thanks, appreciation and honour are to God for giving me strength, health and tolerance for this dissertation to be completed. The completion of this work was a result of my personal effort and contribution of various peoples and institution and I would like mention some of them.

I thank my supervisor Dr. Shyamala Ratnayeke for her assistance, support and encouragement for the whole period of this dissertation, which contribute my completion. Thanks to my family for giving me moral, spiritual and financial support. In addition, I thank my sponsor, State University of Zanzibar for giving me financial support of my study. I thank Zanzibar Second Vice President Office for giving me permission of conducting research. I thank Department of forest and non-renewable resources for allowing me to collect data at JCBNP and special thanks should go to Mr. Tahir, Manager of JCBNP for his contribution and assistance for the whole time of data collection at JCBNP. Other thanks should go to peoples of Muungoni, Kikungwi and Bungi for allowing me to use their land for data collection. Special thanks also should go to Dr. Schlueta and Abdalla Ibrahim for their greater effort to make sure identification of hymenopterans sample is successful. Finally, thanks to all who give me any kind of support to complete this dissertation.

DEDICATION

This work is dedicated to:-

My parents

My wife

My children

ABSTRACT

Natural forest lost at high rate year after year. Most of the area are cleared and transformed to agricultural land, which influences changes in hymenopterans diversity. Therefore, understanding the hymenopterans diversity in various land use forms of agriculture are of vital importance to guide in conservation approaches. This study analyzed the effects of land use in hymenopterans diversity in Unguja Island – Zanzibar. Hymenopterans were sampled in five land-use forms between January to March 2013. In each study a site, four linear transects of 50m long were established. In each transect in three land use hymenopterans species were captured by three pan traps of different colour (blue, yellow and white) and nets. A total of 734 hymenopterans consisting of 60 species were sampled within five land-use forms. Home garden showed higher species richness compared to mixed farming, JCBNP, monoculture and mangrove. Using Kruskal Wallis test species richness and species diversity differ significantly among different land-use forms ($p < 0.1$). There was no different in efficiency between nets and pan traps in assessing hymenopterans diversity ($p > 0.1$). Also there was no significance difference in hymenopterans species richness and diversity captured by blue, yellow and white pan traps. The study concluded that home garden and mixed farming attract mostly hymenopterans species that are very common in natural forest. This study recommended that conservations of hymenopterans species can be enhanced by establishment of home garden and mixed crops farming.

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LIST OF ACRONYMS AND ABBREVIATIONS

FAO	Food and Agriculture Organization
BTP	Blue Pan Traps
YPT	Yellow Pan Traps
WPT	White Pan Traps
EU	European Union
HG	Home Garden
MC	Monoculture
MF	Mixed Farming
MAN	Mangrove
JCBNP	Jozani-Chwaka Bay National Park
NRC	National Research Council
NWFP	Non Wood Forest Products
PT	Pan Trap
SPSS	Statistical package for Social Sciences
URT	United Republic of Tanzania
UV	Ultra violet Light
ZAFFIDE	Zanzibar Association for Fishermen and Farmers Development
ZABA	Zanzibar Beekeeping Association
PRSP	Zanzibar Poverty Reduction Strategy Programme
RGoZ	Revolutionary Government of Zanzibar
UE	European Union
CCD	Colony Collapse Disorder

CHAPTER ONE
INTRODUCTION

1.1 Background information

Hymenopterans provide important services to agriculture, including pollination of crops and pest control (Tscharntke *et al.,* 2005). Insect biodiversity is threatened by loss of natural and semi natural habitats due to agricultural intensification, which includes extensive monoculture planting and increased use of pesticides and herbicides (Tscharntke *et al*., 2005). Even though, it is silent not fully clear what causes the decline of bees, but most probable it is a combination of causes. The most important pointed drivers include degradation, fragmentation and habitat loss, which affect the accessibility of foraging and nesting resources desired by bee populations (Potts *et al.,* 2010). In order to be able to maintain or enhance bee populations and services they provide, it is, therefore, indispensable to better realize how the surrounding landscape affects bee diversity especially in agro-ecosystems, which cover up large areas in the world. Bees in particular have major impacts on the species composition of the savannah vegetation as they are predominant pollinators for most flowering plants and often the most frequent visitors of flowers (Neff and Simpson, 1993). About 15% of flowering plants are pollinated by domestic bee species such as *Apis mellifera, Megachile species* and *Xylocopa species* while at least 80% are pollinated by wild bee species and other wild animals (Ingram *et al.,* 1996). Wasps on other hand play a major role in regulation of other insect populations, often acting as insect predators (Hilmar, 2001), thus reducing the unnecessary applications of pesticides (Aluja, 1999). Pollinator insects are diverse component of the wildlife of natural areas. They include bees and wasps (hymenoptera), butterfly and moth (Lepidoptera), beetles (Coleopteran) and flies (dipteral). In the contest of this study only hymenopterans were assessed. Wasps like a vespula wasps has been shown to compete for forage resource with other insects, for example attacking flower foraging bumble bees (Thomson, 1988). Their competitive behaviour makes them a successful pollinator through increased local abundance in patches of flowering plants and hence increases pollination and fruit set (Jacobs, *et al.*, 2009). The wasps-plants interaction associated with sexual deceptive (Schiestl, 2005) which is limited by mutual evolutionary pollination relationship with the gall wasps (Cooks and Rasplus, 2003). The living associations not only benefit the two partners but also to other living organisms. For instances, fig it is a home to thousands of invertebrates, rodents, bats, reptiles, amphibians and birds. Additionally, it provides an important niche and food source to many rainforest creatures (Cooks and Rasplus, 2003). Fig as a keystone species, their absence affects the survival of the whole other plants and animal's species. Orchid is another example of plants which show specialized interaction with wasps, pompilid in the genus Hemipepsis studied rewarding Africa grassland orchid flowers (Johnson, 2005).

Animal diversity is declining worldwide due to increasing deforestation rates and subsequent land use change, forcing the surviving tropical biodiversity to inhabit in human dominated landscapes such as agricultural areas (Bawa *et al*., 2004). Pollinators, as a group, are declining globally (Potts *et al*., 2010). In the European Union (EU) pollinator population status has been evaluated and several taxas are declining: so far 37-65% of bee species are considered to be of conservation priority (Patiny *et a*l., 2009). In the United Kingdom (UK) 71% of the butterfly species have declined to some extent over the past 20 years (Thomas *et al*., 2004) and recently in North America, the National Research Council (NRC) reports that populations of important pollinators such as bumble bees, butterflies, bats and hummingbirds are declining (NRC, 2006).

Human land use is predicted to increase rapidly over the next few decades as the human population grows (Tilman *et al*., 2001), how pollinators respond to land-use change has important implications for much of the world's flora. Several studies propose that bees are the focal pollinator taxon for most ecosystems, but are sensitive to loss of natural and semi natural habitats (Kremen and Chaplin-Kramer 2007). For example, bee abundance and richness decreases with increasing isolation from natural habitats subtropical dry forest ecosystems (Aizen and Feinsinger 1994). Conversely, in some situations wild bees are more abundant or have greater species richness in human disturbed areas (Winfree *et al.*, 2007).

Hymenopterans are the most beneficial orders for the human economy. Bees pollinate many of our crops, but they also produce goods such as wax and honey. Beekeeping is an important component of agriculture and rural development programs in many countries including Tanzania. It can play a role in providing nutritional, economic, and ecological security to rural communities at the household level and is an additional income-generating activity. It requires few start-up resources, does not necessitate the alteration of native habitat, and being largely a non-land-consuming activity, it does not compete with other resource-demanding components of farming systems (Food and Agricultural Organization, [FAO] 1990). Beekeeping is potentially good source of income in most tropical countries (Lawal and Banjo, 2010). By selling honey and bee wax, the income serves to pay for social services such as school fees and medicine (Pete *et al.,* 1998). The Western Cape has the most well developed large scale apicultural in South Africa (Johannsmeier, 2001). This is primarily because the region is an important producer of deciduous fruits and crops that depend on pollinator services to improve yield Vander (Merwe and Eloff, 1996). Many African women supplement their livelihood by selling honey, or making and selling honey-wine and honey beer (Mehari, 2007). In Ethiopia, the collection and sale of bees honey is an important income generating activity that is carried out in domestic settings, (Mehari, 2007).

The Government of Tanzania has recommended a more comprehensive approach to ensure sustainable forest and beekeeping management in the country as seen in national forest and-beekeeping programme. Currently, beekeeping practiced in various parts of Tanzania, chiefly in Shinyanga and Tabora region where programme is a wide spread main economic activity in rural homes. In bereku woodland, beekeeping is an important socio-economic which produces honey and bee wax which are extensively used for home use and leftover are sold at neighbourhood and external market (Lupala, 2009). Apart from direct selling bee's products, bee pollination is another indirect contribution to household income as they increase crop yield (Lupala, 2009). The average incomes for individual concerned in beekeeping vary stuck between TShs. 22,500 to 15,000,000 (Kihwele *et al.*, 1999)

Beekeeping in Zanzibar has been practiced for centuries (Raymond, 1998). It is a low cost income-generating activity and produces a high value product (honey and bee wax). Bee keeping serves to increase income for rural people as well as to increase forest conservation for sustainable development (Zanzibar Beekeeping Association [ZABA], 2001). About 94.6% of bee keepers in Zanzibar use traditional long hives which are placed in a tree about 4.1m from the ground (Mpuya, 2001). In Zanzibar and mainland Tanzania, beekeeping is an important subsistence activity due to its low startup and maintenance costs, and because it is familiar at some level to all farmers. It is carried out using locally-available resources for hives including logs, bark and baskets and simple harvesting equipment (Forest Resources Management plan, 2009 - 2020). The Zanzibar Poverty Reduction Strategy Programme (PRSP) calls for agricultural diversification including an increase in apiculture (beekeeping). The Zanzibar Forestry Policy1 governs apicultural development in Zanzibar and highlights beekeeping as an important income generating activity with positive implications for environmental conservation (Forest Resources Management and Conservation Act, 2002). The market for honey in Zanzibar is good, with honey being imported from mainland Tanzania to meet demand. Zanzibar traders state that local honey is available only for short periods. However, local honey sells at a higher price than the imported honey, and local beekeepers therefore need help to increase the supply of local honey and meet market demand more efficiently. Adequate volume is the key to efficiently supplying the market as this allows economy of scale (Zanzibar Association for Fishermen and Farmers Development [ZAFFIDE], 2006). Thus, a better understanding of land use practices that support hymenopterans biodiversity will help to make agricultural production more sustainable and beekeeping activities more economically rewarding.

1.2 Statement of the problem

Biological knowledge about pollinator species is very important as far as food production, formal environmental protection and beekeeping is concerned. Beekeeping has been a marginalized activity or, at most, a grassroots form of socio-economic development in developing countries that has been a means to supplement the livelihoods of local people. The potential for beekeeping to contribute to local economies has been barely exploited.

Zanzibar is called Spice Island because it produces a range of spices such as cinnamon, nutmeg, black pepper, turmeric, vanilla. Some of these crops, including many fruit trees are bee-pollinated and honey-producing (Antony, 2000). The opportunities that exist for producing and marketing beeswax and other bee products indicate that beekeeping can play an important part in strengthening the Zanzibarians rural economy. Currently, only 1% of the entire agricultural households were involved in honey production (RGoZ, 2012). District-wise, South district had 3.7% and Micheweni districts had 2% of households involved in honey production (RGoZ, 2012). Honey production was moderately practised in Mkoani (1.7%), Wete (1.2%), Chakechake and Central.each with 0.7% North B and West, each with 0.2% of the total agricultural households within the districts (RGoZ, 2012). However, the activity was reported not to have been practised in North A (RGoZ, 2012). The amount honey harvested differed among different types of honeybees; stinging bees produce marginally higher amount of honey (22,262 lts) than that gathered from stingless bees [19,087 lts or 46%] (RGoZ, 2012). Also, the quantity of sting bees honey sold was slightly higher (17,807lt) than that sold from stingless bees [17,084lt or 49%] (RGoZ, 2012).

Beekeeping can boost the clove industry and, with pollination of other crops, bee keeping would be an added bonus. Moreover, bee keeping activity supports Government strategies for poverty reduction (MKUZA, 2008), Zanzibar vision 2020 and the Millennium Goal in the fight against poverty (MKUZA). Apart from tourism, agriculture is the mainstay of Zanzibar's economy. Human population densities are increasing, currently the population density of Zanzibar is 530 (URT, 2012) while total population had increased from 981,754 (Census, 2002) to 1,303,569 (Census, 2012) and change of land use have occurred and will continue to occur as 70% of the population in Zanzibar depend directly or indirectly in the agriculture sector for their livelihood (Milingi and Rajab 2009). Healthy pollinator populations are necessary for food security. Thus identifying what forms of land use support pollinator's diversity is important.

1.3 objectives

1.3.1 General objective

To assess variation in distribution, abundance and diversity of hymenoptera with land use.

1.3.2 Specific objectives

i. To assess variation in Hymenoptera distribution, diversity and abundance among different forms of land use, namely agricultural crops, natural forest and mangrove habitats.

ii. To compare the efficacy of netting versus pan trap for assessing Hymenoptera species diversity in different land use forms.

iii. To compare the efficiency of different colours of pan traps for assessing Hymenoptera species diversity in different land use forms

iv. To gather socioeconomic information on beekeeping and assess the role of land use in sustaining the beekeeping industry in Zanzibar.

1.3.4 Research question

What forms of land use contribute to species richness, diversity and abundance of bees in Zanzibar?

Which of two popular methods are most effective for assessing Hymenoptera species diversity among different land use forms?

Are there differences in Hymenoptera species diversity caught by different colours of pan traps among different land use?

To what extent does beekeeping contribute to local people's income in Zanzibar?

1.4 Significance of the study

Hymenoptera are of tremendous significance as plant pollinators and thus, play a pivotal role in the shaping and maintenance of ecological communities. Approximately 75% of agricultural crops worldwide depend on insect pollinators such as bees. Additionally, honey production through bee-keeping can be a major source, or generous supplement of household income, aid in poverty reduction, and contribute to the conservation of natural habitats.

The findings will be important to identify possible ecological factors that promote hymenopterans abundance and to examine the current socio-economic and ecological impacts of honeybees in Zanzibar. The study will also help to identify the most profitable ways to integrate beekeeping and agriculture to increase food production as well as forest conservation.

In general, several studies were conducted worldwide involving research into the pollinators of the cultivated plant species because this problem recognized as an important in agriculture. However, the importance of understanding abundance and diversity of pollinators of the surrounding agricultural field such as natural and semi natural areas are very important. The main conclusion based on the previous research in the other country is that, It is very important to assess the effect of land use on pollinator richness, abundance and diversity within cultivated crops, in this case; home garden, mixed crops and monoculture as well as in natural areas; Jozani and mangrove forest were assessed.

The focus of this study was on two Hymenoptera groups; bees and wasps. Both managed (honeybees) and wild pollinators were included in this study as these groups contribute to pollination of cultivated and wild flowers. No previous research regarding the effect of land use on Hymenoptera diversity has been conducted in Zanzibar. The need of this kind of research is very important as many natural areas converted to agricultural areas due to increase of human population with high rate of urbanization

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The section comprises a definition of key terms and a review of the theoretical and empirical literature addressing distribution, diversity and abundance of hymenoptera. A conceptual framework for the study is provided at the end of this chapter.

2.1 Definitions of key terms

Hymenoptera is an insect of the order which including the bees, wasps, and ants, often living in complex social groups and characteristically having two pair of membranous wings. Source: http://www.thefreedictionary.com/hymenopteran.

Land use is the human use of land. Land use involves the management and modification of natural environment or wildness into built environment such as fields, pastures and settlements. It also has been defined as the arrangement, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO, 1992)

The Convention on Biological Diversity defines biodiversity as the variability among living organisms from all sources including, among other things, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes the diversity within species, between species and of ecosystems (Glowka *et al.*, 1994).

Species diversity refers to the variety of living species within a geographical area. It can be measured by characteristics such as species richness and/or relative abundance (Glowka *et al.*, 1994).

A species may be defined as a group of organisms which are able to interbreed freely under natural conditions to produce viable offspring (Glowka *et al.,* 1994).

2.1 Ecological and economic role of pollinators

Hymenoptera (bees, wasps, and ants) are diverse insect orders; approximately 115,000 species have been described (Gauld and Gaston, 1995). They have tremendous importance for human livelihoods and other living globally. Additionally, Hymenopterans as a pollinator are important in wild life food web, example most migratory birds need fruits and a seed from insect's pollinated plants. Pollinator larvae on other hand are important component of many young birds (Buehler *et al.,* 2002). Orchid had shown specialized interaction with wasps, pompilid; genus Hemipepsis as they rewarding Africa grassland orchid flowers (Johnson, 2005). Predatory wasps also are important in the regulation of other insect populations (Hilmar, 2001). Bees pollinate many plants thus; their attendance in a wide variety of habitat is universal. To one side from being pollinator, also generate goods such as wax and honey. Most flowering plants are pollinated by domestic bees species and wild bee species (Ingram *et al.,* 1996). In the United States, 30% of food crops depend on animal pollinator (McGregor, 1976), of which bee species are the most important. The importance of hymenoptera are also seen in diversity of natural habitats, hence emphasize the need for this group to be considered in the conservation of nature (Nieve-Aldrey and Fontal Cazalla, 1997). It is well, known that insects including bees usually increase fruit and seed yields of many plant species, through pollination provision (Sabbahi *et al.,* 2005) which support the life of other species.

Megachilidae is the second largest family which contains more the 4000 species (Michener, 2007; Ascher and Pickering, 2011). The family is ecologically and economically significant as they include many pollinators of natural, urban and agricultural plants. For example *Megachile rotundata* has been introduced to many parts of the world to serve pollination services in alfalfa (Michener, 2007; Pitts-Singer and Cane, 2011). Furthermore, the family constitutes an important group in sustainability of ecosystem as a pollinator of many plants and show greater diversity of behavioral traits, size and forms (O'Toole and Raw, 1991). *Xylocopa* on other hand consists more than 400 species (Raju and Rao 2005), in natural and semi natural habitat they feed on a wide variety of flower species (Gerling *et al*., 1989). *Xylocopa* in agricultural field play a major role in food crop production, example in Australia, it has been observed that *xylocopa* species is the main pollinator of tomato plant (Hogendoorn *et al*., 2000). Although bees are most important pollinator and wasps' predator, the knowledge of their diversity and ecology in margin of Sahara and the West Africa savannah is still poor.

2.2 Pollinator decline

Animal diversity is declining worldwide due to increasing rates of deforestation and subsequent land use changes which force the surviving tropical biodiversity to reside in human dominated landscapes such as agricultural areas (Bawa *et al.,* 2004). The decline of pollinators has become a global issue (Potts *et al.*, 2010), In the European Union (EU), the status of pollinator populations has been evaluated and 37-65%b of bee species are considered to be of conservation concern (Patiny *et al.,* 2004). In the United Kingdom (UK) 71% of the butterfly species have declined to some extent over the past 20 years (Thomas *et al.,* 2004) while in North America, recent National Research Council reports show that bumble bees, butterfly, bat and hummingbird species are in decline (NRC, 2006). Biological diversity is very important for ecosystem functioning as a basis for processes in nature. It is also required for the improvement and sustainability of human wellbeing. Thus, it is necessary to understand the requirement of biodiversity maintenance and predict the effects of biodiversity loss. In this aspect the study of interspecific interaction such as that between plants and pollinators (Frund *et al.,* 2010) is very crucial Many studies have found positive relationship pollinator diversity and plant functioning (Perfectti *et al.,* 2009). Pollination plays a key role in the survival of terrestrial ecosystem through their major role in plant reproduction, thereby providing goods and services to society. 35% of the crop production worldwide relies on animal pollination (Steffan-Dewenter and Westphal, 2008)

Human land use is predicted to increase rapidly over the next few decades as human population grows (Tilman *et al.,* 2001) and how pollinators respond to land-use change has important implications for much of the world flora.

2.2.1 Honeybee decline

Many factors can affect bee distribution richness and diversity. Pollen and nectar availability attract bees to sites (Potts *et al.*, 2004). Disturbance, in the form of fire (Campbell *et al.,* 2007), agricultural development (Williams and Kremen 2007), and residential development and deforestation (Winfree *et al.,* 2007) can affect bee community composition, as can habitat structure by changing availability of nesting resources (Cane *et al.,* 2007) and by modifying the thermoregulatory environment

Between 2007 and 2011, about 30% of U.S. honeybees (*Apis mellifera*) failed to survive and pollinate blossoms in the spring (Rucker and Thurman, 2012). Widespread die off was caused by disease but Colony Collapse Disorder (CCD) was recorded as the worst (Rucker and Thurman 2012). In North America CCD has been a problem in since 2004 (Michel, 2011). Africa are among the continent characterized by the syndrome, The counties along the river Nile such Egyptian have been reported signs of Colony Collapse Disorder (CCD), (Michael, 2011). The phenomenon now is a global issue characterized by symptom like rapid loss of workers bee with no or few dead bees in hive, presence of immature bees, small cluster of bees with live queen and presence of pollen and honey store in a hive (Renee, 2007). CCD has been described as a multifactorial phenomenon with Verroa mites, tracheal mites and bacteria cited as the major causes; Verroa mites (*Varroa destructor*) attach to bees and feed on blood, tracheal mites (*Acarapiswoodi*) attack tracheal tubes of bees and bacteria attack larvae and pupae and cause death of immature bees (Rucker and Thurman, 2012). Other factors include environmental stress, pollution associated with the use of agrochemicals, poor nutrition from habitat loss, and invasive plant species which reduce the availability of plants that produce food for bees, interspecific competition of native versus introduced bees and bee genetics (Renee, 2007).

2.3 Socio-economic roles of hymenoptera

Hymenoptera is the most beneficial order for the human economy; bees as a part of hymenoptera not only pollinate our crops, but also produce income generating goods such as honey and bee wax. Although a single species of honey bee is the main domesticated pollinator, there are at least 17, 000 other described bee species globally (Michener, 2000) and many of these visit crops (Nabhan and Buchmann 1997; Klein *et al.*, 2007). Non-Apis crop pollinators therefore potentially provide an insurance policy against the loss of the honey bee Wild, native bees are known to contribute to the pollination of watermelon (Kremen et al. 2004), coffee (Ricketts 2004), canola (Morandin and Kremen 2012), sun flower (Greenleaf and Kremen, 2006) and many other crops (Klein *et al.,* 2007). Demonstration that native bees can provide sufficient crop pollination throughout a region of intensive human land use would be a convincing example of the insurance value of biodiversity (Naeem, 1998).

2.3.1 Beekeeping in Africa

Beekeeping is an income generating activity for most African rural people as they produce, harvest, process and sells honey and bees wax. Moreover, beekeeping provides income for African women through the sale of honey, and making and selling honey-wine and honey beer (Mehari, 2007). The income from beekeeping serves to pay for social services such as school fees and medicine (Pete *et al.,* 1998). Now, in various parts of Africa (name these parts with references), beekeeping is practiced. The Western Cape, South Africa, has the most well developed large scale apicultural operation in South Africa (Johannasmeir, 2001). The region is important for production of agricultural crops that depend on pollinator services to improve yield (Van der Merwe and Eloff, 1996). In Ethiopia, beekeeping is an important income generating activity that is carried out in home gardens, even in houses, for collection and selling honey (Mehari, 2007). Other studies like (Carlos, 2006) consider beekeeping as an opportunity to develop the export of organic honey, which is largely environmentally friendly. Moreover, apiculture is also a human friendly enterprise because bees are not vectors of diseases affecting humans and other livestock. Bee keeping is a good option in arid and semi-arid regions where agricultural crops cannot be grown year round and the need to conserve tree cover is great (Obanyi *et al*., 2004); for example, in Kenya 80% of the nation’s honey is produced in arid and semi-arid areas (Muya, 2004).

Despite the advantages of beekeeping and achievements in practice, a lot of threats such hunting, habitat loss or diseases have been reported in various parts of Africa. There were several recognized honeybee diseases in Africa (Bradbear, 1988; Hussein, 2000) which is either imported or from local pests, the presence of *Varroa destructor* was discovered for the first time in South Africa, Cape Town in 1997 (Allsopp, 1997). In 2002 it was found in Botswana, Mozambique, Swaziland and Zimbabwe (Scholmke and Schmolke, 2003; Allsopp, 2006). *V. destructor* also was found in North Africa countries such as Algeria, Morocco, Libya, Tunisia and Nigeria (Ongus, 2006) while in West Africa it was detected in 2007 (http://www. apiculturetropicalejosephchauvin-vautier.fr/). The concern resulted in bee mortality even outside their home range (Allsopp, 2006). In general the present data suggests that there is a higher incidence of disease in countries where beekeeping activities have been industrialized (Hussein, 2000).

Forest destruction for charcoal making, little or no beekeeping research, and disorganization of beekeepers and poor infrastructure have been reported to reduce beekeeping potential in Kenya (Carrol, 2006). Also beekeeping industry lack of clear government policies as well as a national co-coordinating body (Carrol, 2006). The program for conservation and utilization of biodiversity should be revised to control the causes of significant loss of diversity among stinging and stingless bees because they play a keystone role in ecosystems, and are extremely important for the nation's socio-economic development through beekeeping, and agricultural productivity (National beekeeping policy, 1998).

2.3.2 Beekeeping in Tanzania

The economy of Tanzania like many parts of Africa and particularly in East Africa depend on subsistence and cash crops; livestock keeping, beekeeping, and charcoal making (Monela and Abdalla, 2007). Beekeeping to date practiced in various part of Tanzania. In Tabora and Iringa subsistence farming employ about 70% of the population, beekeeping is the second topmost economic activity which employ about 21% of the inhabitants in these regions (Abdalla 2001). In Tanzania, most honey produced from miombo (Monela and Abdalla, 2007). About 15,800 tons of honey and 9,200 tons of beeswax produced in Tanzania per year (Monela and Abdalla 2007). According to (Crafter and Awimbo, 1998), in 1988 honey and beeswax (3.8% of the entire forest produce) contributed about T.Shs. 1100 million to the economy of Tanzania. However, production of honey and bees' products is characterized by remarkable fluctuations due to fluctuating rainfall condition in the main beekeeping areas. Honey is another valued non wood forest products (NWFP) around the world. In Tanzania it is reported that honey is a very important food for the Sandawe agriculturalists in central part of the country, Dodoma and Singida Regions (Kihwele *et al*., 1999). It is normally consumed as a side dish of the main dish "*Ugali"*. It is also used as jam and in many parts of Tanzania. Also honey is used for making local brew popularly known as *Wanzuki.* (Kihwele *et al*., 1999).

2.3.3 Beekeeping in Zanzibar

Beekeeping (apiculture) in Zanzibar has been experienced from the time immemorial (Raymond, 1998). Most beekeepers use traditional method; simple hives made from hollow barks and logs, coconut log are widely used by most Zanzibarians beekeepers (direct field observation). For country like Zanzibar with small terrestrial land cover, beekeeping is the most appropriate economic activity which requires little land and does not interfere with other agricultural enterprises interms of resources. One square mile can support 44 bee colonies producing 0.1tons of bee wax and 1.3 tons of honey per year (Lupala, 2009). Additionally, apiculture in Zanzibar also used for conservation of natural forest (Stewart, 1998). Uzi conservation project in Zanzibar was a live example, where women cooperative beekeeping group offered beehive as a motive toward beekeeping and conservation (Stewart, 1998). About 99% of the beekeeping in Tanzania is carried out by forest based small scale beekeeper in rural areas (Lupala, 2009). In Zanzibar and mainland Tanzania, beekeeping is an important subsistence activity which practiced to most farmers due to its low financial startup and maintenance costs (Forest Resources Management and Conservation Act, 2002)

2.4 Hymenoptera response to land-use changes

Land-use change is a complex process and pollinator responses might be conditioned by the type and extent of land-use change. The response is largely negative in areas that have already experienced extreme land-use change; it might be associated with change in floral resources and pollinators diversity (Winfree *et al.,* 2007). Farming systems have a major influence on hymenoptera diversity. Moreover, small human modified habitats such as gardens may give considerably change in biodiversity in cities (Loram, A. 2007, Owen and Owen, 1975). Thus, cities are most precisely characterized as fine-scale, heterogeneous mosaics of buildings, , parks, gardens streets, and other green spaces (Cadenasso *et al.,* 2007) that include both ‘good’ and ‘bad’ areas for wildlife. Home gardens have been identified as playing a critical role in the preservation of genetic variability (Ford, 1994). Conservation of biodiversity occurs at two scales in home gardens: first, the garden itself hosts different species and varieties of plants; secondly, gardens serve as habitats for plants not intentionally planted or tended by households, including insects and animal species that coexist with those plants (Nabhan and Buchmann 1997). Pollinators of home gardens include honeybees, bumble bees, solitary bees and some flies (Kearns, 1997).

Intensive agriculture results in uniform crop cover, reduced spatial heterogeneity, increased use of pesticides and artificial fertilizer, and increased rates of mechanical disturbance (Kleijn *et al.,* 2001,). Proximity to semi-natural area such as deciduous forest or semi-natural grassland seems an important variable influencing high pollinator species richness and/or abundance (Ricketts and Imhoff, 2004). Other findings indicate that pollinator species richness and abundance is positively correlated with the proportion of natural or semi-natural habitat in the landscape (Franzen and Nilsson, 2008). Natural habitats have greater plant diversity and a more heterogeneous habitat which provide more foraging, nesting and/or hibernation resources for both generalist and specialist (Steffan-Dewenter *et al.,* 2002). The loss of semi-natural habitat often favours the dominance of generalist species while decreasing that of rare and specialized ones (Williams *et al.,* 2007).

The term mangrove commonly used to identify trees and shrubs that have developed morphological adaptation to the tidal environment (Tomlinson, 1998). The exact number of mangrove species is still under discussion and range between 50 to 70. High species diversity found in Asia followed by eastern Africa (Tomlinson, 1978). Mangrove forest provide a wide range of services as it support the life of various organisms including arthropods, fish, reptiles, bird and mammals (Mchenga and Abdalla, 2003). Mangroves makes up a second largest natural forest after coral rag in

Zanzibar with diverse aquatic and terrestrial fauna composition including mammals molluscs, gastropods crustaceans, fish, insects, reptile and birds (Akil and Jiddawi, 2001). Mangrove forests and the animals they support depend on each other for survival: animals are the agents of cross pollination of mangrove plant species, permitting both seed production and genetic exchange. Mangroves experience high visitation by diurnal insects such as butterfly and bees (Tomlinson *et al.,* (1978). Mangrove species such *Avicennia marina* flowers' are highly visited by, beetles, ants and bugs and honeybees (*Apis mellifera*) and other bees (Clarke and Myerscough 1991). In Zanzibar, some of the mangrove insects pollinator include hymenoptera (27species), Lepidoptera (19 species) and 12 species belonging to diptera (Mchenga and Abdalla 2003).

2.5 Conceptual framework

Pollination services are provided chiefly by bees (largely the honeybee, *Apismellifera*) but also by many butterflies, moths, flies, wasps and other invertebrates, birds and mammals. In this study we focused on hymenoptera as largely economically important group. Pollinators are important in 35% of global food production (Klein et al. 2007). In this conceptual framework, alterations in pollinator communities are closely linked to changing land-use practices (Fig. 1).

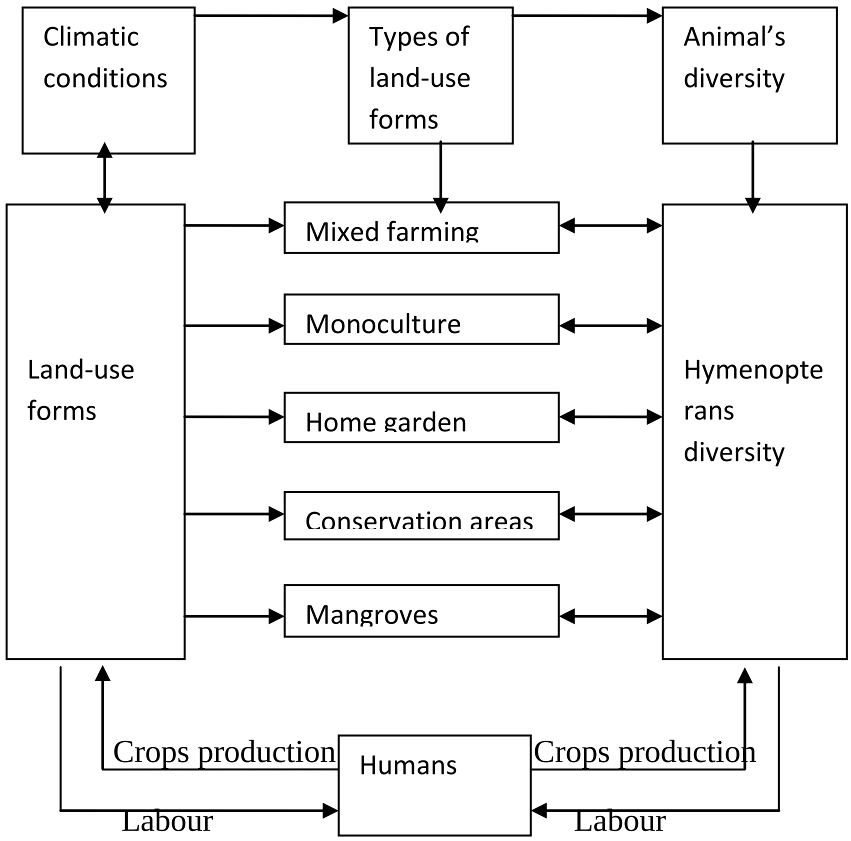

Figure 1 : Conceptual frame work linking different land use forms assessed in this study with hymenopterans diversity

CHAPTER THREE

METHODOLOGY

3.1 Study area

The focus of this study was to assess variation in the diversity, distribution and abundance of different species of bees among different types of land use. This study was conducted between January and March 2013 at Southern region of Unguja Island which is the largest Island of the Zanzibar archipelago. It is located between $5^{o}40'$ and $6^{o}30'$ approximately 40km off the Tanzania mainland and has a surface area of about $1660km^2$ (Mustelin et *al.*, 2009). Five different study sites reflecting different types of land use were selected: monoculture (orange plantation) at Bungi, mixed crop farming at Muungoni, a home garden at Kikungwi, natural forest (Jozani-Chwaka bay National Park-JCBNP) and mangrove vegetation at Mwembekiwete. All five study sites were located in Southern Unguja Island. JCBNP is a protected area. The other sites were situated in a landscape with different kinds of land-use varying in different agricultural crops. The vegetation composition of Unguja is influenced greatly by anthropogenic activities such as different types of agriculture, human settlements. Except for a few protected areas, much of the native forest cover has been removed. Unguja supports a human population of 620,957 with a current growth rate of 3.1% (Tanzania census, 2002). About 65% of peoples in South Region of Unguja Island are engaged in farming food and other cash crops. The remainder are employed in business (16%), white-collar jobs (4.8%), livestock keepers (0.97%), fishing (6.86%), other simple occupations contribute 4.52% (URT, 2002)

Table 1: Location and elevation of study areas where bees were captured on Unguja island (January – March 2013)

Site	location	Elevation (m)
Mwembekiwete	06°14.900'S, 039°19.066'E	1
Bungi	06°15.637'S, 039°20.438'E	14
Kikungwi	06°16.519'S, 039°20.908'E	6
Jozani	06°16.333'S, 039°25.183'E	6
Muungoni	06°18.343'S, 039°25.928'E	8

Source: Field data 2013

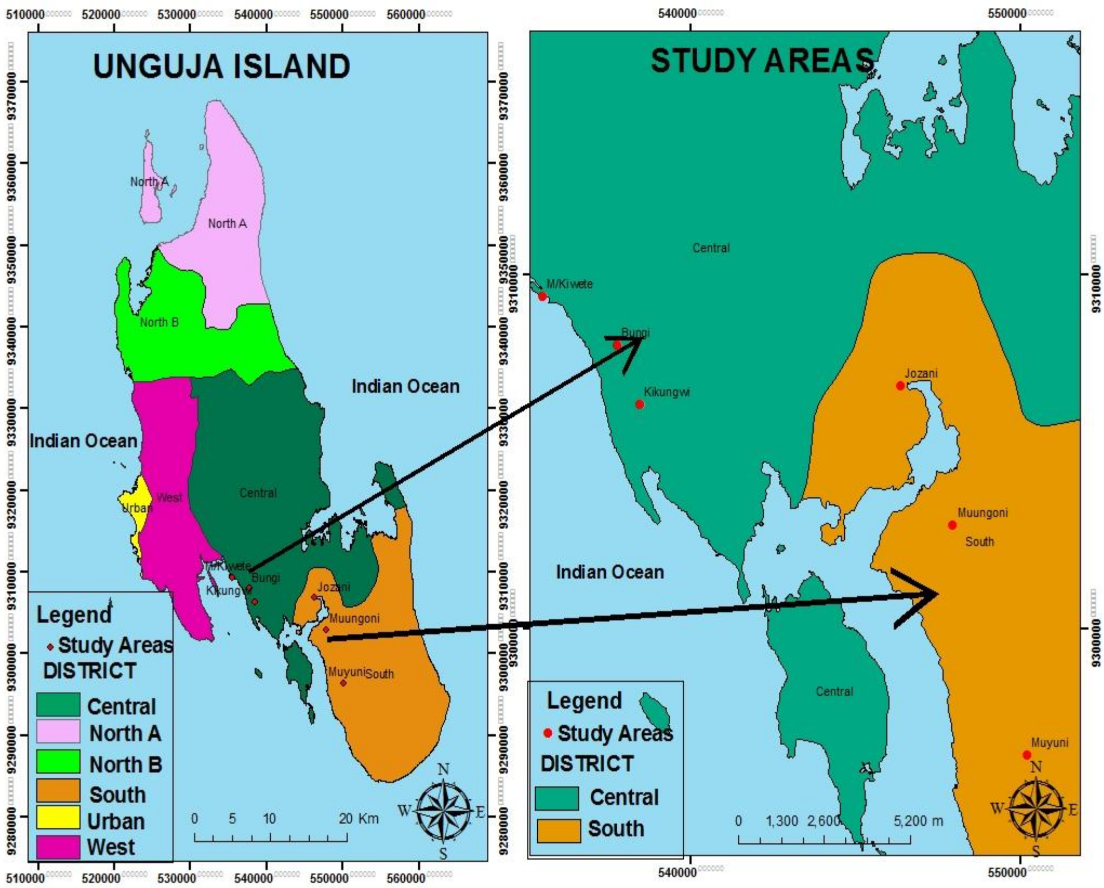

Figure 2: Location of study sites: Mwembekiwete- mangrove vegetation, Bungi – Orange plantation, Kikungwi – Home gardening, JCBNP, Muungoni – mixed crop farming and Muyuni – beekeepers questionnaires

Mangrove vegetation

Sampling in mangrove vegetation was conducted at Mwembekiwete, a part of Bungi village located on the west coast of Unguja's Central District. The human population size of the district is 2,020 (URT, 2002). Major economic activities in the area are food crop agriculture, business, livestock keeping, apiculture and fishing. The mangrove vegetation (Plate 1) is dominated by species such as *Rhizophora mucronata, Bruguiera gymnorhiza, Avicennia marina and Sonneratia alba*. The area is periodically inundated by seawater at high tide and possesses muddy black soil and rocky shores. The flowering period was between October and December, March and April (Nassor, personal observation). Mean annual rainfall of the area averages 96mm.

Plate1. Showing different mangrove species at Kikungwi where bees were captured using PT January – March 2013

Monoculture (orange plantation)

Bungi is estimated to cover about 74ha and is under the authority of the ministry of Agriculture. The area consists almost entirely of orange plantation (Plate 2) and includes a nursery for seedlings of various crops including orange, mango and coconuts. The soil is shallow, dark brown and fertile with stones (coral rag). The flowering period of orange plants was between October and December (Nassor, personal observation). The major economic activities around the area are agriculture, fishing and business and few are employed in white-collar jobs. The population of Bungi is 2,020 (URT, 2002). Mean annual rainfall is about 96.5mm and temperatures range between 24^{o}C and 28^{o}C (Silima *et al.,* 2008).

Plate2 : Orange plantation at Bungi where bees were captured using both nets and pan traps

Home garden

Kikungwi covers approximately 20ha of privately-owned land that supports a human population of 631(URT, 2002). It is a residential area where most of the land consists of home gardens (Plate 2). The economic activities include vegetable growing like eggplant (*Solanum melongena*), lady's finger (*Abelmoschus esculentus*) and tomatoes (*Solanum lycopersicus*). Apiculture is a growing economic activity. Dominant trees in the area are mango (*Mangifera indica*), banana (*Musa sapientum*), pawpaw (*Carica papaya*), passion fruit (*Passiflora edulis*) and coconut (*Cocos nucifera*), Chinese palm (*Ziziphus jujuba*). Understory trees consist largely of guava (*Psidium guajava*). The soils are classified as coral rag.

Plate 3: Typical home garden on Unguja Island. Bees in this land-use type were captured using both nets and pan traps

Natural forest

Jozani is about 35km from Zanzibar town with a total area of 5000ha and about 100 different plant species from 43 families (Musteln *et al*,. 2009). The area was declared national park in 2005. The major economic activity is tourism, attracting visitors to view a well-habituated population of the endemic Zanzibar red colobus monkey (*Procolobus kirkii*) which is now confined to JCBNP, other economic activities around the area include agriculture, apiculture and office work. Approximately 1,101 people live around JCBNP (URT, 2002).

The climate at JCBNP is hot and humid with mean annual temperatures varying between 21ºC and 32ºC. Mean annual rainfall is about 1860mm (Mustelin, 2009). During the long rain season (March to May) the mean monthly rainfall is about 360mm per month, but during the short rain season (November to December) the mean monthly rainfall is about 175mm per month (Mustelin, 2009). The area receives rainfall almost throughout the year (Ruffo and Purkannaine, 1993).

The forest soil is generally fertile, black in colour and rich in organic matter. However, these diagnostic features change abruptly at the forest margin (except to the south) giving way to broken coral rag with shallow pockets of light, red-brown sandy soil (Convention on Biodiversity 1995).

Dominant plants around the area where data collected were guava plants (*Psidium guajava*). Other floras were wild tomatoes (*Solanum incanum*) herbs, shrubs and grasses (Plate 4).

Plate4 : Habitat characteristics of protected forest at JCBNP. Bees were captured by netting only to avoid capture of non-target species

Mixed crops

Muungoni's land-use consists of mixed crop farming with trees like lemon (*Citrus limon*), mango (*Mangifera indica*), banana (*Musa sapienta*) and coconut (*Cocos nucifera*) but also patches of bush consisting mainly of guava (*Psidium guajava*), jackfruit (*Artocarpus heterophyllus*), breadfruit plants (*Artocarpus altilis*), wild tomato plants (*solsnum incunum*) acacia, grasses and herbs. The major economic activities are crop farming, fishing and beekeeping. The population in this village is about 1,320 (URT, 2002).

Plate5 : Muungoni with various food crops planted along the area, bees were captured by both netting and pan traps

3.2 Data collection

Specific objectives i, ii, and iii.

I used quantitative approaches i) to assess bee species abundance, distribution and diversity in different land uses, ii) compare the efficacy of netting and pan traps as capture methods for sampling bee communities, and iii) determine efficiency of different colours of pan traps (blue, yellow and white) for attracting different species of bees.

Field data were obtained by capturing bees using two different methods: i) netting and ii) pan traps (PT). PT have been traditionally used to capture arthropods such as aphids, flies and other agricultural pest (Southwood, 2000) and are now considered an effective and standard technique for sampling hymenopterans (LeBuhn *et al.,* 2003). Pan trap is the standard method used in capturing insects and has been show to be a best technique in agricultural and semi natural land and semi natural land (Wesphal *et al.,* 2008). The method also has been successful used dry tropical forest (Aizen and Feinsinger, 1994), temperate forest (Campbell and Hanula 2007) and seasonal wetland (Leong and Thorp, 1999). In temperate forest in Ohio have been successful used for sampling Coleopteran (Leksono *et al.,* 2005). Therefore, PT has potential to sample insects from range of habitats. Here I reported using blue, yellow and white PT to sample Hymenoptera in four land use; mixed crop farming, monoculture, home garden and mangrove forest.

PT or water traps are plastic bowls painted with UV reflective paint. The bowls are then filled with water to which small quantity of liquid soap is added during operation (Plate 6). The soap decrease surface tension causing insects to sink instead of floating to the surface of water and the colour attract the insects. Currently PT are used for capturing a great variety of insects including pollinators such as bees and wasps. Furthermore samples caught by PT are in a good condition for identification and easy to separate (Southwood, 2000). Distance between one PT and another has significant effects on the number of bees captured. PT set immediately abutting each other catch significantly fewer bees than those spaced 5 or 10m apart (Gretchen *et al.,* 2012). Pan traps and netting were employed at 3 study sites; monoculture, home garden and mixed crop farming At JCBNP only netting was used to comply with park regulations where pan traps ran the risk of capturing non target species. At Mwembekiwete (mangrove habitat) netting could not be feasibly conducted; thus only pan traps were used.

Sampling was conducted from January - March 2013. In each study area, 4 transects of 50m in length were established. Along each transect, one yellow, blue and white pan tarps were placed 5m apart at the beginning of each transect. Thus each study area had 12 pan traps. Samples for each study site were collected over a period of 6 days. Pan traps were operated between 9:00am to 5:00 pm each day Netting was conducted on a rotational basis between 10: 00am and 5:00pm, to avoid bias caused by variation in the diurnal activity pattern of different bee species (Dafni *et al.*, 2005).

Plate 6 : Pan traps arrangement along the transect at Bungi- orange plantation, Unguja island, 2013.

Nets are useful for catching flying insects like bees and wasps and allow for the collection of a variety of insects in a short period of time, including random insects not easily seen (Richards *et al.,* 2011). Bees were captured using a handheld net by walking along each transect. The insect net was composed of a bag made up of fine mesh attached to a wire ring, which was anchored to a metal pole. The net diameter was 0.36m and the length of the metal pole was 0.76m.Insects captured in the net were pinched with fourth finger and thumb, immersed in water till killed and subsequently placed 80% ethanol for preservation. Bees visiting flowers were captured and placed in a container with 80% ethanol. Transects in each study area were sampled four times during 15-minute intervals each day for six days.


Plate 7A show insect netting plate **Plate 7B killing insects by dipping in water**

The bees were mounted by removing from ethanol to water then pinned and dried using blowing hair drier. Other data were obtained through questionnaire to gather socioeconomic information on beekeeping and assess the role of land use in sustaining the beekeeping industry in Zanzibar.

Specific objective iv

Questionnaire is set of questions well designed and organized for data collection in accordance with the specifications of the research questions and hypotheses (Kothari, 2004). Two types of questions was constructed which are, open-ended and closed-ended questions. The open-ended questions enable the respondent to give in deep information as well as to express their ideas freely (Duval, 2005). Closed ended questions restrict the respondent to select answer among the given alternative by the researcher. Either other source of data obtained by questionnaire which were conducted at Pete-Jozani, Muungoni, Muyuni A, Muyuni B and Department of forest and non-renewable natural resources. Random and purposive sampling design was used by researcher. Random sampling were used in attempting to asses bee species abundance, distribution and diversity among different land use selected. Furthermore it was applied in comparison between netting and pan trap bees capture method not only that but also in comparison of attractive efficiency between blue, yellow and white pan trap.

Qualitative and quantitative approaches were used to collect data. Qualitative data grounded in the assumption that, individuals build social reality in the form of meanings and interpretations, and that these constructions tend to be temporary and situational (Maxwell, 1996). Qualitative method was used to capture what people say about honeybees and their roles in sustain beekeeping in Zanzibar. Additionally,

Information such as methods used by beekeepers, source of fund, knowledge of beekeeping, roles played by honeybees and problems or challenges faced by beekeepers were collected through questionnaire in four different villages along south region of Unguja Island were narrative rather than numerical. Thus, approach was qualitative. On other hand, quantitative approach was used to collect numerical data such amount of honey harvested per hives.

3.2.1 Data analysis.

Bee distribution by study area was assessed by categorizing bees into different species and a species list for each land use type was created. Each study area consisted of 4 subsites (transects). Thus species richness and diversity values were calculated for each subsite. Species richness was simply the total number of species (Krebs, 1989) captured at any subsite. Species diversity in each of the study sites was calculated using the Simpson Reciprocal Index I/D (Krebs, 1989), where D was calculated as follows:

$$D = \Sigma p_i^2$$

Where p_i = the fractional abundance of the *i*th species for each transect within each study area. Thus, for each study area 4 measures of diversity were developed because 4 subsites (transects) were sampled.

In study areas where both traps and nets were used, species richness and diversity values were calculated per subsite for each capture technique separately and in combination. Because only nets were used in JCBNP and only pan traps were used in mangrove forests, this allowed comparisons across study areas using 1) both pan traps and nets, 2) pan traps only, and 3) nets only.

Variation in hymenopterans species richness and diversity among different forms of land use was assessed using a Kruskall Wallis test (Sokal and Rohlf, 1995).

$$K = (N-1)\frac{\sum_{i=1}^{g} n_i(\bar{r}_{i\cdot} - \bar{r})^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(r_{ij} - \bar{r})^2},$$ where:

n_i= the number of observations in group i

r_{ij} = the rank (among all observations) of observation j from group i

N = the total number of observations across all groups

$$\bar{r}_{i\cdot} = \frac{\sum_{j=1}^{n_i} r_{ij}}{n_i},$$

$\bar{r} = \frac{1}{2}(N+1)$ is the average of all the r_{ij}

If differences in species richness or diversity among land use types indicated a significant result for the Kruskall Wallis test, pairwise comparisons between different land use types were then conducted using a Mann-Whitney U test (Sokal and Rolf 1989). Calculations were performed using Program R (version 2.14.1; R Development Core Team 2007) Decision on whether particular forms of land use support a greater diversity of hymenopterans, 0.1 was used as arbitrary choice for limiting p-value for judging statistical significance as recommended by several statisticians (Steward-Oaten, 1995; Gigerenzer, 2004; McKillup, 2005) that decision for level of significance for test be based on the nature of the study to balance the risk of Type I and Type II error. This was done for two reasons. Firstly, sample size (4 transects per study area) were small. Secondly the risk of type II error (acceptance of a false null hypothesis), which could ignore a possible effect of land use on pollinator communities could have negative effect for Zanzibar, where the greater human population relies on apiculture for a livelihood

Hymenoptera species richness was assessed by categorizing bees into different species, a species list for nets and PT for four land use types were created. Each technique consist of four transects per land use, thus species richness diversity values were calculated for each transect. Species richness was calculated just by counting the total numbers of species captured at each transect by and species diversity was calculated by using Simpson Reciprocal index (1/D). Variation in hymenopterans species richness and diversity between two approaches in four different forms of land use was assessed using a Kruskall Wallis test (Sokal and Rohlf, 1995). Either, Mann – Whitney U test was performed if p value from Kruskall Wallis test showed there was significant different of hymenopterans richness or diversity captured by nets or/and PT among different land use.

Bee species richness was assessed by sorting bees into different species and a species list for blue PT, yellow PT and white PT in four land use types were created. Each colour in each land use consist of four transects, thus species richness diversity values were calculated for each transect for every colour of PT. Species richness was calculated just by counting and recording the total numbers of species captured each colour of PT for each transect and species diversity was calculated by using Simpson Reciprocal index (1/D). Variation in hymenopterans species richness and diversity among different color of PT in four land use was assessed using a Kruskall Wallis test (Sokal and Rohlf, 1995). Either, Mann – Whitney U test was performed if p value from Kruskall Wallis test show there was significant different ($p < 0.1$) to identify which pair of land use forms showed significant different over other.

Questionnaires were constructed and pre- tested before supplied to the beekeepers. Sampling procedure was done by using simple random procedure in order to avoid bias (Kothari, 2004). To gather socioeconomic information and to assess the role of land use in sustaining beekeeping, sixty respondents from four different villages;

Muyuni A, Muyuni B, Muungoni and Pete-Jozani was interviewed. Either, Shehas (local Government leaders) and beekeeping cooperation leaders were informed and involved in survey. Primary data was obtained by questionnaire survey. Beekeeper was allowed to answer the list of questions by themselves and those who did not know to read and write were helped by researcher and trained assistants. The data was analyzed by SPSS (version 20) tool. Either Descriptive statistics were used to analyse data. Number of respondents chose various responses were entered in SPSS and the data retrieved as descriptive statistic; frequency and percentage. Decision made based on frequencies as well as percentage of respondents chose particular response. Frequencies and percentage are computed from a sample drawn from a larger population with the intention of making generalizations from the sample about the whole population. In quantitative approach, the accuracy of inferences drawn from a sample is critically affected by the sampling procedures used (Wholey *et al.,* 2004).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This section comprise presentation of the results on variation hymenoptera diversity, distribution and abundance in different land use, comparison of netting and PT efficiency as well as comparison of capturing efficiency of blue, yellow and white PT in assessing the hymenopterans diversity at mixed farming, monoculture and home garden. Discussion will be made by comparing results with other related studies.

4.1 Variation in hymenoptera distribution, diversity and abundance among different forms of land use such as agricultural crops, natural forest and mangrove habitats.

In total, 720 hymenoptera were captured in five different land use forms which comprise 8 identified families and 56 species (Table 2). Halictidae had highest species richness (15 species) followed by Apidae (12 species). Other were Vespidae (5 species), Sphecidae (3 species), Multilidae, Pompilidae and Crabonidae (1 species). However, Halictidae had the highest number of species but Apidae was the most abundant family (57.5%) followed by Megachilidae (23.75%) and Halictidae (8.05%). The greatest capture rates were in sites where both nets and pan traps were used (N = 155-173 individuals) and the least number was captured at JCBNP (N= 97). The greatest number of species were captured in home gardens and mixed crops. The least number of species were sampled in mangrove vegetation. *Apis mellifera* was the dominant species in all forms of land uses followed by *Megachile species 1* which was also widely distributed (Table 2). Ten species of hymenoptera were found exclusively in home gardens. Four species were captured at JCBNP only; mangrove had two species that were unique while mixed crop farming had only one species that was unique to this land use. Monoculture also had only one species were unique in this land use only.

Table 2 : Hymenopterans species captured in five land- use from January to march 2013, Unguja-Zanzibar. Both pan traps and nets were used in mixed farming, monoculture and home garden and At JCBNP on nets were used while in mangrove only pan traps were used

Family	Species	MF	MC	HG	JCBNP	MAN	Total
Apidae	*Apis mellifera*	48	98	68	28	71	313
	Amegilla species	17	11	4	6	0	38
	Xylocopa species 1	0	1	0	3	0	4
	Centris species	4	2	3	9	0	18
	Mellisode species	2	4	2	1	0	9
	Meliponini species	0	1	1	6	0	8
	Xylocopa species 2	0	0	0	1	0	1
	Ceratina species 1	1	0	3	0	0	4
	Epeolus species	0	0	3	1	0	4
	Ceratina species 2	0	0	0	1	0	1
	Ceratina species 3	0	0	1	0	0	1
	Ceratina species 4	0	4	0	0	9	13
Megachilidae	*Megachile species1*	46	30	28	6	28	138
	Lithurgus species 1	1	2	7	0	0	10
	Lithurgus species 2	1	1	1	1	0	4
	Megachile species 2	1	0	1	0	0	2
	Athidellum species	0	0	1	2	0	3
	Megachile species 3	1	0	1	9	0	11
	Pepsis species	1	1	0	0	0	2
	Megachile species 4	0	1	0	0	0	1
Halictidae	*Halictus species 1*	3	3	2	0	0	8
	Halictus species 2	3	1	1	2	0	7
	Lasioglossum species 1	3	1	2	2	0	8
	Lasioglossum species 2	1	0	0	2	0	3
	Lasioglossum species 3	1	0	3	0	0	4
	Lasioglossum species 4	1	0	0	1	0	2
	Lasioglossum species 5	0	0	1	0	1	2
	Sphecode species 1	0	0	1	0	0	1
	Nomia speciesv2	0	0	2	0	0	2
	Halictus species 3	1	0	1	0	0	2

Family	Species	MF	MC	HG	JCBNP	MAN	Total
	Sphecode species 2	0	0	1	0	0	1
	Halictus species 4	0	0	1	0	0	1
	Halictus species 5	0	4	0	1	7	12
	Halictus species 6	0	0	0	0	1	1
	Halictus species 7	0	0	1	0	0	1
Vespidae	*Palistes species*	1	0	2	0	0	3
	Popalidia species	1	0	0	1	0	2
	Icaria species	1	0	1	0	0	2
	Palistes species 2	0	0	0	2	0	2
	Delta species	0	1	0	0	13	14
Multilidae	*Snicromyreme species*	0	2	0	1	0	3
Pompilidae	*Hemipepsis species*	0	0	1	0	0	1
Sphecidae	*Bembicinus species*	1	0	1	0	0	2
	Ampulex species	0	0	0	2	0	2
	Sceliphron species	1	0	2	1	0	4
Crabonidae	*Bembix species*	0	0	1	0	0	1
Not identified	*Species A1*	8	4	9	1	0	22
	Species A2	1	0	0	1	0	2
	Species A3	0	0	0	1	0	1
	Species A4	1	0	1	0	0	2
	Species A5	2	0	0	0	0	2
	Species A6	0	0	1	0	0	1
	Species A7	0	0	0	0	1	1
	Species A8	1	0	0	1	0	2
	Species A9	0	0	1	0	0	1
	Species A10	1	0	0	2	0	3
	Total	155	173	164	97	131	720
	Species richness	29	20	36	28	8	56

MF – Mixed Crops, MC – Monoculture, HG – Home garden, JCBNP – Jozani-Chwaka Bay National Park and MAN – Mangrove.

4.1.1 Hymenoptera species richness in land-use forms where nets and pan traps were used.

Both nets and pan traps were used for capturing hymenopterans in mixed crop farming, monoculture and home garden. Species richness differed among the three study areas (Figure 2, KW $\chi^2 = 5.0$, df = 2, p = 0.08). Pairwise comparisons of species richness between study areas with mixed crops and monoculture showed no significant difference (W=14, N=14, p =0.11). Mean species richness in home gardens was not greater than in mixed crops (W=10.5, N=8, p =0.48). The difference between monoculture and home gardens was significant (W=14.5, N=8, p =0.06).

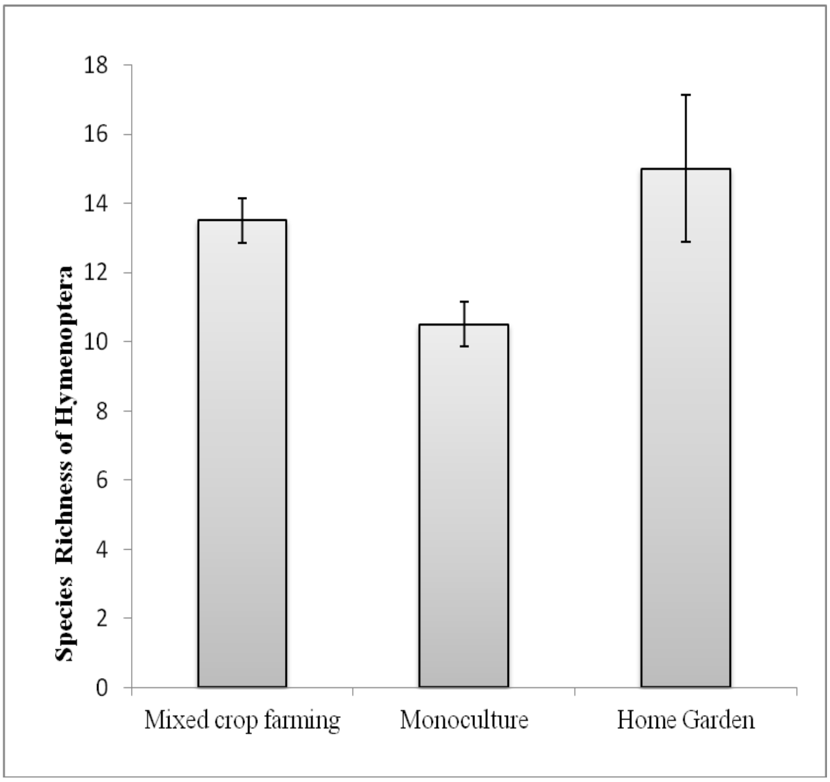

Figure 2 : A comparison of Mean (±SE) hymenoptera species richness among three different forms of land use on Unguja Island, Zanzibar from January – March 2013. Insects were captured using a combination of pan traps and nets.

4.1.2 Hymenoptera species richness in four land-use forms where pan trap was used

Species richness among four land-use forms did not differ (Fig. 3, KW $\chi 2 = 3.94$, df $= 3$, $p = 0.27$).

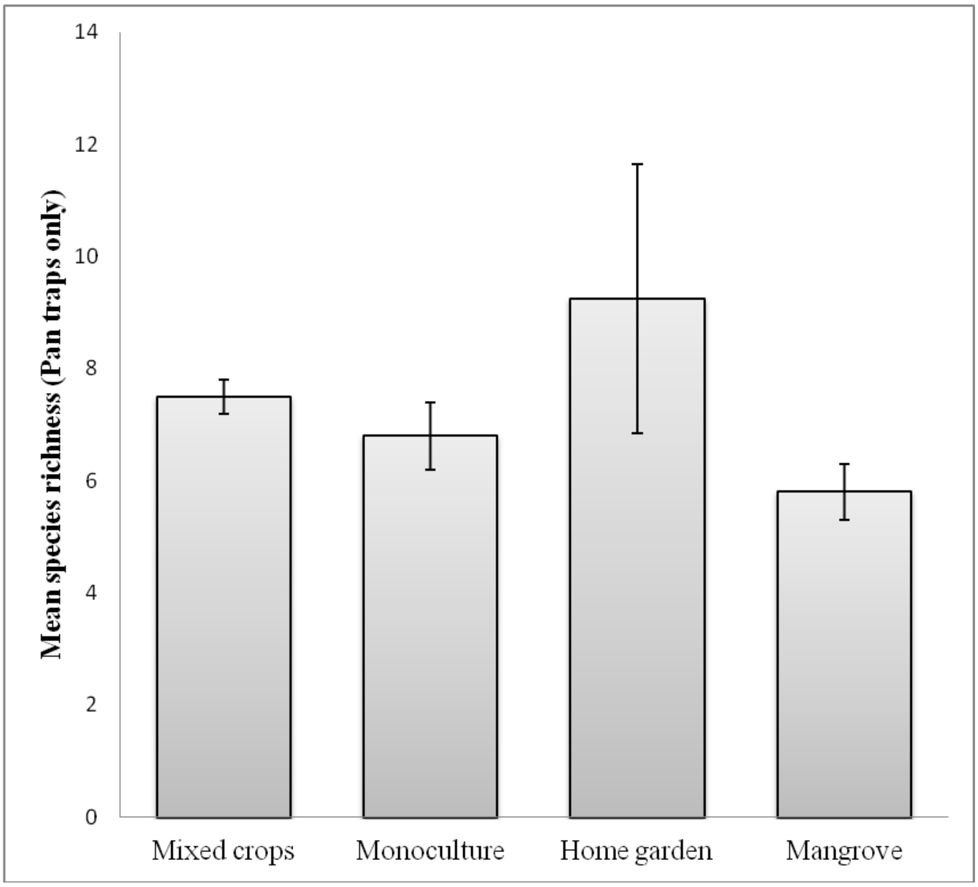

Figure 3 : Comparison of Mean (±SE) species richness in four study areas, hymenoptera were captured by pan trap only at Muungoni (mixed farming), Bungi (monoculture)and Kikungwi (home garden) – Unguja Island, Zanzibar from January – March 2013.

4.1.3 Species richness by net only

Hymenoptera species richness among four land-use forms where bees was captured by net only did not differ (Fig. 4 KW $\chi 2 = 5.13$, df $= 3$, p-value $= 0.16$) however, the average hymenoptera species were higher at Jozani (Xmean = 4.2 ±10.5) and monoculture have low average hymenoptera species richness (Xmean = 2.9 ±6.5).

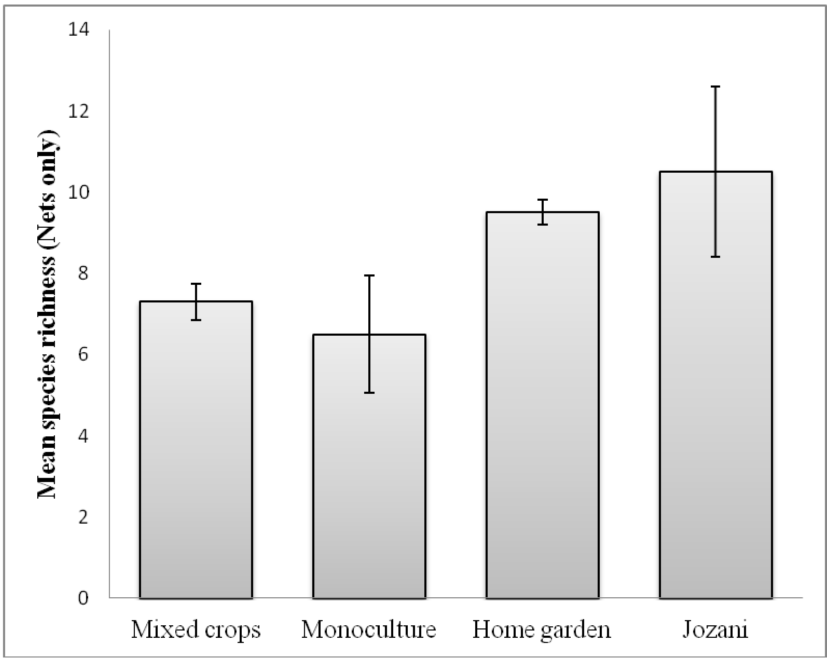

Figure 4 : Comparison of mean (±SE) species richness among four land-use form, bees was captured by nets from January – March 2013, Unguja-Zanzibar

4.1.4 Hymenoptera species diversity in land-use forms where nets and pan traps were used

Hymenoptera species diversity differed significantly among different land- use forms where data was collected by nets and pan traps (Figure 5. KW $\chi 2$ = 7.54, df = 2, p = 0.086). Species diversity in mixed crop farming was significantly higher than monoculture (U = 16, p = 0.03) same as in home garden and monoculture, species richness was significantly greater in home garden than in monoculture (W = 16, p-value = 0.03). However, mean hymenopterans species diversity was higher in home garden (1.5 ± 6.8) than in mixed crops (1.3 ± 4.47) but the difference was not significant (U = 10, p = 0.69).

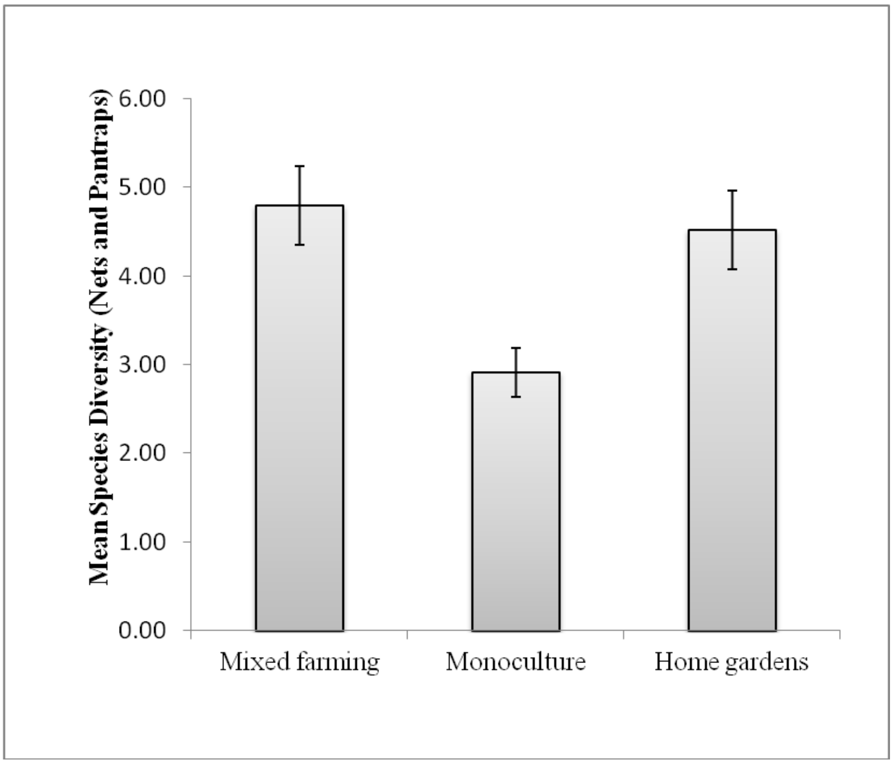

Figure 5 : Comparison of Mean (±SE) species diversity among different types of land-use. Hymenoptera species were captured using nets and pan traps at Unguja, Zanzibar from January – March 2013.

4.1.5 Species diversity by pan trap only

Species diversity among four land-use forms differ significantly from the data I had collect by pan trap from mixed crop farming, monoculture, home garden and mangrove (Fig.6 KW $\chi 2$ = 7.68, df = 3, p-value = 0.05). Pairwise comparison of species diversity among land-use forms shows that species diversity between mixed crop farming and monoculture (U=15, p=0.06) and between mixed crop farming and mangrove (U = 16, p=0.014) was significantly different. In addition to that species diversity did not differ between home garden and mixed crop farming (U=13, p =0.2) as in monoculture and home garden (U = 13, p=0.20). Monoculture and mangrove (U = 12, p=0.34) and between home garden and mangrove (U = 10, p=0.68) species diversity did not differ.

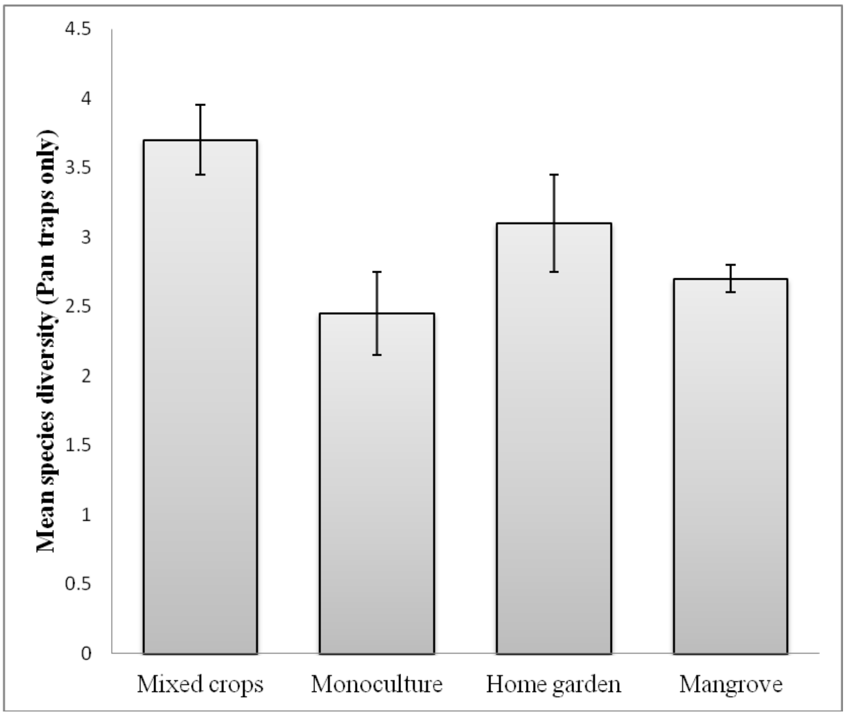

Figure 6 : Comparison of mean (±SE) species diversity of hymenoptera captured from different land-use. Samples were captured by pan traps of three different colour; blue, yellow and white January – March 2013, Unguja Island, Zanzibar.

4.1.2 Species diversity by net only

Hymenoptera Species diversity among four land- use forms did differ significantly from hymenoptera samples captures by net (Fig. 7 KW $\chi2$ = 8.93, df = 3, p-value = 0.03). Pair wise comparison of hymenoptera diversity were done, hymenoptera species diversity were higher in Jozani than monoculture (W = 15, p=0.057). There was also higher hymenopterans diversity in home garden than monoculture.

However, hymenopterans species diversity did not differ between mixed farming and monoculture (W=11, p=0.48), mixed farming and home garden (W=14, p =0.11), Mixed farming and Jozani (W = 13, p=0.2) and home garden and Jozani (W = 12.5, p=0.2).

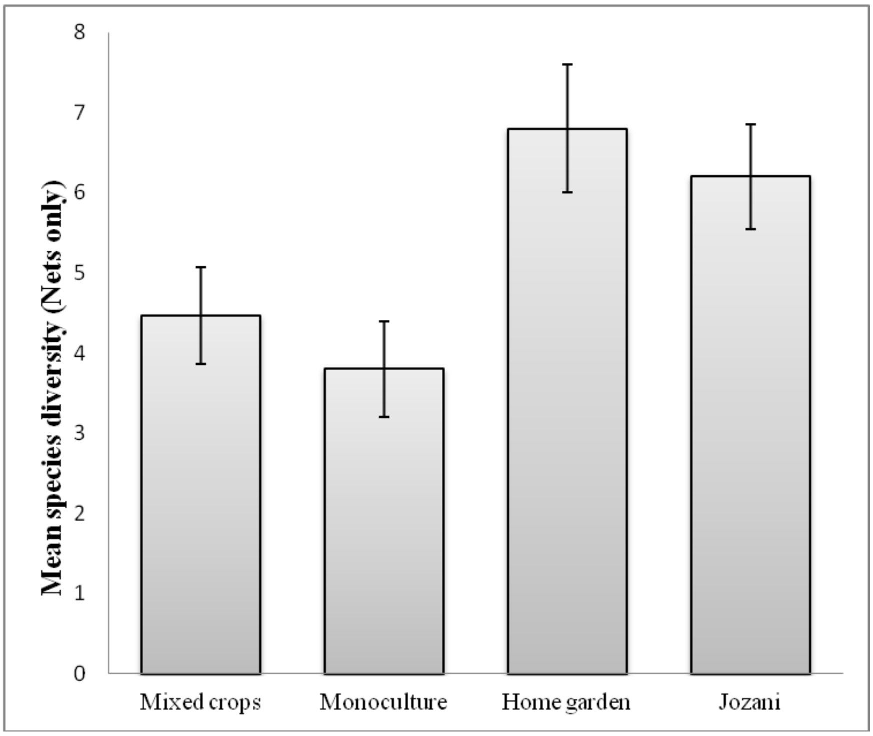

Figure 7 : Comparison of mean (±SE) species diversity of hymenoptera captured from different land-use, samples were captured by net, January – March 2013, Unguja Island, Zanzibar

4.2 To compare the efficacy of netting versus pan trap for collecting different species of hymenopterans

Hymenopter species were collected by two different methods; pan traps and nets in three land-use forms (mixed crop farming, monoculture, and home garden). The performance of these methods was tested in these land use. In total, 496 hymenopterans species were captured, pan trap captured large number of hymenoptera species (314) and 178 hymenoptera species were captured by nets (Table 3). Total of 48 hymenopterans species were captured by both, nets and pan traps. Either, total hymenoptera species captured by pan traps were 30 out of that 13 species were exclusively captured by it. On other hand, total hymenopterans species captured by nets were 34, Hymenopterans species exclusively captured by nets were18. Moreover, total hymenopterans species captured by both; nets and pan traps were 16 while 8 species were not captured at all by both methods in these three land use where nets and pan traps were used. I found that the there was a marginal difference in efficiency for assessing the hymenoptera species richness between hymenoptera species captured by nets (34) and pan traps (30).

Table 3 : Comparison of hymenopterans species captured by nets and PT in three land use where both techniques were used. Hymenopterans were collected from January – march 2013, Unguja, Zanzibar

Family	Species	PT	Nets	Total
Apidae	*Apis mellifera*	161	53	214
	Amegilla species	12	23	35
	Xylocopa species 1	0	1	1
	Centris species	2	7	9
	Mellisode species	1	7	8
	Meliponini species	2	0	2
	Xylocopa species 2	0	0	0
	Ceratina species 1	4	0	4
	Epeolus species	3	0	3
	Ceratina species 2	4	0	4
	Ceratina species 3	0	0	0
	Ceratina species 4	3	1	4
Megachilidae	*Megachile species 1*	69	35	104
	Lithurgus species 1	3	7	10
	Lithurgus species 2	2	1	3
	Megachile species 2	0	2	2
	Athidellum species	0	1	1
	Megachile species 3	2	0	2
	Megachile species 4	2	1	3
Halictidae	*Halictus species 1*	8	0	8
	Halictus species 2	4	1	5
	Lasioglossum species 1	6	0	6
	Lasioglossum species 2	1	0	1
	Lasioglossum species 3	1	3	4
	Lasioglossum species 4	0	1	1
	Lasioglossum species 5	0	1	1

Family	Species	PT	Nets	Total
	Sphecode species 1	0	1	1
	Nomia species	0	0	0
	Halictus species 3	1	2	3
	Sphecode species 2	2	0	2
	Halictus species 4	0	1	1
	Halictus species 5	4	0	4
	Halictus species 6	0	0	0
	Halictus species 7	0	1	1
Vespidae	*Palistes species1*	0	3	3
	Popalidia species	0	1	1
	Icaria species	0	1	1
	Palistes species 2	0	3	3
	Delta species	0	1	1
Multilidae	*Snicromyreme species*	1	2	3
Pompilidae	*Hemipepsis species*	0	1	1
Sphecidae	*Bembicinus species*	3	0	3
	Ampulex species	0	0	0
	Sceliphron species	0	2	2
Crabonidae	*Bembix species*	0	1	1
Not identified	*Species A1*	13	8	21
	Species A2	1	0	1
	Species A3	0	0	0
	Species A4	0	2	2
	Species A5	2	0	2
	Species A6	0	1	1
	Species A7	1	0	1
	Species A8	1	1	2
	Species A9	0	0	0
	Species A10	1	1	2

Source: Field data 2013

4.2.1 Comparison of hymenoptera abundance captured by nets and pan traps

Pan traps captured significant higher abundance of hymenopterans than nets (Fig. 8). Mean abundance per transect was greater in pan traps (N = 12, T = 0, $p < 0.05$)

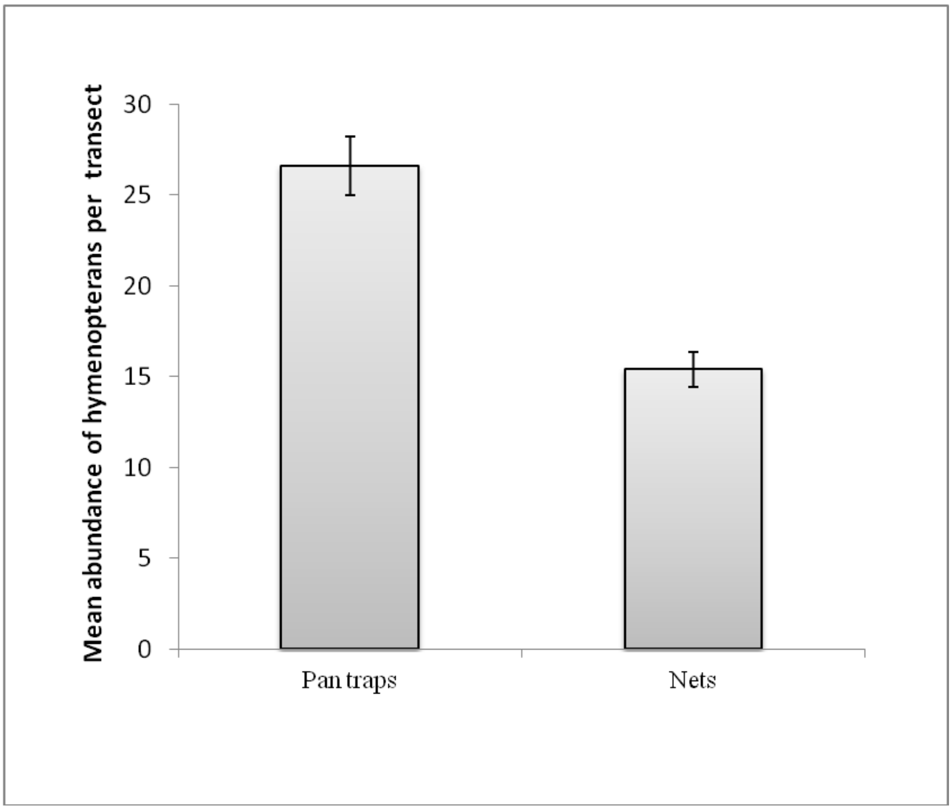

Figure 8 : Comparison of mean abundance of Hymenoptera per transect in three land use, hymenoptera were captured from January to March 2013, Unguja – Zanzibar

4.2.2 Comparison of hymenopterans species diversity between nets and pan traps

Nets captured significant higher diversity of hymenopterans than PT (Fig. 9). Diversity per transects was greater in nets (N = 12, T = 0, $p < 0.025$).

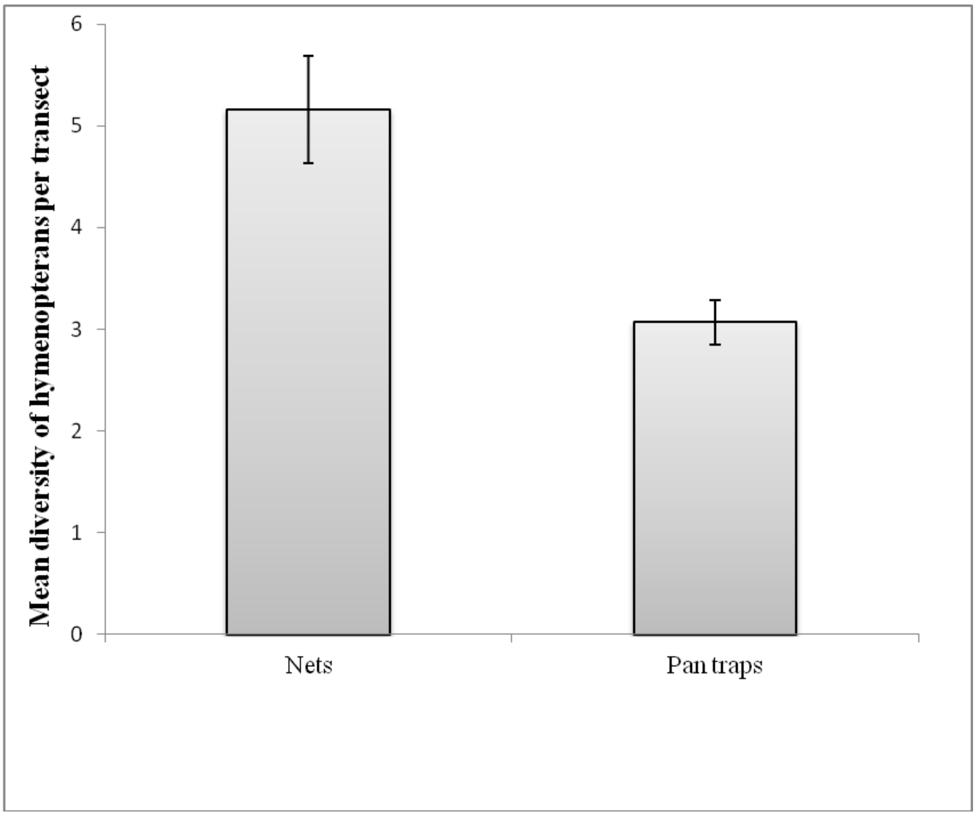

Figure 9 : Mean diversity of hymenopterans per transect collected by net and PT in three land use where both net and PT were used

4.2.3 Comparison of hymenopterans species richness captured by nets and pan traps

There was no difference between nets and PT in species richness of hymenopterans species captures (Fig. 10).

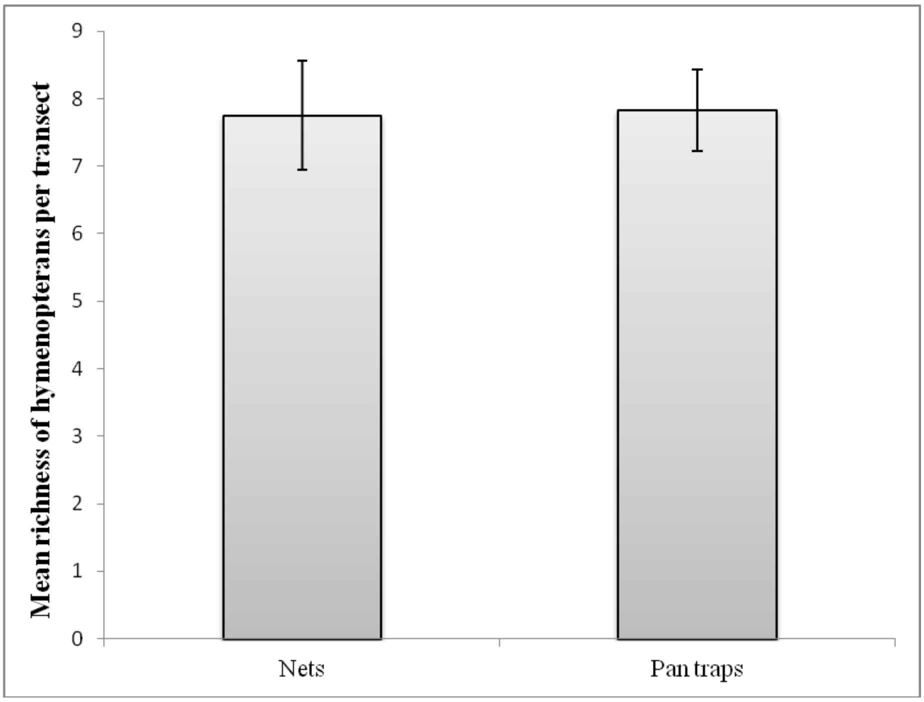

Figure 10 : Comparison of mean richness of hymenopterans species captured by nets and PT.

4.3 Hymenoptera species richness captured by three different pan traps colour

Hymenoptera species were sampled using pan traps of three different colour; blue, yellow and white. The performance of these pan traps colour were tested in land use with mixed crops, mono crop (monoculture), home garden and mangrove. In this study more hymenopterans captured in blue pan traps (161) and lower mean were captured by white pan traps (Table 4) Kruskal-Wallis rank sum test shows that hymenopterans species richness among three colour did not differ (KW $\chi 2$ = 1.11, df = 2, p-value = 0.57)

Table 4 : Comparison of hymenoptera species captured by blue, yellow and white pan traps in four different land use forms from January to March 2013, Unguja- Zanzibar

Family	Species	BPT	YPT	WPT	Total
Apidae	*Apis mellifera*	87	78	67	232
	Amegilla species	4	4	1	9
	Xylocopa species 1	0	0	0	0
	Centris species	1	0	1	2
	Mellisode species	0	0	1	1
	Meliponini species	0	1	1	2
	Xylocopa species 2	0	0	0	0
	Ceratina species 1	2	0	2	4
	Epeolus species	0	0	3	3
	Ceratina species 2	0	0	0	0
	Ceratina species 3	0	0	1	1
	Ceratina species 4	5	2	5	12
Megachilidae	*Megachile species1*	34	37	26	97
	Lithurgus species1	1	2	0	3
	Lithurgus species 2	2	0	0	2
	Megachile species2	0	0	0	0
	Athidellum species	0	0	0	0
	Megachile species3	1	0	1	2
	Pepsis species	0	1	1	2
	Megachile species4	0	0	0	0
Halictidae	*Halictus species 1*	1	3	4	8
	Halictus species 2	0	3	1	4
	Lasioglossum species1	1	3	2	6
	Lasioglossum species2	0	1	0	1
	Lasioglossum species3	1	0	0	1
	Lasioglossum species4	0	0	0	0
	Lasioglossum species5	1	0	0	1

Family	Species	BPT	YPT	WPT	Total
	Sphecode species 1	0	0	0	0
	Nomia species	0	1	1	2
	Halictus species 3	0	0	0	0
	Sphecode species 2	1	0	0	1
	Halictus species 4	0	0	0	0
	Halictus species 5	3	3	5	11
	Halictus species 6	1	0	0	1
	Halictus species 7	0	0	0	0
Vespidae	*Palistes species*	0	0	0	0
	Popalidia species	0	0	0	0
	Icaria species	0	1	0	1
	Palistes species 2	0	1	1	2
	Delta species	3	4	6	13
Multilidae	*Snicromyreme species*	0	0	0	0
Pompilidae	*Hemipepsis species*	0	0	0	0
Sphecidae	*Bembicinus species*	0	1	1	2
	Ampulex species	0	0	0	0
	Sceliphron species	0	0	1	1
Crabonidae	*Bembix species*	0	0	0	0
Un identified	*Species A1*	0	0	0	0
	Species A2	0	1	0	1
	Species A3	0	0	0	0
	Species A4	0	0	2	2
	Species A5	0	0	2	2
	Species A6	0	0	0	0
	Species A7	1	0	0	1
	Species A8	0	0	0	0
	Species A9	0	0	1	1
	Species A10	0	0	0	0
	Total	161	152	137	450
	Species richness	18	18	24	34

BTP – Blue pan traps, YPT – Yellow pan traps and WPT – White pan traps Source: Field data, 2013

4.4 Socioeconomic information on beekeeping and its role of land use in sustaining the beekeeping industry

Sixty respondents were interviewed at four different village; 11 from Muyuni A, 10 from Muyuni B, 20 from Muungoni and 19 from Pete- Jozani village. Out of 60 respondent male were 58.3% and female were 41.7% (Table 5). The respondent who got secondary education was about 50%, primary education 35% and the remaining 15% have non-formal education. About 85% of beekeepers interviewed depend on crop production and beekeeping as a source of income and other 15% employed in fishing, business and doctor with beekeeping.

Table 5 : Beekeepers details gathered through interview conducted April, 2013 at four villages, Unguja – Zanzibar.

Category	Number of respondents	Percentage (%)
Gender		
Male	35	58.3
Female	25	41.7
Age		
Teen	9	15.0
25 - 35	15	25.0
36 - 45	19	31.7
46 and more	17	28.3
Type of Activities		
Beekeeper and Doctor	2	3.3
Beekeeper and Farmer	51	85.0
Beekeeping and Business	4	6.7
Beekeeping and House wife	2	3.3
Beekeeping and Fishing	1	1.7
Education		
Non formal	9	15.0
Primary	21	35.0
Secondary	30	50.0
Total	60	100.0

Source: Field data, 2013

4.4.1 Gender participation

Both male and female beekeepers were interviewed from Muyuni A Muyuni B, Muungoni and Pete-Jozani. Total respondents were sixty: 58% were male and 42% were female (Fig. 11).

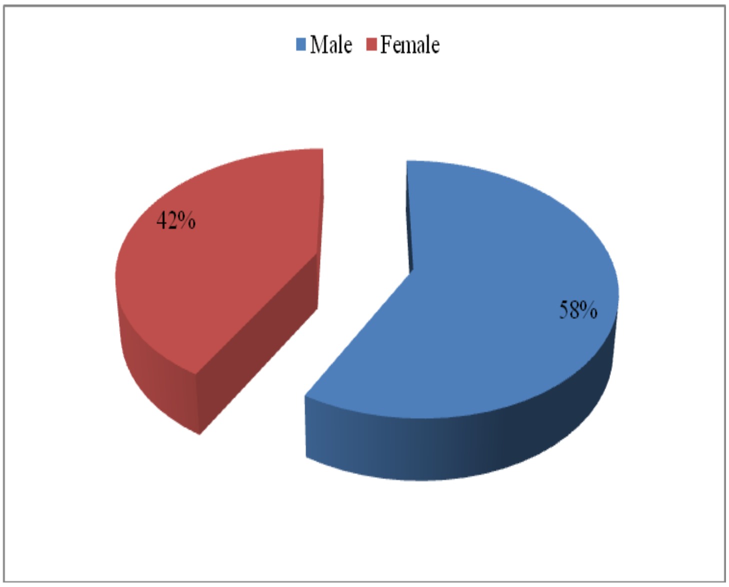

Figure 11 : Gender participation in beekeeping among beekeepers interviewed April 2013 at four villages – Southern Unguja

4.4.2 Age of beekeepers

Beekeeping is a commercial activity carried out in various parts in Zanzibar including four villages where beekeepers were interviewed. Age wise, beekeepers included teenagers, adults in their 20's, 30's and 40's (Fig. 12).

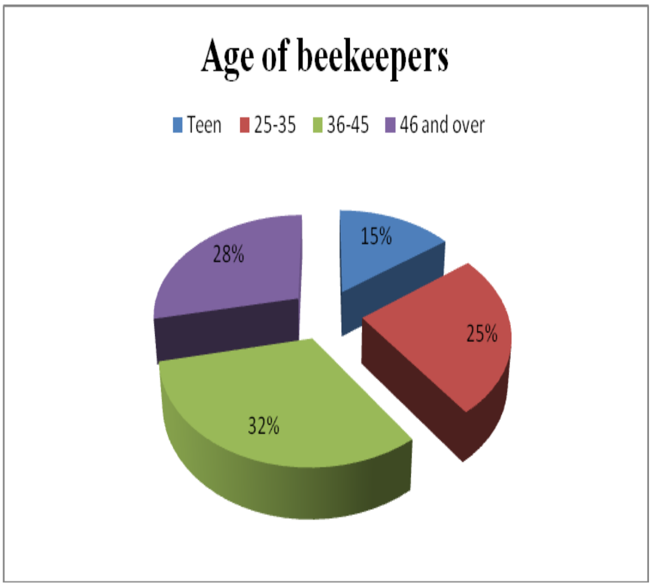

Figure 12 : Age distribution of beekeepers (N=60) interviewed April 2013 in four villages at Sothern Unguja

Table 6: Main occupations of beekeepers interviewed April 2013 at four villages in Southern Unguja.

Occupations	Frequency	Percent
Beekeeping and Doctor	2	3.3
Beekeeper and Farmer	51	85.0
Beekeeping and Business	4	6.7
Beekeeping and House wife	2	3.3
Beekeeping and Fishing	1	1.7
Total	60	100.0

Source: Field data, 2013

Beekeeping is an additional source of income as all of the interviewed beekeepers had another job (Table 6) which can serve to get income for education and health care of the family member.

Table 7 : Level of education of beekeepers interviewed in four villages April 2013, Unguja - Zanzibar

Level of education	Frequency	Percent
Non formal	9	15.0
Primary	21	35.0
Secondary	30	50.0
Total	60	100.0

Source: Field data, 2013

Most of the beekeepers were educated to secondary and primary level and there were very few who did not attend school at all but had received a non- formal education. Interviewed respondents reported that they got education from workshops, seminars, and short courses organized by Zanzibar Beekeeping Association (ZABA) or direct from elders or long experience beekeepers

Table 8 : Types of honeybees mentioned by beekeepers interviewed April 2013

Types of honeybees	Frequency	Percent
Two	56	93.3
Four	4	6.7
Total	60	100.0

Source: Field data, 2013

Beekeepers lack scientific knowledge of honeybees but they have local knowledge of categorizing bees into various groups. Two major criteria used in classifying honeybees were body size: large bees and small bees. The second criterion was the presence or absence of a sting; stinging and stingless bees were mentioned. Those who mentioned two types of bees either said they were large or small bees, or stinging and stingless bees. In general beekeepers in Zanzibar seem to have only a superficial knowledge of classifying bees.

Table 9 : Distribution of honeybees as mentioned by beekeepers interviewed April 2013 in four villages, Southern Unguja

Land uses	Frequency	Percent
Natural forest	39	65.0
Farm area	4	6.7
Home garden	1	1.7
Mangrove	16	26.7
Total	60	100.0

Source: Field data, 2013

Respondents reported the presence of honey bees in various land use forms such natural forest, agricultural fields and mangrove forests. Based on 65% of the responses from various beekeepers, honeybees were found mainly in natural forest, (Table 9). The second land use which support larger number of honeybees was mangrove forest (26.7% respondents) and the least number were mentioned in home garden (1.7% respondents).

Table 10 : Factors affecting honeybees distribution as mentioned by beekeepers interviewed April 2013 in four villages, Southern Unguja.

Factors	Frequency	Percent
Get their basic need in forest	18	30.0
Large area in natural forest	0 6	10.0
Different trees and flower in forest	26	43.3
Enough water in mangrove	0 5	0 8.3
Good environmental condition	0 4	0 6.7
Total	59	98.3
Missing	0 1	01.7
Total	60	100.0

Source: Field data, 2013

Among the factors affecting bee distribution in different types of land use were area, availability of basic needs for the bees, flower diversity, water and enviromental conditions (Table 10). The major factor mentioned was flower diversity; 43.3% of the respondents pointed out this factor. Other basic needs were the second most important factor. Environmental factors did not seem to have much importance as only 6.7% of the respondents cited it as a factor.

Table 11 : level of honey production among beekeepers interviewed in four villages April 2013, Southern Unguja

Level of honey production	Frequency	Percent
low production	41	68.3
intermediate	11	18.3
high production	6	10.0
no production	2	3.4
Total	60	100.0

Source: Field data, 2013

About 68% of the respondents interviewed reported low honey production and only 10% reported high production.

Table 12: Number of hives possessed by beekeepers in four villages, Unguja - Zanzibar

Number of hives	Frequency	Percent
1-5	24	40.0
6-10	17	28.3
11-15	6	10.0
16-20	8	13.3
More than 20	5	8.3
Total	60	100.0

Source: Field data, 2013

Most of the beekeepers interviewed possess a moderate or small number of hives (Table 12). More beekeepers reported low honey production regardless of the number of hives owned by beekeepers. Nineteen out of 24 beekeepers with few hives reported low production of honey and only one beekeeper with few hives report high production of honey. Moreover, only two out of eleven respondents with many hives reported high production.

Table 13 : Roles of beekeeping mentioned by beekeepers April, 2013, Unguja - Zanzibar

Importance of beekeeping	Frequency	Percent
Money	8	13.3
Honey	15	25.0
Medicine	11	18.3
Pollination of food crops	10	16.7
Forest conservation	9	15.0
Total	53	88.3
Missing	7	11.7
Total	60	100.0

Source: Field data, 2013

4.4.3 Roles of beekeeping

4.4.3.1 Social role

Getting honey was among the target of beekeeping activities in Zanzibar, 15% of the respondents pointed out getting honey as the role of beekeeping. Money and medicine are the most commonly derived benefits of honey production;.

4.4.3.2 Economic role

Income obtained by selling honey was among the pointed source of income in four villages where beekeepers interviewed to family income. 15% of the respondent said that they get money by selling honey (Table 13).

4.4.3.3. Ecological role

Forest conservation was pointed out as an additional role of beekeeping, apart of producing honey. !6.7% of the respondent mentioned that beekeeping contributed to forest conservation (Table 13). Another ecological benefit mentioned was pollination services; honeybees take pollen from anthers to the stigma of the same or different flowers, which contribute to production of fruits and seeds. Oddly enough, aggressive behaviour of honeybees was cited as a deterrent; thus people avoided cutting trees for charcoal or fire wood out of fear of being stung by honeybees . Also, beekeeping maintained food security as it was mentioned as an activity that contributed to fruit production (Table 13)

Table 14 : Problems face beekeeping in Unguja, Zanzibar

Problems	Frequency	Percent
Theft	10	16.7
Lack of training	9	15.0
Termites and other pests	9	15.0
Environmental degradation	19	31.7
Lack of fund	5	8.3
Colony migration	7	11.7
Total	59	98.3
Missing	1	1.67
Total	60	100.0

Source: Field data, 2013

4.5 Problems of beekeeping

Environmental degradation was reported as a major problem facing the beekeeping industry in Zanzibar (31.7% respondents). The second largest problem reported was theft (16.7% respondents). Respondents reported that thieves sometimes used pesticides to kill honeybees. Also 19% said that cutting trees for fuel and fire wood contributed to colony migration (Table 14). Also, pests and lack of funds were reported as other problems facing beekeepers in Zanzibar, all of which contributed to low honey production.

Table 15 : Beekeeping methods mentioned by beekeepers interviewed April 2013 in four villages, Unguja - Zanzibar

Methods of beekeeping	Frequency	Percent
Modern beekeeping	2	3.3
Traditional beekeeping	28	46.7
Both	29	48.3
Total	59	98.3
Missing	1	1.67
Total	60	100.0

Source: Field data, 2013

The majority of beekeepers use both traditional and modern hives and very few reported using modern hives exclusively. They said that modern hives were expensive and needed more expertise to construct and use, thus they were compelled to use traditional methods which were cheaper and easier to make and use.

4.5 Discussion

4.5.1 Hymenopterans diversity in five different land use

This study attempted to analyze the effects of land use on hymenoptera diversity in Zanzibar. The results of this study showed that home garden, mixed crops farming and JCBNP have greater species richness and diversity then monoculture (orange plantation) and mangrove vegetation. I expected that bee abundance and richness would be negatively associated with land use change as found by previous studies such as (Aizen and Feinsinger 1994; Kremen *et al.,* 2002; Kremen *et al.,* 2004). There are several possible explanations for why findings differed from my initial expectations. First, bee abundance and richness depend on the level of disturbance as in some findings bee species richness was higher at intermediate level of human disturbance (Winfree *et al.,* 2006). Second, disturbance followed different succession stage, each succession stage contribute to increase species richness over time (Chesson and Hunty, 1997). In Europe, for example, anthropogenic disturbance has replaced river flood plains creating early successional habitats used by many bee species (Klemm, 1996). Sunlight and the presence of a forest canopy is considered as another factor limiting hymenoptera diversity, whereas open habitats positively influence hymenoptera diversity (Bell *et al.*, 2000). The home garden where this study was conducted was a single family residential garden with open habitat characterized by tree and shrubs ranging from 2m - 20m in height (Plate 3). Also the garden had more wild/unmanaged vegetation, which might have provided sources of food and shelter for larva and pupa to develop (Buchmann and Nabhan, 1997). Also, when surrounding natural forest is removed; hymenopteran species may be forced into agricultural areas where food and nesting resources are available. The family gardens are controlled by man and the vegetation is composed mainly of ornamental or food plants. Greater variety in components might correspond to an increase in nesting and foraging opportunities for hymenoptera. Although, observation showed that there was a significant difference of hymenoptera species diversity among different land use forms future work should entail detailed analyses of the composition of the habitat in order to gain more insight into the environmental effects on the diversity of hymenoptera species.

4.5.1 The influence of land use

In agricultural landscapes, diversity of flower-visiting insects are affected by a number of factors which are integrated into conservation measures. In this study, hymenopteran diversity was assessed in five different kinds of land use; mixed crop farming, monoculture, home garden, Conservation area (JCBNP) and mangrove. As land type affects plant species composition, hymenoptera species diversity is determined by plant species richness (Keller and Waller, 2002). Two agricultural areas (home gardens and mixed farming) supported larger numbers of hymenoptera; home garden was the leading land use where many species were captured (Table 1). The results correspond to (Owen, 1991) who recorded larger number of bee species in a small residential garden in Leicestershire, England. Additionally, Westphal *et al.,* (2008) and Winfree et al 2006 reported higher pollinator abundance in agricultural areas than in natural areas. The results also correspond with William's *et al.,* (2010) study where it was found that certain bee species that nested in the ground increased with land-use change probably because human activities improved access to bare soil. Similar trends were observed by DeVries's *et al.,* (1997), where some tropical butterfly abundance was higher in disturbed area. Sweet bees (*Lasioglossum* species) were higher in cucumber flowers in the urban garden (Morath, 2008).

4.5.2 Hymenopterans diversity in captured by PT and nets in different land use

The results showed that mean abundance per transect was significant higher in PT than in nets. However, mean diversity of hymenopterans per transect was significant higher in nets than in PT. There was no significant different of mean hymenopterans species richness captured by nets and PT. The results confirmed that, the use of both methods is far better as 13 hymenopterans species was captured only in PT and 18 hymenopterans species captured by nets only (Table 3). Thus, caution should be used when developing generalizations about potential prejudices of different survey methods for bee fauna (Grundel *et al.,* 2011). The results correspond to other studies: more samples were collected in PT than in nets (Grundel *et al.,* 2011). The number of species captured by nets was significantly greater (Grundel *et al.,* 2011), The results correspond to this study where more specie captured by nets even though the difference was not significant. In contrary, PT was the superior method for detecting bee species richness (Potts *et al.*, [2003]; Cane *et al.*, [2006]) in both agricultural and semi-natural grassland. As in (Roulston *et al.,* 2007), Halictidae family was more captured in PT as by netting.

4.5.3 Hymenopterans species diversity captured by blue PT, yellow PT and white PT in three land use

Generally, PT captured 450 hymenopterans comprised of 8 families and 34 species. *Apis mellifera* was most commonly observed species followed by *Megachile species1* while other species were only represented by one individual. Results showed that mean hymenopterans species richness was somewhat higher in blue PT than in yellow and white PT. Simpson index of diversity were nearly same, even though yellow PT captured a slightly higher mean index of diversity (1/D = 2.87) than blue (1/D = 2.47) and white (1/D = 2.66). Statistical tests showed no significant difference among hymenopterans species richness ($p = 0.39$) and diversity ($p = 0.57$) captured by blue, yellow and white PT meaning little influence of PT colour on both species richness and diversity of hymenopterans species. Individual species showed different response to PT colour. *Apis mellifera* and *Megachile species 1* showed neutral response to pan trap colour as they are captured in all three colour of PT. Some species captured in all three PT colours but prefer more one or two colours; for example, *Amegilla* species were less attracted by white PT, *Ceratina species 4* was attracted more to yellow while *Halictus species 5* and *Delta species were* attracted more to white colour. Some species showed positive responses to one colour only, 8 species captured by white PT only, 5 species captured by blue only and 3 species was unique in yellow PT. So, different colours of PT could be employed to deal with differential preferences of certain hymenopterans group for particular colour (Campbell and Hanula, 2007). The results of this study showed some resemblance to other studies. High capture rates in blue PT as measured by abundance and richness was observed in various studies such as (Grundel et al 2011); Campbell and Hanula 2007); Grundel *et al.*, 2010; Stephan and Rao, 2005). In some studies such as (Kwapong *et al.*, 2002) blue PT o attracted more bees and the remaining taxas preferred yellow. Preference of blue and white colour also was observed in Encyrtidae and Pompilidae (Berglind, 1993) and in female *Andrena limnanthis* (Leong and Thorp, 1995). In contrary, other study studies conducted by (Krug and Alves-dos-Santos, 2008) found yellow PT was more efficient while (Wilson *et al.*, 2008) found same number from yellow and blue. Wild bees captured more in yellow PT (Theodore, 2013); and *Limnanthis* bees were caught significant greater in number in yellow PT than in blue and white (Trebicki *el al.*, 2010).

4.5.4 Socio-economic information on beekeeping and its role of land use in sustaining the beekeeping industry

Beekeeping plays a key social role as it employ and provides income for a large number of young rural people who drop out from school and those who did not get an opportunity to continue with advance and college education. Also reduce the chance for youth to be engaged in drug-abuse. The results revealed that 100% of the interviewed beekeepers had only a primary, secondary or informal education and none had graduated from secondary school.

4.5.4.1 Honeybees' distribution

Based on responses from beekeepers, natural forests were the leading land use considered to support more honeybees, followed by mangrove (Table 9). Only 5% of the respondents considered farm areas and home gardens to be good habitats for bees. The findings of this study are thus illuminating; more honeybees were captured in monoculture followed by mangrove then mixed farming. Natural forest showed the least number among all types of land use in this study (table 2). However, at Jozani natural forest, only netting was allowed by the authority, which might contribute to low capture rates, while in mangrove there were logistic difficulties environmental using nets.

4.5.4.2 Level of honey production

Most beekeepers reported low honey production; they obtained honey harvests below what they expected (Table 11). Low production might be contributed by various problem or challenges; thieves, lack of training, pest attacks, lack of funds and colony migration were among the chief problems cited by beekeepers. Environmental degradation was the major problem, mentioned 19 times followed by theft (Table 14). Many rural people use fire wood for cooking which might contribute to habitat degradation as a major problem. Other problems included lack of funds, which forced beekeepers to use traditional and less efficient beekeeping methods. As reported, 46.7% of the respondents used traditional methods, 29% use both methods and only 3.3% use modern method. It is possible that the use of traditional methods to be one among factors contributing to low honey production.

The study findings show that beekeeping in Southern Unguja plays some role in increasing awareness of the importance of honeybees through their products and services. Thus, beekeeping plays a major role for conservation of bees and plants. Bee products are reported to have wide domestic use such as food, medicine, and making candles (Table 13) among rural people. Selling honey is a major income generating activity, which had potential to help in poverty reduction if beekeeping methodologies are updated and improved; beekeeping has the potential to provide income to pay social services such as education and health care in rural Zanzibar. The study also showed that most of the respondents had dependents (children) that they supported by selling honey and beeswax.

Ecologically beekeeping is associated with various tangible benefits which contribute to sustainable management of natural resources (Mariki, 2007) and increases biodiversity of plants and animal fauna. Honey residues left behind in hives attract many animal fauna such as mites, butterflies, beetles ants and wasps (direct observation by researcher), even though these organisms might attack sometimes attack hives and cause honeybee death or abandonment of the hive. Biologically, honeybees play a major role to the plants and animals through pollination. Pollination, especially cross pollination increase plants vigor and diversity. Where apiaries are held, plants may get greater protection against deforestation by encroachers who fear being stung by honeybees.

Apart from those benefits, beekeeping in Zanzibar faced a lot of problems/challenges which might contribute to low production of honey. Financial problems force beekeepers to adopt traditional beekeeping such as the use of log hives, lack of modern equipments, pest attack, theft and environmental degradation have been reported by most beekeepers as among the problems they faced. Lack of knowledge of beekeeping also was another constraints face beekeeping industry among Zanzibar beekeepers.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter comprise conclusive summary of the report based on the findings. Either, recommendations, limitation of the study and areas for further studies is included in this section.

5.1 Conclusion

The effects of land use on hymenopteran diversity in Zanzibar was assessed by capturing Hymenoptera species in five types of land use; mixed farming, monoculture, home garden, JCBNP and mangrove vegetation. The results showed that land use had different impacts on hymenopteran diversity. Home garden had a higher species richness of hymenopterans. Diversity index was higher in a land use with mixed farming. Methodological evaluation between nets and PT done in mixed farming, monoculture and home garden showed that nets captured more species than PT even though the difference was not significant. Significant higher index of diversity was captured by nets. The attractive efficiency of PT colour showed that more hymenopterans were sampled in blue PT while more hymenopterans species were sampled by white PT. Thus, the use of more than one method in assessing hymenopterans diversity is more advisable, as some species biased to one method only. The preference of PT colour to certain species had been observed, thus to get maximum representative sample, the use of different colour of PT is highly insisted.

5.2 Recommendations

Based on the findings of this study, I would like to give the following recommendations:

To encourage urban dwellers to establish gardens around their residential areas to conserve hymenopteran diversity as well as plant diversity through plant – pollinators' relationships.

Farmers should adopt mixed farming in their agricultural fields, which creates greater plant diversity, which in turn will contribute to higher diversity of hymenopterans in agricultural fields.

Special awareness campaigns on the importance of hymenopterans as pollinators should be organized and delivered to farmers to develop positive attitudes towards conservation of hymenopterans and other pollinators.

To educate farmers on the roles played by pollinators such as hymenopterans on maintaining food security.

Farmers should use beekeeping as additional source of income; the two activities are interdependent and mutually beneficial.

Governments should provide financial support, and governments and universities should provide expertise to beekeepers to maximize honey production through the adoption of modern beekeeping (use of hives and modern equipments such smoker, special wearing and gloves).

5.3 Limitation of the study

Sampling was conducted in one season only due to shortage of time which could influence species richness/diversity conclusion.

Hymenoptera was sampled only one site for each land use thus the results may not be truly representative of each land use type.

Restriction to the use of pan traps in JCBNP to avoid capture of non target species in conservation area likely contributed to fewer species being captured in that area

Nets were not used in mangrove vegetation, because of difficulties accessing the area during high tide. Additionally, high tides also limited the use of PT in the area in some days.

5.4 Areas for further study

Based on the results obtained, home garden and mixed farming supported higher diversity of Hymenoptera than JCBNP and mangrove vegetation. Higher diversity might be influenced by other factors apart from land use change. Assessment of the effects of garden area, distance from natural areas, and vegetation canopy, floral diversity and soil type on hymenopterans diversity are among other areas for further study. Assessing the relative importance of these different factors will be important to develop stronger conclusions about the effects of land use on hymenopteran diversity.

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APPENDIX

Survey questionnaire

Background information of the respondent

Form No... Date...

Village.............................. District.......................... Shehia.................................

Sex................................... Age................................ Marital status......................

Level of Education

Non formal ☐

Primary ☐

Secondary ☐

Diploma ☐

Degree ☐

Occupation................................... Number of Children.................

Knowledge about honeybee

Do you know honeybee?

YES ☐

NO ☐

UNSURE ☐

If yes, how many types of honeybee do present in your surrounding?

Two ☐

Four ☐

More than four ☐

Do you benefit by having honeybee in your village?

YES ☐

NO ☐

If yes, describe the benefits you gain from honeybees

…………………………………………………………………………………………….

…………………………………………………………………………………………….

……………………………………………………………………………………………

Honeybee distribution

In your community, where are honeybees most abundant?

Forest ☐

Farm area ☐

Home garden ☐

Mangrove ☐

Others ☐

Mention other areas

....

……………………………………………………………………………………………

Why is honeybee abundance greater in the areas you have mentioned above?

……………………………………………………………………………………………

…………………………………………………………………………………………….

…………………………………………………………………………………………….

Socio-economic aspect of beekeeping

Do you any previous training about beekeeping

YES ☐

NO ☐

If yes where did you get knowledge?

Formal institution ☐

Short course ☐

Seminar ☐

Work shop ☐

Traditional knowledge from elders ☐

Which method of beekeeping do you use?

Modern beekeeping ☐

Traditional ☐

Both ☐

Mention the equipments you use in beekeeping?

…………………………………………………………………………………………….

…………………………………………………………………………………………….

…………………………………………………………………………………………….

How many hives do you have?

1 – 5 ☐

6 – 10 ☐

11 – 15 ☐

16 – 20 ☐

More than 20 ☐

Where did you get funds to initiate the beekeeping practice?

Own ☐

Donors ☐

Government ☐

NGOS/ CBOS ☐

What are the problems/challenges you face with your beekeeping practice?

……………………………………………………………………………………………

……………………………………………………………………………………………

Beekeeping and poverty reduction:

1. How many litres of honey do you harvest per hives?

Normal as expected ☐

Below expected amount ☐

More than expected ☐