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Effects of Land Use on Hymenoptera Pollinators Diversity in Zanzibar

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Abstract: ***This study analyses the effects of land use in Hymenopterans diversity in Unguja Island, Zanzibar. Hymenopterans were sampled in five forms of land-use. In each study site, four linear transects of 50m long were established, three pan traps and sweep-nets were used to capture Hymenopterans. A total of 734 Hymenopterans consisting of 60 species were sampled. Kruskal Wallis test shows that species richness and diversity differ significantly among different land-use. There was no difference in efficiency between nets and pan traps in assessing Hymenopterans diversity (p > 0.1). Home gardens showed higher species richness than other study sites. There was no significance difference in Hymenopterans species richness and diversity captured by traps. This study concludes that home garden and mixed farming attract more Hymenopterans species than natural forest. The study recommends the conservations of Hymenopterans should be by establishment of home gardens and mixed crops farming practices.***

Keywords: Hymenopterans, Landscape, Diversity, Pollination, Gardens, Vegetation

1. Introduction

Land-use change; it might be associated with change in floral resources and pollinators diversity [1]. Pollinator species richness and abundance is positively correlated with the proportion of natural or semi-natural habitats in the landscape [2]. Farming systems have a major influence on change Hymenoptera diversity and biodiversity in cities [3],[4]. Home gardens have been identified as playing a critical role in the preservation of honeybees, bumble bees, solitary bees, and some flies [5], [6]. Semi-natural area such as deciduous forest or semi-natural grassland seems an important variable influencing high pollinator species richness and/or abundance [7]. Insect biodiversity is threatened by loss of natural habitats due to agricultural intensification [8]. Natural habitats have greater plant diversity and more heterogeneous habitats for both generalist and specialist pollinators [9]. The loss of semi-natural habitat often favours the dominance of generalist species while decreasing specialized ones [10].

Hymenopterans pollinator insects provide important services to agriculture, including pollination of crops and pest control [6]. About 15% of flowering plants are pollinated by domestic bee species while at least 80% are pollinated by wild bee species and other wild animals [11]. Wasps on other hand play a major role as a predator in regulation of other insect populations [12], thus reducing the unnecessary applications of pesticides [13]. Wasps like a *Vespula* wasps has been shown to compete for forage resource [14]. Their competitive behaviour makes them a successful pollinator through increasing of pollination and fruit set [15]. The decline of Hymenopterans pollinators has become a global issue [16]. In the European Union (EU), the status of pollinator populations has been evaluated and 37-65%b of bee species is considered to be of conservation concern [17]. Habitats loss and fragmentation affect the accessibility of foraging and nesting resources of bee populations [16].

Human population densities are increasing, currently the population density of Zanzibar is 530 [18] while total population had increased from 981,754 [19] to 1,303,569 [20] 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 [21]. Healthy pollinator populations are necessary for food security. Thus, identifying what forms of land use support pollinator's diversity is important. Currently there are little information on the role of Hymenoptera abundance and species richness in Zanzibar. This study aimed to assess variation in distribution, abundance and diversity of Hymenoptera with land use in Zanzibar. The study focused on variation in Hymenoptera distribution, diversity and abundance among different forms of land use, namely agricultural crops, natural forest and mangrove habitats.

2. Material and methods

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. Major economic activities in the area are food crop agriculture, business, livestock keeping, apiculture and fishing. The mangrove vegetation 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. Flowering period October and November was observed

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 and includes a nursery for seedlings of various crops including oranges, mangoes and coconuts. 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 are few are employed in white-collar jobs.

Home garden
Kikungwi covers approximately 20ha of privately-owned land that supports a human population of 631[22]. It is a residential area where most of the land consists of home gardens. The economic activities include vegetable growing like eggplants (*Solanum melongena*), lady's fingers (*Abelmoschus esculentus*) and tomatoes (*Solanum lycopersicus*). Apiculture is a growing economic activity. Dominant trees in the area are mango (*Mangifera indica*), bananas (*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.

Natural forest
Jozani is about 35km from Zanzibar town with a total area of 5000ha and about 100 different plant species from 43 families [23]. The area was declared a national park in 2005. The major economic activity is tourism, attracting visitors to view a well-habituated population of the endemic Zanzibar red colobus monkeys (*Procolobus kirkii*) which are now confined to JCBNP, other economic activities around the area include agriculture, apiculture and office work. Approximately 1,101 people live around JCBNP [22]. The climate at JCBNP is hot and humid with mean annual temperatures varying between 21ºC and 32ºC. Mean annual rainfall is about 1860mm [23]. 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) [23]. The area receives rainfall almost throughout the year [24].

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

Mixed crops
Muungoni's land-use consists of mixed crop farming with trees like lemon (*Citrus limon*), mangoes (*Mangifera indica*), bananas (*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 (22).

2.1 Data Collection Methods

Quantitative approaches were used to assess bee species abundance, distribution and diversity in different land uses, compare the efficacy of netting and pan traps as capture methods for sampling bee communities, and 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 pests (25) and are now as considered an effective and standard technique for sampling Hymenopterans (26). Pan trap is the standard method used in capturing insects and has been shown to be the best technique in agricultural, semi natural land and tropical forest 1994(27)(28)(29). PT or water traps are plastic bowls painted with UV reflective paint. The bowls are then filled with water to which a small quantity of liquid soap is added during operation. The soap decreases surface tension causing insects to sink instead of floating to the surface of water and the colour attract the insects. 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 (30). 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 2020. 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 (31).

2.2 Data Analysis

Species diversity in each of the study sites was calculated using the Simpson Reciprocal Index I/D (32), where D was calculated as follows:

$$D = \Sigma p_i^2$$

Where p_i = the fractional abundance of the ith species for each transects 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 [33].

$$K = (N-1)\frac{\sum_{i=1}^{g} n_i(\bar{r}_{i\cdot} - \bar{r})^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(r_{ij} - \bar{r})^2},$$ 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 [34]. Calculations were performed using Program R (version 2.14.1;

3. Results

Variation in Hymenoptera distribution, diversity and abundance among different forms of land use

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 which was unique in this land use only.

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 χ^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). Species richness among four land-use forms did not differ (Fig. 3, KW $\chi2$ = 3.94, df = 3, p = 0.27). Hymenoptera species richness among four land-use forms where bees were captured by nets only did not differ (Fig. 4 KW $\chi2$ = 5.13, df = 3, p-value = 0.16) however, the average Hymenoptera species were higher at Jozani (Xmean = 4.2 ±10.5) and monoculture had a low average Hymenoptera species richness (Xmean = 2.9 ±6.5).

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 $\chi2$ = 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).

Species diversity by net only

Hymenoptera Species diversity among four land- use forms differed significantly from Hymenoptera samples captures by net (Fig. 7 KW $\chi2$ = 8.93, df = 3, p-value = 0.03). Pair wise comparisons of Hymenoptera diversity were done, Hymenoptera species diversity was higher in Jozani than monoculture (W = 15, p=0.057). There was also a higher Hymenopterans diversity in home gardens 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 gardens and Jozani (W = 12.5, p=0.2).

The efficacy of netting versus pans traps 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 gardens). The performance of these methods was tested a in these land uses. In total, 496 Hymenopterans species were captured, pan traps captured large number of Hymenoptera species (314) and 178 Hymenoptera species were captured by nets. A total of 48 Hymenopterans species were captured by both, nets and pan traps. Either, the total of Hymenoptera species captured by pan traps were 30 out of 13 species were exclusively captured by it. On the other the hand, total of Hymenopterans species captured by nets were 34, Hymenopterans species exclusively captured by nets were18. Moreover, the total number of 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 uses where nets and pan traps were used. It was found that there was a marginal difference in efficiency for assessing the Hymenoptera species richness between Hymenoptera species captured by nets (34) and pan traps (30). Pan traps captured a 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). Nets captured a significant higher diversity of

Hymenopterans than PT (Fig. 9). Diversity per transects was greater in nets (N = 12, T = 0, p < 0.025). There was no difference between nets and PT in species richness of Hymenopterans species captured (Fig. 10).

Hymenoptera species richness captured by three different pan traps colour

Hymenoptera species were sampled using pan traps of three different colours; blue, yellow and white. The performance of these pan traps colour was 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 a lower mean was captured by white pan traps Kruskal-Walli's rank sum test shows that Hymenopterans species richness among three colours did not differ (KW $\chi2$ = 1.11, df = 2, p-value = 0.57).

Table 1: Hymenopterans species captured in five land- uses from January to March 2020, 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 species 1*	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 species	0	0	2	0	0	2
	Halictus species 3	1	0	1	0	0	2
	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 species1*	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	O	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

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

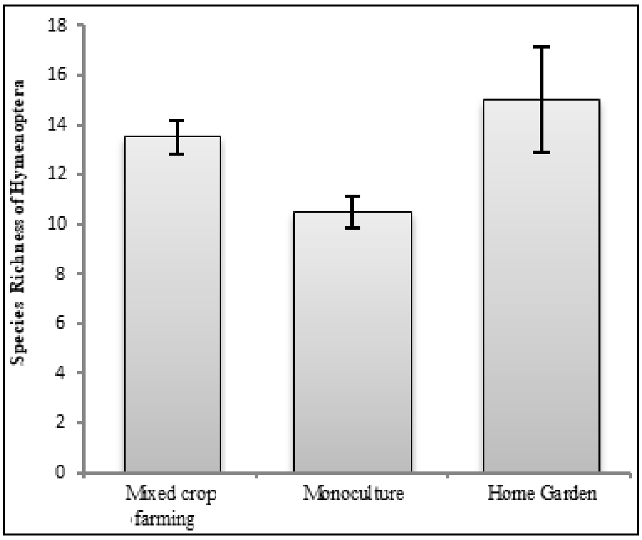

Figure 1: A comparison of Mean (±SE) Hymenoptera species richness among three different forms of land use in Unguja Island, Zanzibar from January – March 2020. Insects were captured using a combination of pan traps and nets

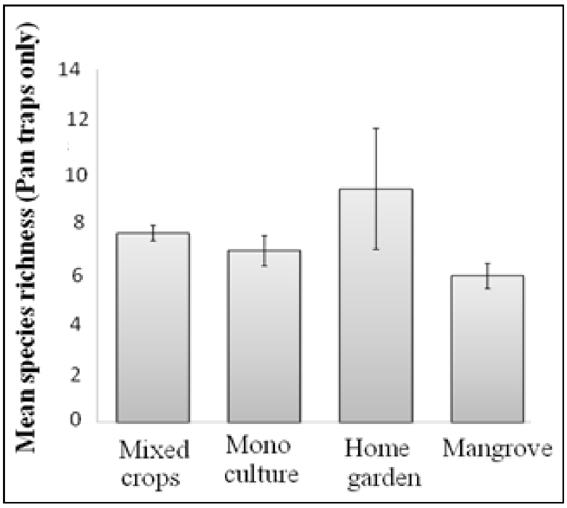

Figure 2 : A comparison of Mean (±SE) species richness in four study areas, Hymenoptera were captured by pan trap only at Muungoni (mixed farming), Bungi (monoculture) and Kikungwi (home garden) – Unguja Island, Zanzibar from January – March 2020.

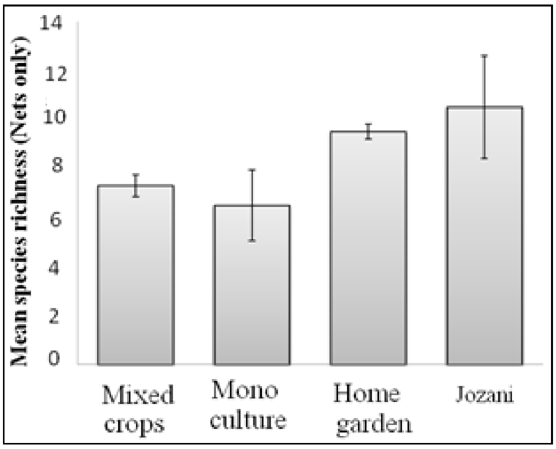

Figure 3: A comparison of mean (±SE) species richness among four land-use form, bees was captured by nets from January – March 2020, Unguja-Zanzibar

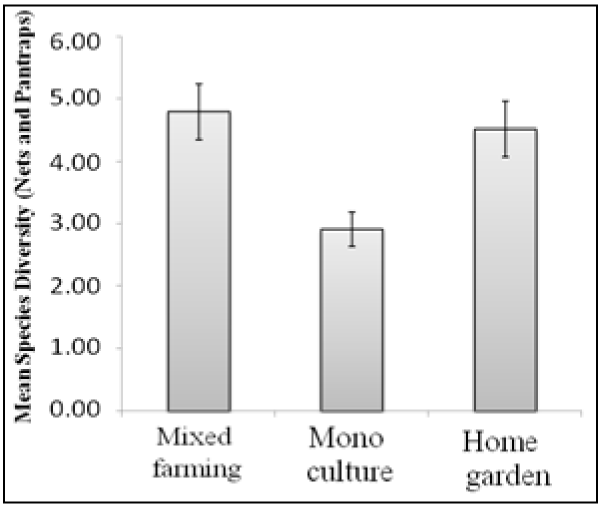

Figure 4: A comparison of Mean (±SE) species diversity among different types of land-use. Hymenoptera species were captured using nets and pan traps at Unguja, Zanzibar from January – March 2020.

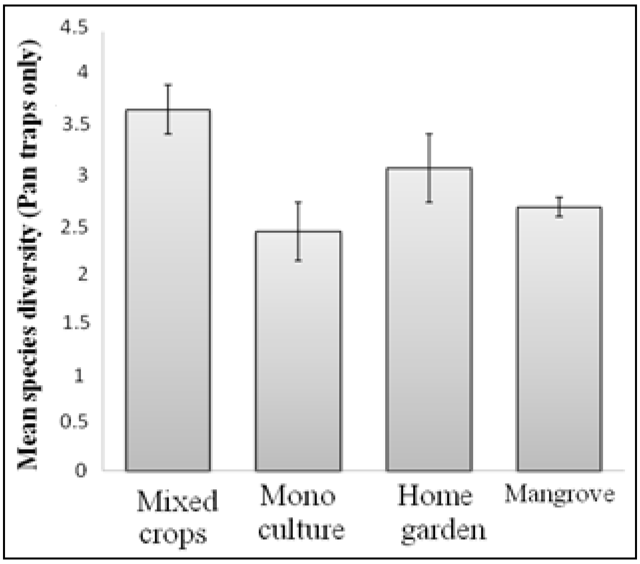

Figure 5: A comparison of mean (±SE) species diversity of Hymenoptera captured from different land-use. Samples were captured by pan traps of three different colour; blue, yellow and white January – March 2020, Unguja Island, Zanzibar.

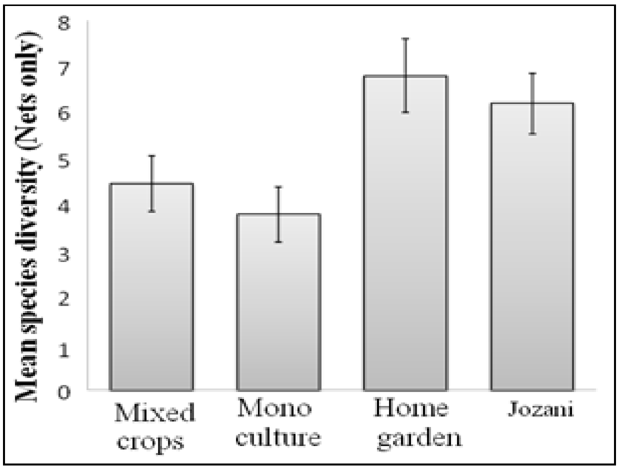

Figure 6: A comparison of mean (±SE) species diversity of Hymenoptera captured from different land-use, samples

were captured by net, January – March 2020, Unguja Island, Zanzibar

Table 2: A comparison of Hymenopterans species captured by nets and PT in three land use where both techniques were used. Hymenopterans were collected from January – march 2020, Unguja, Zanzibar

Family	Species	PT	NET	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
	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

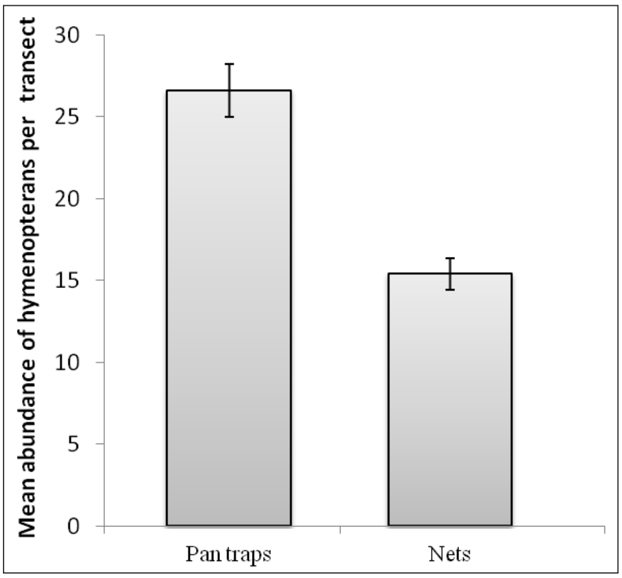

Figure 7: A comparison of mean abundance of Hymenoptera per transect in three land use, Hymenoptera were captured from January to March 2020, Unguja – Zanzibar

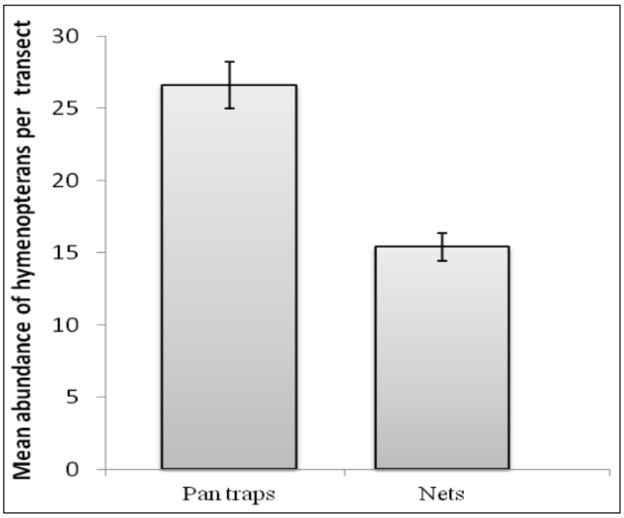

Figure 8: Comparison of mean abundance of Hymenoptera per transect in three land use, Hymenoptera were captured from January to March 2020, Unguja – Zanzibar

A 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 ($N = 12$, $T = 0$, $p < 0.025$).

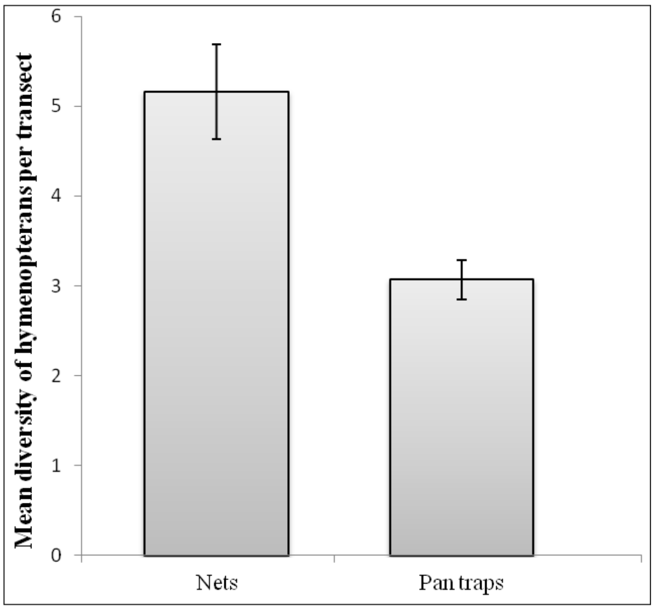

Figure 9: A mean diversity of Hymenopterans per transect collected by net and PT in three land use where both net and PT were used

A 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).

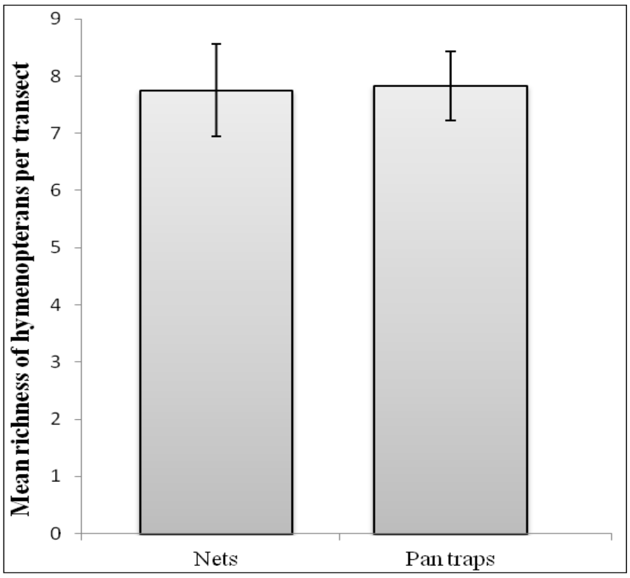

Figure 10: A comparison of mean richness of Hymenopterans species captured by nets and PT. A comparison of Hymenoptera abundance captured by nets and pan traps Pan traps captured significant higher abundance of Hymenopterans than nets (Fig. 8). Mean abundance per transect was greater in pan traps (N = 12, T = 0, $p < 0.05$)

4. Discussion

4.1 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 [(27)(35)(36)]. 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 [(37)]. Second, disturbance followed different succession stage, each succession stage contributes to increase species richness over time [(38)]. In Europe, for example, anthropogenic disturbance has replaced river flood plains creating early successional habitats used by many bee species [(39)]. Sunlight and the presence of a forest canopy is considered as another factor limiting Hymenoptera diversity, whereas open habitats positively influence Hymenoptera diversity [(40)] 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. Also, the garden had more wild/unmanaged vegetation, which might have provided sources of food and shelter for larva and pupa to develop [(41)]. 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.

4.2 The influence of land use

In agricultural landscapes, diversity of flower-visiting insects is 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 [(42)]. 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 [(43)] who recorded larger number of bee species in a small residential garden in Leicestershire, England. Additionally, [(29)(37)] reported higher pollinator abundance in agricultural areas than in natural areas. The results also correspond with [(44)] 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 [(45)], where some tropical butterfly abundance was higher in disturbed area. Sweet bees (*Lasioglossum* species) were higher in cucumber flowers in the urban garden [(46)].

4.3 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. Thus, caution should be used when developing generalizations about potential prejudices of different survey methods for bee fauna (47). The results correspond to other studies: more samples were collected in PT than in nets (47). The number of species captured by nets was significantly greater (47). 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 (48)(49). in both agricultural and semi-natural grassland. As in (50) Halictidae family was more captured in PT as by netting.

4.4 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 showed neutral response to pan trap colour as they are captured in all three colours 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 (51). 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 (52)(51)(47). In some studies, such as (53). blue PT attracted more bees and the remaining taxas preferred yellow. Preference of blue and white colour also was observed in Encyrtidae and Pompilidae (54). and in female *Andrena limnanthis* (55). In contrary, other study studies conducted by (56). found yellow PT was more efficient while (Wilson *et al.*, 2008) (57). found same number from yellow and blue. Wild bees captured more in yellow PT (58).; and *Limnanthis* bees were caught significant greater in number in yellow PT than in blue and white (59).

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