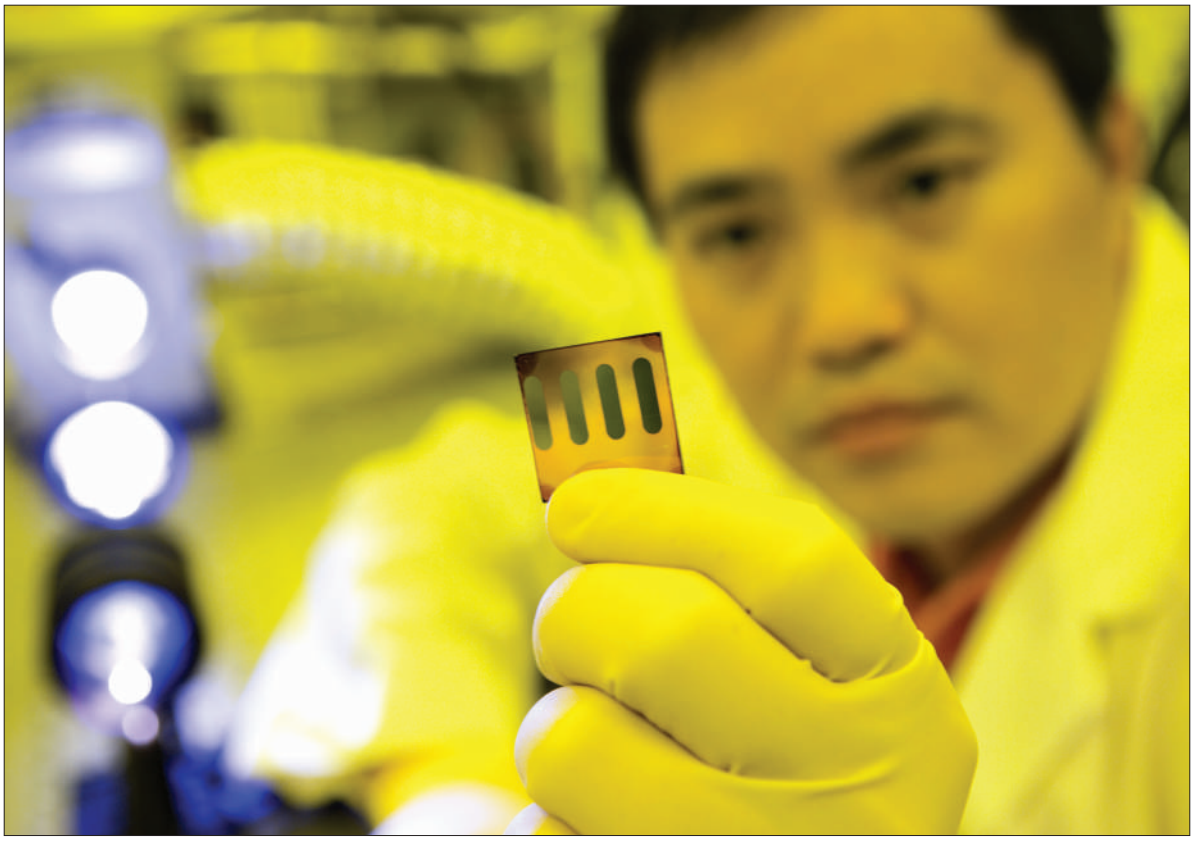

Singapore Journal of

Scientific Research

ISSN: 2010-006x

science alert

http://scialert.net/sjsr

OPEN ACCESS Singapore Journal of Scientific Research

ISSN 2010-006x
DOI: 10.3923/sjsres.2021.59.66

Research Article
Diversity of Butterflies with Respect to Habitat Types at Menagesha-Suba State Forest, Central Ethiopia

[1]Abaynew J.J. and [2]G. Emana

[1]Department of Plant Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University, P.O. Box 79, Bahir Dar, Ethiopia
[2]Department of Zoological Sciences, College of Natural Sciences; Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia

Abstract

Background and Objective: Butterflies are one of the largest and most important species components of biodiversity, which can be indicators of disturbance in any area. This study carried out with the objective to examine diversity of butterflies across habitats at Menagesha-Suba state forest from July, 2012 to June, 2014. **Materials and Methods:** It was investigated by the use of sweep nets along transects in three types of habitats i.e., grassland, natural forest and artificial forest. Samples were taken from one of the quadrant of each transect line in each habitat every month. Morphological characteristics were used to identify species. Data were analysed using diversity indexes such as Shannon-Wiener diversity, Simpson's index, Margalef's index, Pielou's evenness index and Sorensen's similarity index. **Results:** The natural forest had the greatest, while the artificial forest had the lowest species and individual. Shannon-Wiener diversity index, Simpson's diversity index as well as Margalef's richness index indicated that the natural forest had highest diversity while the artificial forest had the lowest diversity. Family Nymphalidae was the most dominant. The highest similarity of species was observed between grassland and natural forest habitats. **Conclusion:** By protecting the vegetation and water resources of the area, varied sub habitats of Menagesha-Suba state forest can supports good diversity of butterflies.

Key words: Butterflies diversity, diversity indices, habitats, species richness and abundance

Citation: Abaynew J.J. and G. Emana, 2021. Diversity of butterflies with respect to habitat types at Menagesha-Suba state forest, central Ethiopia. Singapore J. Sci. Res., 11: 59-66.

Corresponding Author: Abaynew Jemal Jenber, Department of Plant Sciences, College of Agriculture and Environmental Sciences, Bahir Dar University, P.O. Box 79, Bahir Dar, Ethiopia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Butterflies have been recognized as indicators of biodiversity. Their fragility makes them quick to react to change so their struggle to survive is a serious warning about our environment. The disappearance of these beautiful creatures is more serious than just a loss of colour in the countryside. As many butterflies are food bio-indicators of the environment, they can be used to identify ecologically important landscapes for conservation purposes and help to plan an appropriate management strategy to protect the habitats[1]. Diversity of butterflies in an area depends primarily on the availability of variable vegetation[2].

The degree of diversity of butterflies depends upon the adaptability of a species to a particular micro habitat. The dimension, population size and diversity of the species are most significant biological elements of an ecosystem. Species diversity sometimes enhances productivity and stability of ecosystems. Positive relationships have been found between butterfly diversity and plant diversity[3]. Holistic inventory of diversity requires nearly impossible levels of time and effort[4]. Insects are examples of these challenges. As a result insects remain undiscovered from conservation assessments. Historically, there have been less attention given to smaller animal taxa and until very recently, surveys have focused on large mammals[5]. As species are lost at an increasingly high rate from both outside and within protected areas, it becomes important to establish baseline data on species richness, abundances and distribution to which future surveys and conservation efforts can be related. Nonetheless, it is increasingly recognized that smaller species like insects are important for ecological and conservation monitoring because some are particularly sensitive to environmental pollution and changes in habitat structure through their close adaptation to the environment and because they embody the majority of the links in the community food chain[6,7]. Some tropical butterflies show changes in species composition in response to selective logging that would be unlikely to affect ungulates or carnivores to the same degree[8,9]. Butterflies can typically be sampled and identified in a short time and provide an indication of habitat or conservation value as well[10]. In an effort to provide baseline information on butterflies' diversity, this study was carried out on butterfly species richness and abundance at Menagesha-Suba state forest, place where no quantitative data on butterflies have been collected earlier. Therefore, this study was started with a view to examine the diversity of butterfly population across habitats.

Significance of the study: This study discovered the butterfly community changes in these mountainous habitats that can be beneficial for our whole environment, for wildlife and enrich the lives of people now and in the future. This study will help the researcher to uncover the critical areas of butterfly diversity that many researchers were not able to explore. The results of this study can provide baseline data for future study.

MATERIALS AND METHODS

Study site: The study was carried out at Menagesha-Suba state forest from July, 2012 to June, 2014 located at the coordinates of 38°33'59 E and 9°03'00 N, Ethiopia. The altitude ranges from 2200-3385 m above sea level. It has a bimodal rainfall pattern. It is one of the few remaining highland forest blocks in the Central plateau of Ethiopia, dominated by *Juniperus procera.* The structural diversity of the forest is minimal and is described as undifferentiated evergreen montane forest. The vegetation of the area varied with altitude, from high forest on the lower slopes to sub-afro-alpine vegetation at higher altitudes[11].

Sampling site: The study area was divided into the following habitat types: Natural forest, artificial forest and grassland. The study area was divided in to 10 transects, each of 0.1 km lengths, with ten quadrates having a size of 10×10 m, on each of them were marked through various habitats in the study area.

Sampling methods, butterfly collection and identification: All sampling were done once in a month for about 4-5 days. All quadrates were sampled within every hour between 10:00 and 14:00. According to Holl[12], this is the period within which most butterfly species are probably active.

Samples were taken from one of the quadrant of each transect line in each vegetation type in every month from the study areas. Butterflies samples were collected with 0.38 diameter sweep net constructed of muslin with fin mesh net at the tip. Each sweep represents a horizontal swing with an arc of approximately 135° and height between 0.5-2.00 m above the ground. These specimens were killed by pinching their thorax by taking proper care or by killing the small specimen using ethyl acetate and finally placed in paper envelop.

The collected butterflies were identified using identification key at the species level with the help of available literatures such as[13-15]. Besides, books, different drawings of butterflies, datasheet, specimens of butterflies in Addis Ababa University museums were used as a means of identifications tools. When identifying and describing butterfly taxon, morphological characteristics were used to separate species.

Data analysis: The diversity index was calculated by using the Shannon-Wiener diversity index[16]:

$$\text{Diversity index} = H = -\sum Pi \ In \ Pi$$

Where:

$$Pi = \frac{S}{N}$$

S = Number of individuals of one species
N = Total number of all individuals in the sample

Simpson's index (D): It measures the probability that two individuals randomly selected from a sample will belong to the same species. Simpson index[17] was computed for each of the sites. Simpson's index is expressed as:

$$D = \Sigma = \frac{ni\ (ni-1)}{N\ (N-1)}$$

Where:
N = Total number of individuals encountered
ni = Number of individuals of ith species
D = Subtracted from 1 to give Simpson's index of diversity,1-D

The value of this index ranges between zero and one, the greater the value, the greater the sample diversity. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species.

Measurement of species richness: In this study, the total number of butterfly species collected in each habitat was considered as species richness. Margalef's index was used as a simple measure of species richness[18] which is expressed as:

$$\text{Margalef's index } R = \frac{(S-1)}{In\ N}$$

Where:
S = Total number of species
N = Total number of individuals in the sample

Measurement of evenness: For calculating the evenness of species, the Pielou's evenness index (e) was used[19]:

$$e = \frac{(H)}{In\ S}$$

where:
H = Shannon-Wiener diversity index
S = Total number of species in the sample

Sorensen's similarity index: Sorensen's similarity index was used to measure butterfly species compositional similarity and/or variation between habitats. Sorensen's index[19] is expressed as:

$$SI = \left(\frac{a}{a+b+c}\right) \times 100$$

Where:
a = Number of species present in both sites
b = Number of species present in site 1 but absent in site 2
c = Number of species present in site 2 but absent in site 1

RESULTS

Butterfly composition: Five butterfly families such as Papilionidae, Pieridae, Lycaenidae, Nymphalidae and Hesperidae were recorded at Menagesha-Suba state forest during the study period. These families phylogenetically break down in to 29 genera and 59 species (Table 1). Nymphalidae had the highest number of species comprising 26 numbers of species and 11 genera, which accounts 44.07% of the total number of species of the study area. Nymphalidae was followed by Pieridae, which contained 12 species and 6 genera. This accounts 20.34% of the total species. The 3rd largest family was Papilionidae with 9 numbers of species grouped in 2 genera accounts 15.25% from all the species recorded in the study area. Then, it was followed by Lycaenidae comprising 7 species and 6 genera, which accounts 11.86% of the species collected from Menagesha-Suba state forest. The remaining 5 number of species and

Table 1: Taxonomic profile of menagesha-suba state forest butterflies

Family	Genera	Species	Composition (%)
Papilionidae	2	9	15.25
Pieridae	6	12	20.34
Lycaenidae	6	7	11.86
Nymphalidae	11	26	44.07
Hesperidae	4	5	8.47
Total	29	59	99.99

4 genera were belongs to the family Hesperidae which accounts 8.47% of the species recorded in the study (Table 1). Therefore, family Nymphalidae was the most frequently collected family compared to Hesperidae, which was less collected.

Species richness and abundance: A total of 59 species and 936 individuals of butterflies belonging to 29 genera and 5 families were recorded from Menagesha-Suba state forest during the study period (Table 1).

The most abundant species was *Graphium colonna* (Ward), which accounted 2.56% of all individuals recorded at Menagesha-Suba State Forest. The other abundant species were *Graphium leonidas* (Fabricius), *Charaxes castor* (Cramer) and *Bicyclus anynana* (Butler) which composed of 2.46% (each species), followed by *Phalanta phalantha* (Rothschild and Jordan), *Appias epaphia* (Butler), *Papilio constantinus* (Ward) and *Papilio dardanus* (Oberthür) which accounted about 2.24%, each of the species. The species represented by less than ten individuals were seven (5.95% of all individuals), while most of the species (44 species) yielded 11-20 butterfly individuals which are about 74.99% from all species recorded. Species represented by more than 20 individuals were eight (19.06% of all species) (Table 2).

Out of the 59 species, ten species were recorded (16.95%) only from the natural forest; seven species (11.86%) were recorded from the grassland habitat. Another thirteen species (22.03%) were common to all of the habitats. Notably, no habitat contained all of the 59 species that were in the census list (Table 2).

Butterfly species abundance in different habitats: The natural forest appears to support the greater number of species and individuals that composed of 52 numbers of species and 558 individuals of butterflies. The most abundant species along the natural forest area were *Charaxes etheocles* (van Someren and Jackson), *Deudorix dinochares* (Grose-Smith), *Precis coelestina* (Dewitz), *Vanessa abyssinica* (Felder and Felder), *Tirumala Formosa* (Rothschild), *Mylothris yulei* (Ungemach), *Appias Sabina* (Felder and Felder), *Appias epaphia* (Butler), *Papilio dardanus* (Oberthür), *Graphium colonna* (Ward), *Charaxes castor* (Cramer), *Charaxes varanes* (Mabille) and *Charaxes phoebus* (Butler). They make up about 35.1% of all butterflies found in the natural forest habitat.

The artificial forest shows the least species diversity and abundance with 21 numbers of species and 93 butterflies. The most abundant species in the artificial forest butterflies.

Table 2: Butterfly population at different habitats of menagesha-suba state forest

	Number of individuals		
Species	Grassland	Natural forest	Artificial forest
Papilio nireus	6	8	3
Papilio rex	2	6	0
Papilio dardanus	7	14	0
Papilio constantinus	6	12	3
Papilio microps	0	5	0
Papilio echerioides	0	10	4
Graphium leonidas	11	12	0
Graphium antheus	0	11	8
Graphium colonna	10	14	0
Colotis agoye	15	5	0
Colias electo	18	0	0
Colotis danae	11	6	0
Appias epaphia	0	15	6
Appias sabina	0	15	0
Appias sylvia	0	12	0
Belenois raffrayi	4	10	0
Mylothris agathina	3	11	0
Mylothris yulei	4	15	0
Mylothris sagala	2	13	0
Mylothris rueppellii	4	13	0
Dixeia orbona	8	0	0
Leptomyrina boschi	9	7	4
Deudorix dinochares	0	17	0
Uranothauma antinorii	2	8	0
Uranothauma nubifer	5	8	0
Cupidopsis jobates	8	5	0
Cacyreus tespis	4	6	3
Eicochrysops messapus	11	0	0
Acraea bonasia	0	8	10
Acraea insignis	0	12	2
Acraea johnstoni	0	11	5
Acraea necoda	6	10	3
Acraea pharsalus	4	7	0
Acraea safie	4	9	3
Eurytela hiarbas	6	13	0
Hypolimnas misippus	4	10	3
Hypolimnas salmacis	0	10	7
Precis coelestina	0	16	0
Vanessa abyssinica	0	16	0
Vanessa dimorphica	0	12	0
Charaxes etesipe	6	8	0
Charaxes castor	6	14	3
Charaxes varanes	4	14	0
Charaxes etheocles	0	17	0
Charaxes phoebus	0	14	0
Bicyclus vulgaris	3	11	6
Bicyclus anynana	16	4	3
Bicyclus sandace	6	4	5
Ypthima pupillaris	9	0	0
Ypthima yatta	10	0	0
Ypthima simplicia	12	0	0
Amauris niavius	0	12	6
Tirumala formosa	0	15	0
Phalanta phalantha	16	5	0
Coeliades keithloa	3	12	0
Eagris nottoana	4	13	3
Sarangesa motozi	6	10	3
Coeliades anchises	4	13	0
Eretis mixta	6	0	0
Total	285	558	93

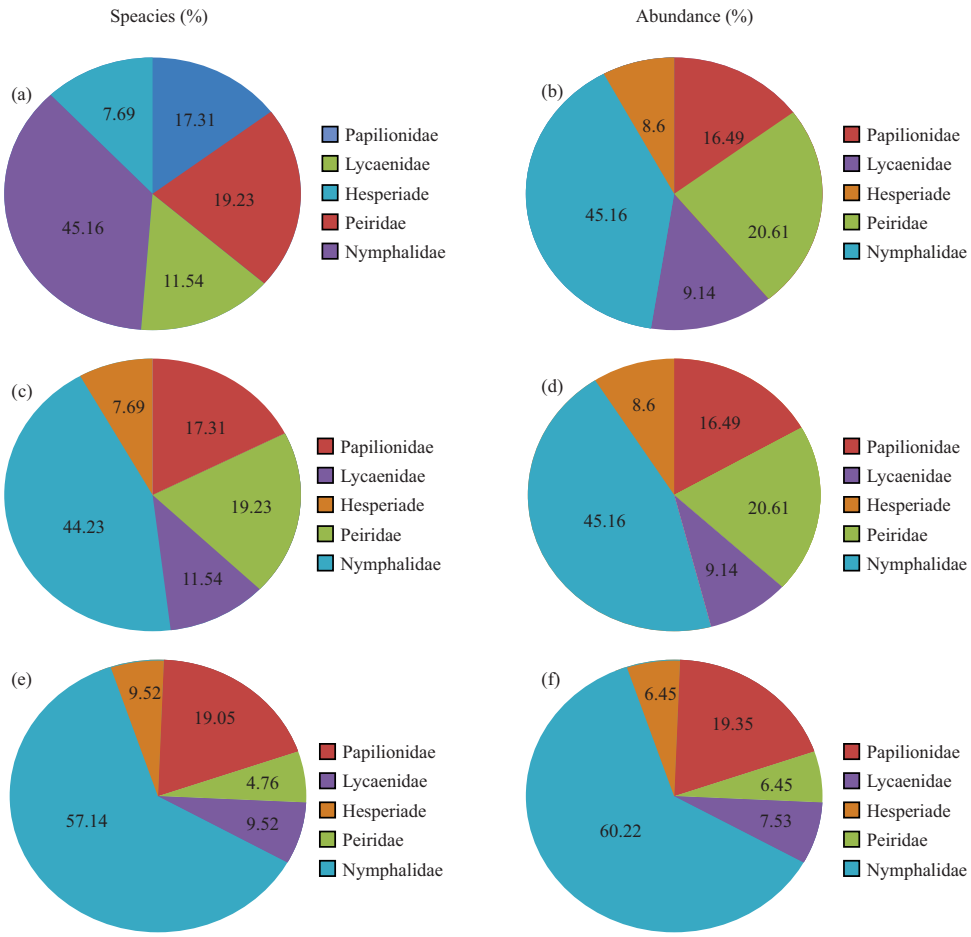

Fig. 1: Butterfly species and abundance by families at different habitats of menagesha-sub a state forest, (a) Grassland, (b) Natural forest and (c) Artificial forest

The most abundant species in the artificial forest habitat were *Acraea bonasia* (Eltringham), *Graphium antheus* (Cramer), *Hypolimnas salmacis* (Rothschild and Jordan), *Appias epaphia* (Butler), *Bicyclus vulgaris* (Butler) and *Amauris niavius* (Rothschild and Jordan). These species composed about 46.18% of all individuals recorded in the artificial forest (Table 2).

The grassland yields more number of species and individuals than the artificial forests, which is 41 species and 285 individuals of butterfly. The most abundant species in these habitats were *Colias electo* (Berger), *Bicyclus anynana* (Butler), *Phalanta phalantha* (Rothschild and Jordan), *Colotis agoye* (Marshall) and *Ypthima simplicia* (Butler) which account about 27.1% of all individuals encountered in the grassland habitat (Table 2).

From all recorded individuals in the three different habitats: the natural forest area had the highest number of individuals of butterflies, which is 558 followed by grassland with 285 individuals of butterflies and artificial forest had 93 individuals of butterflies. Therefore, maximum abundance within the habitats was recorded in natural forest followed by grassland and artificial forest.

Distribution of butterflies species and abundance among butterfly families at different habitats: The distribution of butterfly species and abundance among butterfly families in various habitats is shown in Fig. 1. In terms of families, Nymphalidae constituted the highest percentage of individuals in the artificial forest followed by Papilionidae, 60.22 and 19.35%, respectively. In the natural forest the Nymphalidae accounted the highest percentage 45.16% followed by Pieridae, which is 20.61%, While in the grassland the Nymphalidae were the most commonly found family comprising 39.3% followed by Pieridae, which is 24.21%. The family Nymphalidae had the highest number of species in all of the three habitats, while Hesperidae had the least number of species in the grassland and natural forest. Pieridae had the least number of species in the artificial forest.

Table 3: Butterfly diversity at different habitats of menagesha-suba state forest

Habitats	Species number	Spp. richness index, R	Simpson's diversity index 1-D	Evenness index e	Diversity index H'
Grassland	41	7.07	0.88	0.94	3.5
Natural forest	52	8.06	0.96	0.97	3.83
Artificial forest	21	4.41	0.78	0.96	2.92

Table 4: Sorensen's similarity indices for the different sites at Menagesha-Suba state forest

	Grassland	Natural forest	Artificial forest
Grassland		57.63	26.53
Natural forest	57.63		40.38
Artificial forest	26.53	40.38	

Butterfly diversity indices: The diversity parameters of butterflies showed variations in the three sampling habitats. In general, the three sampling habitats showed high species richness and diversity of butterflies and high evenness of distribution. The species richness index of butterfly communities is the highest at the natural forest and the least at the artificial forest, which are 8.06 and 4.41, respectively. The evenness indexes of butterfly communities are similar, 0.97 in the natural forest, 0.96 in the artificial forest and 0.94 is in the grassland habitat. The highest diversity index of butterfly communities is at the natural forest, which is 3.83, while the lowest diversity index is at the artificial forest habitat that is 2.92. Simpson's diversity index also indicated more butterfly species diversity in the natural forest followed by the grassland habitat and the less butterfly species diversity in the artificial forest (Table 3).

Butterfly species similarity between habitats: The level of similarity between each pair in terms of their butterfly species composition was generally below 58%. The highest similarity (57.63%) was observed between grassland and natural forest, followed by natural forest and artificial forest (40.38%), while the least similarity (26.53%) was observed between Grassland and Artificial forest (Table 4).

DISCUSSIONS

This is the first study on the diversity of butterflies in area. The diversity indices H for the natural forest, artificial forest and grasslands were 3.83, 2.92 and 3.5, respectively (Table 3). The level of species similarity between habitats was generally low. The highest similarity index 57.63 was recorded between grassland and natural forest habitats. Family Nymphalidae was richest in terms of abundance as well as species richness in all the habitats. High diversity and evenness was recorded in the natural forest habitat. This can be due to stability and easily availability of larval food. This result is in agreement with that of Sreekumar and Balakrishnan[20] where the prevalence of butterfly species at a particular habitat depends on a wide range of factors, of which the availability food is the most important ones. The lowest diversity index at the artificial forest habitats, which is 2.92, was due to the artificial forest habitats were highly exposed to fuel wood collection that affected diversity.

The highest species richness in the natural forest area could be because of higher diversity of plant species, restriction of human induced activities and fragment area. Because of the diverse nature of plant species in the forests, insects are more attracted to plant species for the forging purpose that could result in richness and abundance[21].

In general, butterfly species are found with the highest diversity in areas containing large amount of host plants and butterfly diversity at local or regional scales are also closely related to their host plant density. Such an intimate association between butterflies and their respective plants points towards the nature of vegetation being an important factor in determining the dependence and survival of a species in a particular habitat[22].

Habitat specificity of butterflies can be directly related to the availability of food plants[23]. Each habitat has a specific set of microenvironment suitable for a species. For example, species such as *Appias epaphia*, *Papilio demodocus*, *Deudorix dinochares* and *Charaxes etheocles* were collected only in the natural forests and species like *Colias electo*, *Ypthima simplicia* and *Eicochrysops messapus* were recorded only from the grassland habitats of Menagesha-Suba state forest. However, about 22% of the species recorded were not habitat specific, i.e. they occur in all of the three habitats. Such general occurrence would help them to have a wider distribution and to maintain larger population size.

The level of species similarity between habitats was generally low. The highest similarity index, which is 57.63, was recorded between grassland and natural forest habitats while; the least similarity 26.53 was recorded between the habitats grassland and artificial forest. The low species similarity recorded between habitats can be due to habitat specificity of butterflies for food plants. In addition, habitat fragmentation, ecosystem loss and separation account for the low species similarity and are noticed as the main causes of the current biodiversity problems[24]. Debinski and Holt[25] also observed that habitat fragmentation reduces area, changes ecological processes and reduces connectivity. Perrins *et al.*[26] equally

asserted that the distribution of any species is restricted by the distribution of its habitat and within that habitat the availability of food and other resources.

Local people searching for fuel wood had almost removed the grass cover in the artificial forest. On the other hand, the natural forest was relatively far from human activities that helped it to retain its grass cover. Therefore, the grassland and natural forest habitats shared the same vegetation (grass) and thus shared phytophagus insects like butterflies. This can be the reason for the high similarity of species between grassland and natural forest habitats at Menagesha-Suba state forest.

In the butterfly diversity of Menagesha-Suba state forest, out of the 5 butterfly families recorded, Nymphalidae was richest in terms of abundance as well as species richness. It was the dominant family at the grassland, natural forest and artificial forest habitats. The dominance of Nymphalidae can be due to the polyphagous habit that helps them to live in all habitats, which comprise the largest family of butterflies[27].

The pieridae were the second family in abundance and species richness at Menagesha-Suba state forest. Pieridae are sun lovers seen basking in sun with wings partially open[28]. Study by Tiple and Khurad[29] in the Gir protected area indicated that pierids were observed to be the most common family in the dense forest vegetation. Menagesha-Suba state forest, which is a forest ecosystem with gaps where sunlight can penetrate easily, the abundance of Pieridae, was good.

Papilionidae were the dominant family next to Nymphalidae and Pieridae because they prefer tall trees providing moderate sunlight[30]. This type of habitat is present at Menagesha-Suba state forest where major vegetation is composed of large woody trees such as *Juniperus procera* and *Olea africana*.

Family Lycaenidae, their species richness and abundance was comparatively low at Menagesha-Suba state forest. Although low in species richness and abundance, the moderate presence of Lycaenidae can be due to the presence of some species that were common in the area such as *Leptomyrina boschi* (Strand) and *Deudorix dinochares* (Grose-Smith).

Family Hesperiidae was represented by only 5 species with low species richness and abundance. Their general flight period is early morning hours at dawn and dusk whereas the present study was conducted during daytime and hence low abundance and diversity of Hesperidae[28].

Butterfly gardens are the gateways to protect the butterfly population. Therefore, it should be established in the study area. Monitoring programs that are based on genus-level identifications would provide information for identifying potential hotspots to evaluate the changes over time and may therefore have considerable conservation relevance. Since people inhabit the area, conservation could be achieved through the involvement of the local community for better diversity of butterflies.

The flight period of Hesperidae is early morning and dusk whereas the present study was conducted during daytime and hence low abundance and diversity. This can be the limitation of the study. Hence, Family Hesperiidae should be studied in detail in the future.

CONCLUSION

A total of 29 genera comprising 59 species belonging to 5 families were collected. Shannon-Wiener, Simpson's diversity as well as the Margalef's indexes indicated that the natural forest had highest while the artificial forest had the lowest diversity. This is probably due to the destruction of host plant in the artificial forest and human disturbance. Low species similarities between each pair of habitats were indicated.

ACKNOWLEDGMENTS

We are grateful to Addis Ababa University, Department of Zoological Sciences, for Laboratory and other provisions. We would like to thank Menagesha-Suba state forest to host the field research and for their technical support in the fieldwork. Field assistants and local people who supported the field study are also acknowledging.

REFERENCES

1. Sergio, F., L. Marchesi and P. Pedrini, 2004. Integrating individual habitat choices and regional distribution of a biodiversity indicator and top predator. J. Biogeogr., 31: 619-628.
2. Hamer, K.C., J.K. Hill, L.A. Lace and A.M. Langan, 1997. Ecological and biogeographical effects of forest disturbance on tropical butterflies of sumba, Indonesia. J. Biogeogr., 24: 67-75.
3. Tilman, D., D. Wedin and J. Knops, 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature, 379: 718-720.
4. Lawton, J.H., D.E. Bignell, B. Bolton, G.F. Bloemers and P. Eggleton *et al.*, 1998. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. Nature, 391: 72-76.
5. Caro, T.M., N. Pelkey, M. Borner, K.L.I. Campbell and B.L. Wood worth *et al.*, 1998. Consequences of different forms of conservation for large mammals in Tanzania: Preliminary analyses. Afr. J. Ecol., 36: 303-320.

6. McGeoch, M.A., 1998. The selection, testing and application of terrestrial insects as bioindicators. Biol. Rev. Cambridge Philos. Soc., 73: 181-201.
7. Nally, R.M., E. Fleishman, L.P. Bulluck and C.J. Betrus, 2004. Comparative influence of spatial scale on beta diversity within regional assemblages of birds and butterflies. J. Biogeogr., 31: 917-929.
8. Daily, G.C. and P.R. Ehrlich, 1995. Preservation of biodiversity in small rain-forest patches: Rapid evaluations using butterfly trapping. Biodivers. Conserv., 4: 35-55.
9. Hamer, K.C., J.K. Hill, S. Benedick, N. Mustaffa, T.N. Sherratt, M. Maryati and V.K. Chey, 2003. Ecology of butterflies in natural and selectively logged forests of northern Borneo: The importance of habitat heterogeneity. J. Applied Ecol., 40: 150-162.
10. Brown, K.S., 1997. Diversity, disturbance and sustainable use of Neotropical forests: Insects as indicators for conservation monitoring. J. Insect Conserv., 1: 25-42.
11. Teketay, D., 2001. Deforestation, wood famine and environmental degradation in Ethiopia's highland ecosystems: Urgent need for action. Northeast Afr. Stud., 89: 53-76.
12. Holl, K.D., 1996. The effect of coal surface mine reclamation on diurnal lepidopteran conservation. J. Appl. Ecol., 33: 225-236.
13. Williams, J.G., 1969. A Field Guide to the Butterflies of Africa. Viking Pr, United Kingdom, ISBN-13: 9780002110921, Pages: 238.
14. Carcasson, R.H., 1975. The Swallowtail Butterflies of East Africa (Lepidoptera, Papilionidae). Vol. 6. East Africa Natural History Society, United States, Pages: 31.
15. D'Abrera, B., 1997. Butterflies of the Afrotropical Region, Part 1. 2nd Edn., Hill House Publishers, United States, ISBN-13: 9780947352349, Pages: 263.
16. Shannon, C.E. and W. Weaver, 1949. The Mathematical Theory of Communication. 1st Edn., University of Illinois Press, Urbana, IL., ISBN-10: 0252725484, Pages: 117.
17. Simpson, E.H., 1949. Measurement of diversity. Nature, 163: 688-688.
18. Magurran, A.E., 1988. Ecological Diversity and its Measurements. 1st Edn., Princeton University Press, Princeton, New Jersey, ISBN: 978-94-015-7358-0, Pages: 179.
19. Pielou, E.C., 1969. An Introduction to Mathematical Ecology. 1st Edn., Wiley-Interscience, New York, USA, ISBN: 0-471-68918-1, Pages: 286.
20. Sreekumar, P.G. and M. Balakrishnan, 2001. Diversity and habitat preferences of butterflies in Neyyar wildlife sanctuary, South India. Entomon, 26: 11-22.
21. FAO, 2001. Global Forest Resource Assessment 2000. Main Report. FAO Forestry Paper 140. Food and Agriculture Organization of the United Nation, Rome, Italy, Pages: 479.
22. Krauss, J., I. Steffan-Dewenter and T. Tscharntke, 2003. How does landscape context contribute to effects of habitat fragmentation on diversity and population density of butterflies? J. Biogeogr., 30: 889-900.
23. Thomas, J.A., 1995. The ecology and conservation of *Maculinea arion* and other European species of large blue butterfly. Ecol. Conserv. Butterflies, 19: 180-197.
24. Sih, A., B.G. Jonsson and G. Luikart, 2000. Habitat loss: Ecological, evolutionary and genetic consequences. Trends Ecol. Evol., 15: 132-134.
25. Debinski, D.M. and R.D. Holt, 2000. A survey and overview of habitat fragmentation experiments. Conserv. Biol., 14: 342-355.
26. Perrins, C.M., J.D. Lebreton and G.J.M. Hirons, 1991. Bird Population Studies: Relevance to Conservation and Management. Oxford University Press, United States, ISBN-13: 9780198577300, Pages: 650.
27. Sreekumar, P.G. and M. Balakrishnan, 2001. Habitat and altitude preferences of butterflies in Aralam wildlife sanctuary, Kerala. Trop. Ecol., 42: 277-281.
28. Kehimkar, I., 2008. The Book of Indian Butterflies. 1st Edn., Oxford University Press, India, ISBN: 9780195696202, Pages: 497.
29. Tiple, A. D. and Khurad, A. M. 2009. Butterfly species diversity, habitats and seasonal distribution in and around Nagpur city, central India. World J. Zool., 4: 153-162.
30. Mathew, G. and M. Anto, 2007. *In situ* conservation of butterflies through establishment of butterfly gardens: A case study at Peechi, Kerala, India. Curr. Sci., 93: 337-347.