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Studies on butterflies' diversity in relation to habitats and seasons at Gulele Botanical Garden in Central Ethiopia: implication of protected area for in-situ conservation of biological entity

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ABSTRACT: Butterflies are the most important biodiversity components, which are under different threats including climate change that varies with habitat type and seasons. Intra-annual variation in temperature (i.e. seasonality) can have important implications for thermal tolerance, which affect climate change vulnerability. Habitat type can additionally influence a population's capacity to respond to climatic change. As Gullele Botanical garden is home of small animals like butterflies owing to its different habitats in different seasons, studying the diversity of these useful group of organism is vital. The study was conducted from July 2012 to June 2014. Butterfly diversity was investigated using sweep nets along transects (500 m x 300 m) in three types of habitats: natural forest, artificial forest and Grassland. Data were analyzed using Xcel Software, Tukey's HSD test and diversity indexes. Maximum abundance (162) and species richness (26) was recorded in grassland followed by natural forest though they are not statistically different (p>0.05). Butterflies evenly distributed in the three habitats (P>0.05). The highest Shannon diversity index was at the grassland (H=3.09) followed by the natural forest (H=3.02). The species richness index was the highest (R=4.91) in the grassland and the least (R=3.79) in the artificial forest. Simpson's diversity index indicated higher butterfly species diversity in the natural forest (D=0.92) and grassland habitat (D=0.96). Members of the family Lycaenidae were the most dominant (28.5%) and Hesperidae (8.03%) was the least. There was a significance difference (P<0.05) among seasons. Multiple comparisons of Tukey HSD test showed that there was a significant (P<0.05) difference between autumn and winter. Species richness showed the maximum (R=6.06) record in autumn and minimum (R=4.10) in winter. Shannon diversity index showed higher diversity (H=3.396) in autumn. Among families, Lycaenidae had high values in autumn (H=1.09) and spring (H=1.03), while Nymphalidae and Pieridae had high values during winter (H=0.952) and summer (H=0.980), respectively. Hesperiidae had the highest value (H=0.32) in autumn and the lowest (H=0.00) in winter. In Artificial forest *Hypolimnas salmacis* (Rothschild & Jordan), *Bicyclus campus* (Karsch) and *Euchrysops albistriata* (Capronnier) were abundantly found. *Deudorix dinochares* (Grose-Smith) and *Papilio echerioides* (Trimen,) were species specific to the natural forest habitat. The most abundant species in the grassland were *Eicochrysops messapus* (Wallengren), *Colias electo* (Berger) and *Danaus chrysippus* (L.).

Key words/Phrases: Butterflies, Diversity Indices, Habitats, Season, Species richness and abundance

INTRODUCTION

As species are lost at an increasingly rate both in protected and non-protected areas, it is paramount importance to establish baseline data on species richness, abundances and distribution on which future surveys and conservation efforts can be based. It is increasingly recognized that smaller species like insects are important for ecological health monitoring because some of them are indicators of environmental pollution, changes in habitat structure and variations in season among other things (Tesfu et al, 2019). Insects are also embodying the majority of the links in the community food web (MacNally *et al*., 2004).

Intra-annual variation in temperature (i.e. seasonality) can have important implications for thermal tolerance, but thermal variation over other time scales and variation over spatial gradients also affect climate change vulnerability (Bonbrake et al., 2010). Habitat and behavioral actors can additionally influence a population's capacity to respond to climatic change at a regional, landscape

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or microclimatic scale (Sunday et al., 2014). For example, Huey et al. (2009) showed that tropical forest lizards living in relatively homogeneous shaded habitats may be highly vulnerable to warming, while Logan et al. (2009) using finer-spatial-scale thermal data, argued that forest lizards might not be so vulnerable due to high (and underestimated) spatial variance in temperature. Behavioral thermoregulation (e.g. shade-seeking) can also affect a species response to climate change (Knowlton and Grham, 2010). Species interactions are critical such that extinction or distribution change of one species could result in the extinction of other members of that species interaction network (Urban et al., 2012).

A botanical garden is a garden dedicated to the collection, cultivation, preservation and display of a wide range of plants labelled with their botanical names (Ensermu Kelebesa, 2005). The main goal of botanical garden is for conservation of plants and other living organisms associated to plants such as insects including butterflies (Tesfu *et al*., 2019). Gulelle Botanical garden is a recently established botanical garden mainly for the purpose of conservation of the endangered plants and other living things associated to it. Previously, Gulele was unprotected area exposed to human exploitation of all the resources, but now highly protected which may have positive impact on living organisms like butterflies. Though there is no data for comparison in the pre-Gulele Botanical garden, it can be assumed that the Botanical Garden created a favourable ecological niche for the insect.

Some tropical butterflies show changes in species composition in response to selective logging (Hamer *et al*., 2003) that would be unlikely to affect ungulates or carnivores to the same degree. Many species of butterflies are strictly seasonal and prefers only a particular set of habitat. Tesfu *et al*. (2019) reported the existence of 48 families in the order Lepidoptera in Ethiopia. According to them about 350 species of butterflies which is 10% of the moths were reported from Ethiopia. Butterflies have been generally neglected and there are very few studies available on their community structures, population dynamics and the eco-climatic factors which affect them (Tesfu *et al*., 2019).

Therefore, the current study was conducted to see the diversity of butterflies in terms of species richness and abundance in relation to different habitats and seasons at Gullele Botanical Garden.

Materials and Methods

Description of the study area

Gullele Botanical Garden is a newly established *in-situ* conservation initiative located at the northwestern part of Addis Ababa city which shares its vegetation zone and climatic characteristics with adjacent part of Oromia National Regional State (Figure 1). The geographical co-ordinate of the garden lies between latitude 80 55' N and 90 05' N and longitudes 380 05' E and 390 05' E. It covers a total area of 936 ha. The northern half is a plain land whereas the southern half is mountainous with a maximum elevation of 2,960 m. a. s. l. (Ensermu Kelbessa, 2005). The mean annual temperature is about 13.9°C. The mean annual rainfall is 1215.4 mm. It is mostly covered by *Eucalyptus globules* Labill (1832) tree species, but the land closer to the river banks and inaccessible areas are covered by many plant species such as *Juniperus procera* Hochst (1847), *Olinia rechetiana* A. Juss (1846), *Myrsine melanophloeos* (L., 1758), *Myrsine africana* L. (1758) and Erica arborea L. (1758). The major threat to the garden is the population growth rate of Addis Ababa which is very fast. The massive population of the city requires basic need such as housing and employment which have negative impact on conservation role of the Botanical Garden.

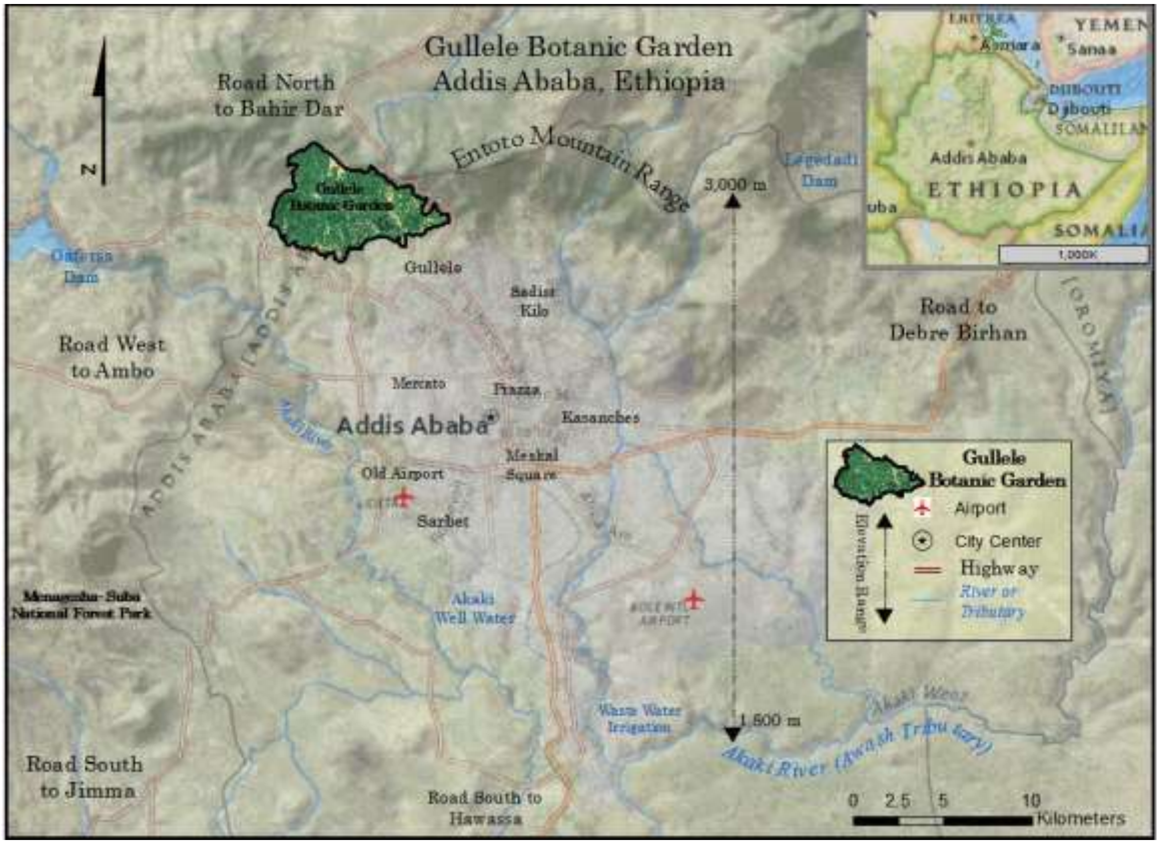

Figure 1. Map of Gullele Botanic Garden (Map adapted from Van Rooijen & Taddesse, 2009)

Selection of Sampling Site

Sampling sites were systematically selected. The study area were divided into different sections based on the transect line following Tanka and Tanka (1982) and Tayyab et al. (2006) procedures which classify on the spot (transact line). The study area was divided into twelve transects, starting at the edge of the road from the bottom (Sansuzi) to the upper (“Fitesha of Gojam-ber. The distance between two successive transects and plots were 500 m and 300 m, respectively. The numbers of quadrates were 60 (10m x 10m) which cover a total area of 0.6 hectares. The quadrates were laid on three habitats: natural forest, artificial forest and grasslands. Twenty quadrates were laid on each habitat type and butterfly collections were done on each habitat using sweeping net.

According to the Ethiopian calendar, for convenience of data interpretation, the year was divided into four seasons (i) winter – December, January and February (ii) summer- June, July and August (iii) Autumn- September, October and November (iv) Spring- March, April and May. For assessing population fluctuations across seasons, species were arranged in a definite order and then a simple matrix with species in rows and seasons in columns was made for each site.

Sampling methods, butterfly collection and identification

All quadrates were sampled within every hour between 10:00 and 14:00 daily. According to Holl (1996) and Gardiner *et al*. (2005) 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 habitat type in every monthfor about 4-5 days. Butterflies samples were collected with sweep net represents a horizontal swing with an arc of approximately 135^0 and height between 0.5-2.00 meters above the ground. These specimens were killed by pinching their thorax by taking proper care or by killing using ethyl acetate and finally placed in paper envelop.

The collected butterflies were identified using dissecting microscope and identification key at the species level with the help of available literatures such as Williams (1969), Carcasson (1975) and

D'Abrera (1997).When identifying and describing butterfly taxon, morphological characteristics were used to separate species.

Data analysis

Measurement of diversity

The type of diversity used is α-diversity, which is the diversity of species within a community or habitat. The diversity index was calculated by using the Shannon–Wiener diversity index (Shannon, 1949).

Diversity index = H = – ∑ Pi In Pi

Where Pi = S / N

S = number of individuals of one species

N = total number of all individuals in the sample

In = logarithm to base e

Simpson's Index (**D**) - It measures the probability that two individuals randomly selected from a sample will belong to the same species or some category other than species. Simpson Index (Simpson, 1949) was computed for the site.

Simpson's Index is expressed as: **D =Σ=ni (ni-1)**
N (N -1)

Where

N = total number of individuals encountered

ni = number of individuals of i^{th} species

The value of D ranges between zero and one. With this index, zero represents infinite diversity while, one represents no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is subtracted from 1 to give: Simpson's Index of Diversity 1 – D. The value of this index also ranges between zero and one, but now, the greater the value, the greater the sample diversity. This makes more sense. 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 (Magurran, 1988).

Margalef's index R = (S – 1) / In N

S = total number of species

N = total number of individuals in the sample

In = natural logarithm

Measurement of evenness – for calculation the Pielou's Evenness Index (e) was used (Pielou, 1969).

e = H / In S

H = Shannon – Wiener diversity index

S = total number of species in the sample

Dominance index

Patterns of relative abundance of species determine the dominance component of diversity. In this study, the relative dominance of each butterfly family in a habitat was determined by calculating the dominance index using the following formula:

Relative dominance = ni x 100
N

Where ni= number of butterflies in the 'i' th family, and

N = the total number of butterflies in all the families collected in each habitat.

Sorensen's similarity index

Sorensen's similarity index was used to measure butterfly species compositional similarity and/or variation between habitats.

Sorensen's index (Pielou, 1969) is expressed as:

SI = [a / a + b + c] * 100

Where

a = number of species present in both Sites under consideration

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 Diversity at Different Habitats of Gullele Botanical Garden

Butterfly species composition of the various habitats

A total of 36 species and 386 individuals of butterflies belonging to 23 genera and 5 families were recorded. The total species, abundance and their proportion in the various habitats are shown in Table 1. The highest number of species was found in the grassland followed by the natural forest while the lowest being in the artificial forest.

The grassland had the highest total number of individuals for all the species, followed by the natural forest, while the artificial forest habitat had the lowest individuals. The most abundant species in the grassland were *Eicochrysops messapus* (Wallengren, 1957) , *Colias electo* (Berger, 1940) and *Danaus chrysippus* (L., 1758). *E. messapus* had the largest population with the highest number of individuals occurring in the grassland. The grassland also supports the greater number of species. Species that were recorded only from the grassland habitat were *E. messapus, Eretis mixta* (Evans, 1937), *Euchrysops mauensis* (Bethune-Baker, 1923) and *Cupidopsis jobates* (Hopffer, 1855).

The natural forest area was next to grassland habitat in both the number of species as well as species abundances. The most abundant species in artificial forest were *Acraea necoda* (Hewitson, 1861) and *Papilio echerioides* (L., 1758). *Anthene otacilia* (Trimen, 1868) and *Acraea sotikensis* (Sharpe, 1892) are also common species in this area. *Deudorix dinochares* (Grose-Smith, 1887) and *P. echerioides* (Trimen, 1868) were species specific to the natural forest habitat.

Artificial forest showed the least species diversity and abundance. The most abundant species in this area were *Hypolimnas salmacis* (Rothschild & Jordan, 1903) and *Bicyclus campus* (Karsch, 1893), and *E. albistriata* (Capronnier, 1889).

In general, maximum abundance and species richness within the habitats was recorded in grassland followed by natural forest and artificial forest.

Table 1. Families of butterfly in the three habitat types of Gullele Botanical Garden showing total number of species, abundance and proportion of the total.

Family	Genera	TS	PTS (%)	Abundance	PTA (%)	Habitats					
						NF		AF		G	
						NS	No	NS	No	NS	No
Papilionidae	2	5	13.89	5	1.30	4	29	2	11	3	15
Pieridae	5	8	22.22	92	23.83	4	23	3	17	7	52
Lycaenidae	9	11	30.56	110	28.50	6	28	6	27	8	55
Nymphalidae	5	9	25.00	98	25.39	6	40	7	34	5	24
Hespieridae	2	3	8.33	31	8.03	2	15	0	0	3	16
Total	23	36	100	386	100	22	135	18	89	26	162

A. = Total species, PTS=Proportion of total species, PTA=Proportion of total abundance, NF= Natural forest, AF= Artificial forest, G= Grassland, NS = number of species, NO = total number of individuals

Distribution of butterflies species and abundance among families in different habitats

The distribution of butterfly species and abundance among butterfly families in the various habitats are shown in Table 2. In terms of species, Lycaenidae constituted the highest percentage of species in the grassland habitat followed by Pieridae and Nymphalidae, 31%, 27% and 19%, respectively. In the natural forest, the Nymphalidae and Lycaenidae accounted for the highest percentage (27% each) of species followed by Papilionidae that is 18%. Nymphalidae and Lycaenidae also accounted for the highest percentage of species, which were 39% and 33%, respectively in the artificial forest. Hesperidae had the least number of species in all of the three habitats.

In terms of abundance, Lycaenidae constituted the highest percentage of individuals (34%) in the grassland habitat followed by Peiridae (32%), while Papilionidae and Hesperidae had the least number of individuals. Hesperidae had also the least number of individuals in the natural forest and artificial forest.In the natural forest, the Nymphalidae had the highest percentage, which was 29.62% of individuals followed by Papilionidae (21.48%) and Lycaenidae (20.74%). Nymphalidae and Lycaenidae accounted for the highest percentage of individuals that were 38% and 30%, respectively in the artificial forest.

Table 2. Butterfly species and abundance by families at different habitats of Gullele Botanical Garden during the year 2012 to 2014.

Family	Habitats					
	Grassland		Natural forest		Artificial forest	
	Species	Abundance	Species	Abundance	Species	Abundance
Papilionidae	11.53	9.25	18.18	21.48	11.11	12.35
Peiridae	26.92	32.09	15.38	17.03	16.67	19.10
Lycaenidae	30.79	33.95	27.27	20.74	33.33	30.33
Nymphalidae	19.23	14.81	27.27	29.62	38.89	38.20
Hesperidae	11.53	9.87	9.09	11.11	0	0
Total	26	162	22	135	18	89

Butterfly diversity indices

There was no significance difference among the habitats as the value P > 0.05 (Table 3). The diversity indices of butterflies are presented in Table 4. In general, the three sampling habitats showed high diversity of butterflies and high evenness of distribution. The evenness indices of butterfly communities were similar; 0.98 in the natural forest, 0.97 in the artificial forest and 0.94 in the grassland habitat which indicated more evenness of species abundance in the natural forest followed by artificial forest and grassland. The highest Shannon diversity index of butterfly communities was at the grassland followed by the natural forest, while the lowest diversity index was at the artificial forest habitat. The species richness index of butterfly communities was the highest at the grassland and the least at the artificial forest.

Simpson's diversity index indicated higher butterfly species diversity in the natural forest and grassland habitat and least butterfly species diversity in the artificial forest.

Table 3. ANOVA test at various habitats of Gullele Botanical Garden.

	Sum of Squares	df	Mean Square	F	P
Between Groups	544.933	2	272.467	1.266	0.32
Within Groups	2582.000	12	215.167		
Total	3126.933	14			

Dominance index

The dominance index for various butterfly families at Gullele Botanical Garden is given in Table 5. The indices indicated that Lycaenidae is the most dominant group (33.95) followed by Peiridae (32.1) in the grassland. The dominant group in the natural forest was Nymphalidae (29.63) followed by Papilionidae (21.48) and Lycaenidae (20.74). In the artificial forest the dominant group was Nymphalidae (38.2) followed by Lycaenidae (30.34). The pooled data indicated that, Lycaenidae was the most dominant group followed by Nymphalidae.

Butterfly species compositional similarity between habitats

The similarity index for the different habitats is shown in Table 6. The similarity index demonstrated the differences and similarities between the species composition recorded in three habitat types. The level of similarity between each pair in terms of their species composition was generally below 41.18 %. The highest variation (72.3%) was recorded between artificial forest and grassland, followed by natural forest and artificial forest that was linked at 62.07 %, while the least variation (58.82%) was recorded between grassland and natural forest.

Table 4.Butterfly diversity indices in different habitats at Gullele Botanical Garden during the year 2012 to August 2014.

Habitats	Species number	Shannon diversity index H	Evenness Pielou's index e	Species richness index	Simpson's diversity index 1-D
Grassland	26	3.09	0.94	4.91	0.96
Natural forest	22	3.02	0.98	4.28	0.96
Artificial forest	18	2.82	0.97	3.79	0.92

Table 5. Butterfly families' dominance index in various habitats at Gullele Botanical Garden during the year 2012 to 2014.

Family	Habitats			Pooled value
	Grassland	Natural forest	Artificial forest	
Papilionidae	9.26	21.48	12.36	14.24
Pieridae	32.1	17.04	19.10	23.83
Lycaenidae	33.95	20.74	30.34	28.5
Nymphalidae	14.81	29.63	38.20	25.39
Hesperidae	9.88	11.11	0.00	8.03

Table 6. Jaccard's coefficient index for the different habitats at Gullele Botanical Garden during the year 2012 to 2014.

	Grassland	Natural forest	Artificial forest
Grassland	*	41.18	27.27
Natural forest		*	37.93
Artificial forest			*

Butterfly Diversity in Different Seasons at Gullele Botanical Garden

Seasonal changes in the total number of butterflies

The maximum species richness was recorded in autumn (31 species) followed by summer with 27 species and the minimum were in winter (18 species). Spring consist of 22 specie. Maximum abundance was noted in autumn and summer. In autumn, October and November had peak number of individuals of 53 and 49, respectively. During summer it was August that had the maximum abundance of 49 individuals. The minimum abundance was recorded in winter during the month of December, which composed of 18 individuals. The population showed highest population sightings during August to November and then, showed a gradual decline from December onwards (Figure 2).

Distribution of butterflies species and abundance among families in different seasons

Butterfly species distribution among butterfly families across seasons is shown in Figure 2. Family wise distribution of butterfly species revealed that Lycaenidae had the highest species percentage composition in autumn (10) and spring (8), while Nymphalidae constituted the highest percentage of species during winter (6) and summer (8). Hesperidae had the least species composition in all of the seasons.

The seasonal population trend of various families of butterfly abundance is presented in Figure 3. In terms of abundance, Lycaenidae contained the highest individuals in autumn followed by spring. Lycaenidae reached its peak during autumn and they were present in all seasons in varying number. Nymphalidae was nearly all were present though vary in number. Nymphalidae had the highest individuals during autumn followed by summer. Even though the Nymphalids were most common and adapted, population count was low. Pieridae present in all seasons in significant numbers; the highest being in autumn and summer followed by spring. The population was low during winter. The population of Hesperidae was very low and had the least abundance composition almost in all of theseasons. Papilionidae was present in all of the seasons with maximum sightings in autumn followed by winter.

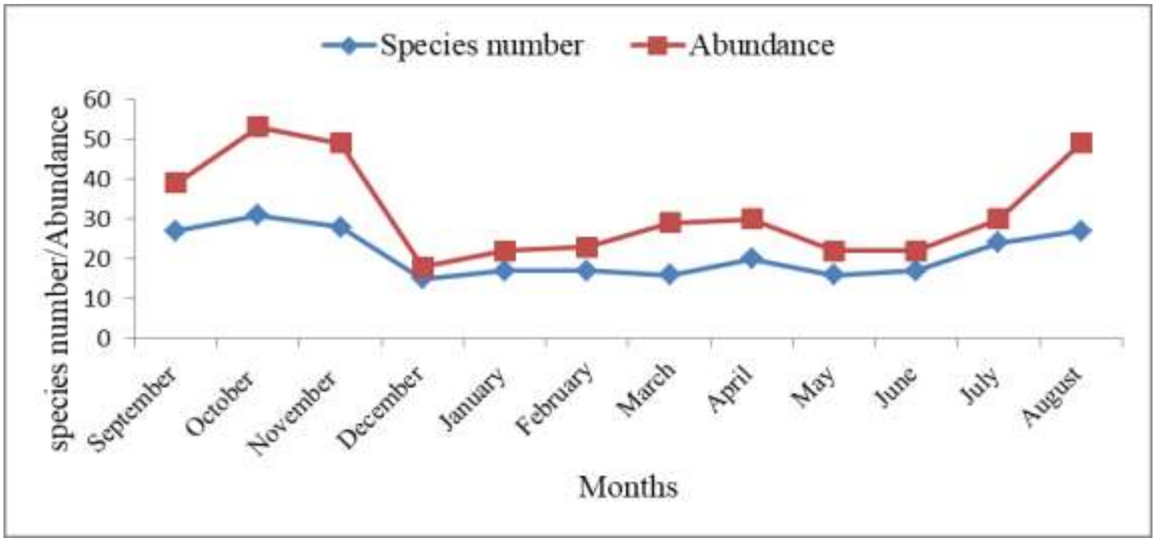

Figure 2.Number and abundance of butterfly species across months at Gullele Botanical Garden during the year 2012 to 2014.

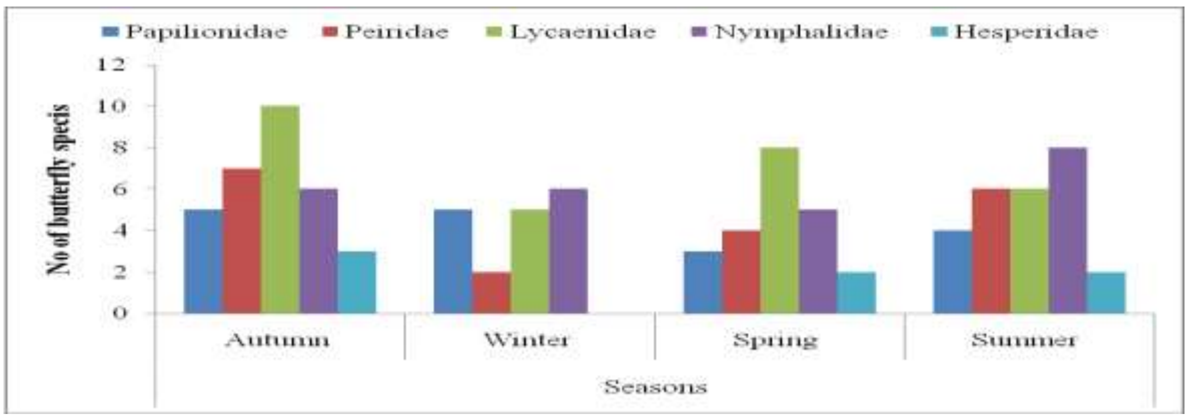

Figure 3. Family-wise trend in species richness of butterflies across seasons at Gullele Botanical Garden during the year 2012 to 2014.

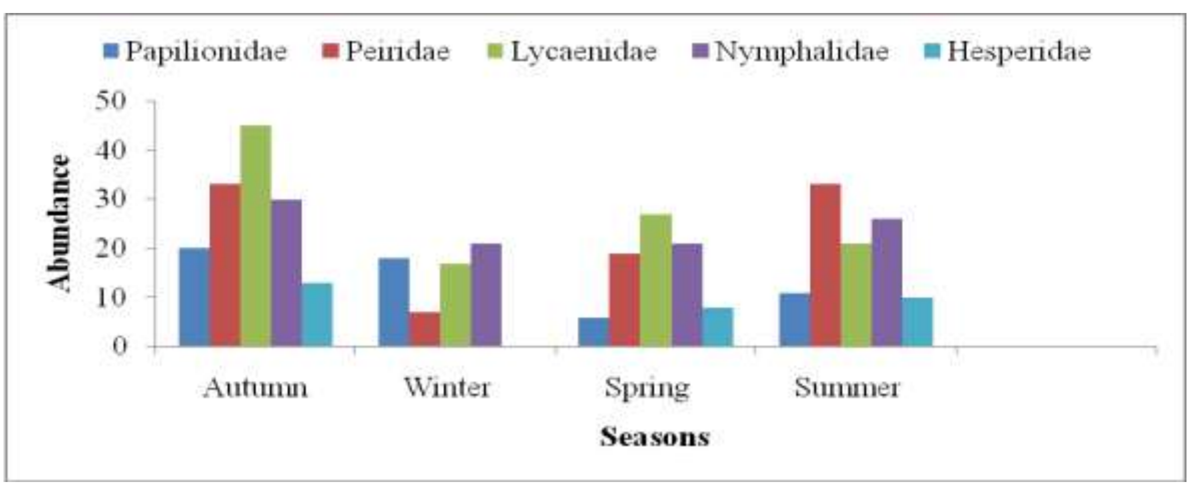

Figure 3.Overall population trend of various families of Butterflies across seasons at Gullele Botanical Garden during the year 2012 to 2014.

Species richness and diversity indices

There was a significance difference among seasons as ($p < 0.05$, F= 5.529 and df =3). Multiple comparisons of Tukey HSD test showed that there was a significance difference between autumn and winter (P=0.020) (Table 7). The diversity indices of butterflies are presented in Table 8. Species richness showed maximum recorded in autumn (6.06) and minimum in the winter (4.10), while it was (4.77) and (5.63) in spring and summer, respectively. Comparison of the Shannon diversity index showed higher diversity in autumn (3.396) followed by summer (3.216) and spring (2.968) while winter showed the lowest diversity index of 2.857.

The comparison of Shannon diversity index among five different families showed Lycaenidae had high value in autumn and spring, while Nymphalidae and Pieridae had high value during winter and summer, respectively. Hesperiidae had the least diversity Shannon index in all seasons. Hesperiids prefers autumn and Papilionidae had high index in winter and least in spring (Table 9).

The dominance indices for various butterfly families are given in Table 10. The indices indicated that Lycaenidae is the dominant family in autumn and spring, Nymphalidae in winter and Pieridae in summer. Papilionidae had high dominance index in the winter. The pooled data indicated that, Lycaenidae is the most dominant family followed by Nymphalidae and Pieridae. Butterflies species recorded against each family are shown in Table 11. The highest number (11) species were recorded in the family Lycaenidae followed and the least (3) was Hesperidae.

Table 7. ANOVA and Tukey HSD test at various seasons of Gullele Botanical Garden.

	Sum of Squares	Df	Mean Square	F	P
Between Groups	1121.000	3	373.667	5.529	.024
Within Groups	540.667	8	67.583		
Total	1661.667	11			

Multiple Comparisons, Tukey HSD

(I) season	(J) season	Mean Difference (I-J)	Std. Error	P	95% Confidence Interval Lower Bound	Upper Bound
Autumn	Winter	26.00000*	6.71234	.020	4.5047	47.4953
	Spring	20.00000	6.71234	.068	-1.4953	41.4953
	Summer	13.33333	6.71234	.269	-8.1620	34.8286
Winter	Autumn	-26.00000*	6.71234	.020	-47.4953	-4.5047
	Spring	-6.00000	6.71234	.808	-27.4953	15.4953
	Summer	-12.66667	6.71234	.305	-34.1620	8.8286

**. The mean difference is significant at 0.05 level.*

Table 8. Butterfly diversity indices across seasons at Gullele Botanical Garden during the year 2012 to 2014.

Seasons	Species number	Individuals	Simpson's diversity 1-D	Pielou's evenness index	Species richness index	Shannon diversity index H
Autumn	31	141	0.972	0.978	6.06	3.396
Winter	18	63	0.956	0.988	4.10	2.857
Spring	22	81	0.955	0.960	4.77	2.968
Summer	27	101	0.967	0.975	5.63	3.216

Table 9. Shannon index (H) of various butterfly families across seasons at Gullele Botanical Garden during the year 2012 to 2014

Family	Seasons			
	Autumn	Winter	Spring	Summer
Papilionidae	0.502	0.804	0.267	0.385
Pieridae	0.783	0.319	0.635	0.980
Lycaenidae	1.09	0.782	1.03	0.687
Nymphalidae	0.701	0.952	0.743	0.87
Hesperidae	0.32	0	0.293	0.294

Table 10. Dominance index of butterfly families in various seasons at Gullele Botanical Garden during the year 2012 to 2014.

Family	Dominance index				
	Seasons				
	Autumn	Winter	Spring	Summer	Pooled value
Papilionidae	14.18	28.57	7.40	10.89	14.25
Peiridae	23.4	11.11	23.46	32.67	23.83
Lycaenidae	31.91	26.98	33.33	20.79	28.5
Nymphalidae	21.28	33.33	25.93	25.74	25.39
Hesperidae	9.22	0	9.88	9.9	8.03

DISCUSSIONS

The butterfly fauna appeared to be less diverse at Gullele Botanical Garden because of logging activities, construction and other human interferences. It may be due to increased construction and population pressure that Gullele Botanical Garden showed least butterfly fauna because species composition and abundance are dependent upon maintenance of natural habitat. The lowest diversity observed may be also due to lack of habitat diversity and food sources in the site since it is a monoculture plantation, eucalyptus is the dominant.

High diversity and evenness was recorded in the natural forest habitat, which can be due to stability and availability of larval food. This result is in agreement with that of Sreekumar and Balakrishnan (2001a) 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.

The lowest diversity index (2.82) at the artificial forest habitats was due to the artificial forest habitats were highly exposed to fuel wood collection that affected diversity. The intensive interference of both human and animal, and the absence of food plant diversity, mainly eucalyptus, was the reason for less diversity. The grassland was high in species diversity (3.09) and richness (4.91) which might be due to the abundance of family Lycaenidae in the habitat than other families that can adapt to varied climate and feed on variety of larval food plants.

The highest species richness and diversity 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 foraging purpose that could result in richness and abundance (FAO, 2001).

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 (Krauss *et al*., 2003).

Habitat specificity of butterflies can be directly related to the availability of food plants (Thomas, 1995). Each habitat has a specific set of microenvironment suitable for a species. For example, species like *P. echerioides* and *Deudorix dinochares* GROSE-SMITH (1887) were recorded from the natural forest. Species such as *Eurema hecabe* (Linnaeus, 1758), *Colotis danae* (Fabricius, 1775), *C. jobates* and *E. messapus* were recorded in the grassland habitats and species specific to the artificial forest were *Graphium angolanus* (Goeze, 1779) and *Hypolimnas salmacis* (Drury, 1773). However, about 14% of the species at Gullele Botanical Garden 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, 41.18, was recorded between grassland and natural forest habitats while, the least similarity 27.27 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 (Sih *et al*., 2000). Debinski and Holt (2000) also observed that habitat fragmentation reduces area, changes ecological processes and reduces connectivity. Perrins *et al*. (1991) 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.

In the butterfly diversity, out of the five butterfly families recorded, Nymphalidae was richest in terms of abundance as well as species richness next to Lycaenidae, even though it was also the dominant family at the natural and artificial forest habitats. The dominance of Nymphalidae can be due to the polyphagous habit that helped them to live in all habitats (Sreekumar and Balakrishanan, 2001b), which comprised the largest family of butterflies.

The Pieridae were the third family in abundance and species richness. Pieridae are sun lovers seen basking in sun with wings partially open (Kehimkar, 2008). Study by Tiple and Khurad (2009) in the Gir protected area indicated that Pierids were observed to be the most common family in the dense forest vegetation. Gullele Botanical Garden, which is an open type forest can attribute for the dominance of Pieridae especially in the grassland habitat.

Family Lycaenidae known to adapt various climates and feeding on a variety of larval food plants (Kunte, 2001). This could be the reason for the dominance of family Lycaenidae at Gullele Botanical Garden.

Papilionidae were the dominant family next to Nymphalidae and Pieridae because they prefer to tall trees providing moderate sunlight (Mathews and Anto, 2007). Papilionidae dominance was relatively high in the artificial and natural forests rather than in the grassland habitat.

Family Hesperiidae, was represented by only three species.Hence, low species richness and abundance. Their general flight period is early morning hours at dawn and dusk (Kehimkar, 2008) whereas the present study was conducted during daytime and hence low abundance and diversity of Hesperidae.

The butterflies of Gullele Botanical Garden showed distinct seasonality and well-defined seasonal peaks and only the lesser proportion of the species being active throughout the year. Seasonal preferences were also shows distinct variation of the proportional abundance in various months or seasons. These differences of abundances were due to well-defined dry and wet seasons.

Species diversity was consistently highest during autumn season, primarily due to a greater abundance of species. The abundance of butterfly families was also usually highest during autumn season. Therefore, highest abundance was noted after the rainy season in autumn and this may be related to an increase in young vegetation, flowering of plants and the appropriate climatic conditions. Optimum light, temperature and rainfall usually increase the vegetation and thereby directly favour their abundance. Hence, there is a direct correlation between abundance of butterflies with flowering of plants, intensity of light and larval host plant (Kitahara*et al*., 2000; Kunte, 2000; Hussain *et al*., 2011).

During winter season the declined of species diversity and abundance are associated with habitat dryness and differences in microhabitat conditions in various seasons. The butterfly population showed a gradual decline in numbers from December onwards with the onset of dry condition. This dry period was least favorable to many butterflies, probably due to the scarcity of water, nectar and fresh foliage.

In addition, the diversity and species richness indices were also high during spring and lowest during summer. There were population peaks and troughs, because butterflies try to time the emergence of their larvae with their food plants having fresh young leaves. Therefore, this variation of butterfly diversity in different seasons indicates that, the abiotic factors such as rainfall, temperature and humidity played a vital role in influencing the distribution and abundance of butterflies (Shubhalakshmi and Chaturvedi, 1999; Hill *et al*., 2003).

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