Article

Butterfly diversity and abundance at two different habitat types of Gozamen woreda, Amhara regional state, Ethiopia

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Abstract
Assessment of butterfly biodiversity at different habitat type s of Gozamen woreda, Amhara regional state, Ethiopia, studied from mid-June 2021 to mid-July 2021. There were 44 butterfly species from five families, with a total of 1023 individuals identified. The Nymphalidae family had the most diversity, while the Papilonidae and Hespariidae families had the least diversity. The diversity and abundance of butterflies reported at Gozamen woreda varied between the forest habitat and the mosaic habitat. The largest diversity and abundance of butterflies were found in the forest habitat, with 41 species and 680 individuals, and the lowest were found in the mosaic habitat, with 22 species and 343 individuals. The Simpson diversity indices were higher in the forest habitat (0.96) than in the mosaic habitat (0.94). The evenness index of butterflies was higher in the forest habitat (3.5) than in the mosaic habitat (3.0). The evenness and equitability index were highest in the mosaic habitat, with 0.88 and 0.96 respectively. The diversity and abundance of butterflies were significant, with $\chi^2 = 10.43$ and $p = 0.001$. The Jaccarda index of similarity revealed that forest habitat and mosaic habitat were 43.2% similar. Accumulation curves for mosaic habitat and forest habitat showed an increase until the 200th and 300th individuals were captured.

Keywords accumulation curves; butterfly diversity; Gozamen woreda.

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1 Introduction

Insects are among the most vital members of the ecosystem (Regier et al., 2013; Yang and Gratton, 2014). Among insects butterflies are one of the most studied insect groups on the globe (Robinson et al., 2012). Like other insects species, butterflies serve a critical part in the proper functioning of a healthy ecosystem for humans and other species (Dangles and Casas, 2019). They are useful indicators for monitoring environmental effects on biodiversity in many habitat types because of their sensitivity to changes in environmental parameters such as temperature, humidity, light, and rainfall patterns, as well as their short generation time and great mobility (Bonebrake et al., 2010). Furthermore, they are used in biological research, including navigation,

pest control, embryology, mimicry, evolution, genetics, population dynamics, and biodiversity conservation (Horn, 2003; Bonebrake et al., 2010; Syaripuddin et al., 2015; Hellmann, 2001; Tanda, 2021). The availability of food plants in the environment is strongly related to species diversity and richness. Butterflies' diversity and distribution are influenced by habitat and climatic changes (Robinson et al., 2012; Dangles and Casas, 2019). Thus, ecologists have used butterflies as model organisms to study the effects of habitat loss and fragmentation as well as climate change (Ratnasingham and Hebert, 2007).Worldwide, there are more than 20,000 species of butterflies (Powell, 2009), of which more than 426 species have been recorded so far in Ethiopia (Tujuba et al., 2013).

However, today, in many areas of the world, including Ethiopia, habitat fragmentation is increasing from time to time, mainly due to deforestation and other human-induced factors (Thomas, 2005; Van Dyck et al., 2009; Serrat et al., 2015). As a result, the diversity of insects, including butterflies, is on the front line of decline (Serrat et al., 2015; Van Halder, 2017). To understand the degree of impact of habitat fragmentation on invertebrates, more specifically on butterflies, it is important to study the diversity and distribution of organisms (Van Dyck et al., 2009). Neither the diversity nor the abundance of species, nor their distribution, are adequately investigated and documented in Ethiopia (Tujuba et al., 2019).

Despite the fact that some efforts have been made to study lepidopterans in general and specifically butterflies in different parts of Ethiopia, no documented data was found in the current study area. The current study area is covered with different types of forests and is characterized by large areas of cropland. It is also one of the fertile areas of Ethiopia where Teff and other crop production is the highest, and at the same time there is high environmental and habitat degradation. Thus, as butterflies are environmental indicators (Andrade, 1998; Horn, 2003; Parmesan, 2019; Legal et al., 2020) and pollinators of important crops (Duara, 2014; Rader et al., 2016; Tanda, 2021), assessment and documentation of butterfly species is essential for planning habitat conservation activities. The main target of the current study was there for assessing and documenting of butterfly species from the different habitat types of Eastern Gojam Gozamen woreda in different habitat type.

2 Materials and Methods

2.1 Study area

The research was carried out in Ethiopia's Amhara Regional State's Gozamen woreda of the East Gojam zone (Fig. 1). The Gozamen wereda is 1,173.80 km^2 in size and has a population of 143,483. Gozamen woreda is bordered by Abay River to the south, Debre Elias to the west, Sinan woreda to the north, and Aneded woreda to the east. Debre Marqos is a Gozamen enclave, serving as the East Gojam zone's capital(Wikipedia contributors, 2021). The study was conducted in purposely selected forests and agricultural lands of Gozamen woreda from June to July 2021. The study sitescover all types of habitats, mainly natural forests and mosaic habitats with altitudinal range from 1200 to 2400 m.a.s.l.

2.2 Selection of the study sites

Two habitat types were selected purposely based on human anthropogenic disturbances and on the accessibility of the habitats, namely, forest habitat and mosaic habitat. The first habitat was the mosaic habitat, which was characterized by the presence of natural forest, crop cultivation, grasslands, and human settlement. Some common plantation types of mosaic habitat include *Aloe macrocarp*, *Brassica carinata*, *Carissa spinarum*, *Dodonaea angustifolia*, *Olea europaea*, *Podocarpus falcatus*, and *Persea Americana*. The second habitat type was the forest habitat, which was characterized by different plant species. The main plant species of this habitat type were *Ficus vasta*, *Ficus ovata*, *Dovyalis abyssinica*, *Dodonaea anguistifolia*, *Cordia Africana*, *Croton macrostachyus*, *Dodonaea anguistifolia*, *Rhus glutinosa*, *Rosa abyssinica*, *Steganotaenia araliacea*, *Vernonia amygdalina*, *Vernonia myriantha*, *Arundinaria alpine*, and *Clausena anisate*.

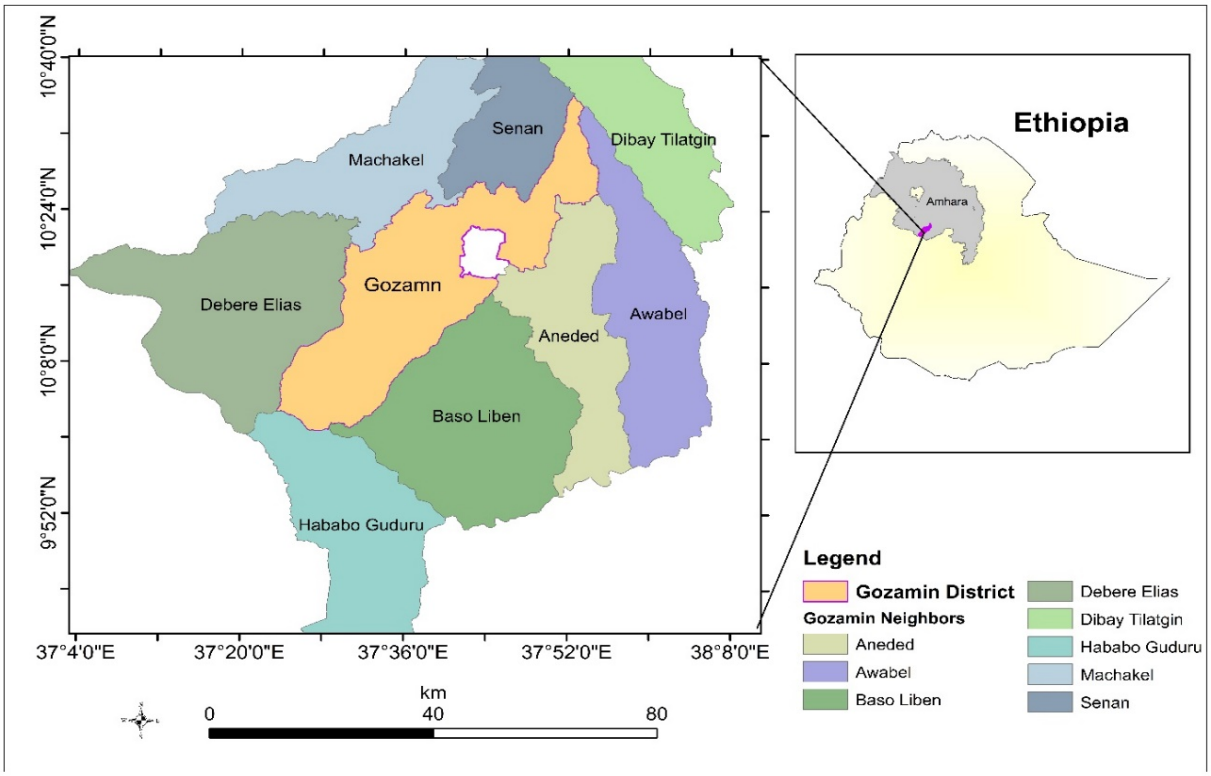

Fig. 1 Map of Gozamen woreda of east Gojam zone.

2.3 Butterfly survey and identification

The survey of butterflies was done using purposive sampling of the selected habitats from mid-June to mid-July 20201. A butterfly net was used for the collection of butterflies, and collection and observation of butterflies were done from 8:00 am to 11:00 am and 2:00 pm to 4:00 pm, where the butterflies are active (Woodhall, 2020). Representative butterfly species captured, photographed, and identified in the Ethiopian Biodiversity Institute laboratory.

Identification butterflies was done based on external morphological features and comparison of the photographs with identified butterflies at Ethiopian Biodiversity Institute and with other databases (Ratnasingham and Hebert, 2007; Nugent, 2018; Lepidoptera in GBIF Secretariat, 2019; Woodhall, 2020). Finally, all voucher specimens were kept at the Ethiopian Biodiversity Institute, Addis Ababa.

2.4 Data analysis

The collected data were used to calculate species richness (S), species abundance (total organisms collected), species diversity (Shannon Weiner index and Simpson's diversity index), and Pielou's evenness index for both the forest and mosaic habitats. The raw data of species richness counts of each sampling site was pooled to get rarefaction curves for comparison of estimated species richness between the habitats. PAST version 4.08 version was used to determine diversity indices, cluster analysis, species rarefaction curves, and species richness estimates. Accumulation curves was graphed to analyze the species captured at each habitat types.

3 Results

In the research area, 44 butterfly species from five families were identified, with a total of 1023 individuals. The Nymphalidae family had the most diversity, accounting for 52 percent of the total species, while the Papilonidae and Hespariidae families had the least diversity, each accounting for 7% of the total species.

Individuals' family Nymphalidae was the most abundant, with 321 individuals accounting for 31% of the total collected butterflies, followed by Pieridae with 303 individuals accounting for 30%, and the family Hespariidae with only 20 individuals accounting for 2% of the total collected butterflies (Table 1, Plate 1).

Table 1 Butterfly composition and distribution across families in Gozamen woreda.

Family name	Number of species	Percentage %	Number of individuals	Percentage %
Nymphalidae	23	52%	321	31%
Pieridae	11	25%	303	30%
Lycaenidae	4	9%	267	26%
Papilionidae	3	7%	112	11%
Hesperiidae	3	7%	20	2%

3.1 Butterfly diversity in different habitats

The highest diversity and abundance of butterflies were found in the forest habitat, with 41 species and 680 individuals, and the lowest diversity and abundance were found in the mosaic habitat, with 22 species and 343 individuals (Table 2 and Table 3). The significance of butterfly diversity and abundance was tested using the Kruskal-Wallis test for equal medians, and the findings showed that the difference between sample medians was significant, with $\chi^2 = 10.43$ and $p = 0.001$. The Jaccarda index of similarity, which used to determine how similar the species composition of different habitats is, was found 43.2% between the forest and mosaic habitat.

The diversity and abundance of butterflies reported at Gozamen woreda varied depending on the habitat types (Table 3, Fig. 2 and Fig. 3), with the Nymphalidae family having the maximum diversity, with 21 species in the forest and 9 species in the mosaic habitat (Fig. 2). The Hespariidae family had the fewest species, with only two species in each habitat. The Nymphalidae family was the most abundant across the two habitats, with 227 individuals in the forest and 94 individuals in the mosaic habitat. The Hesparidae family had the least number of members, with 15 individuals in the mosaic and 5 in the forest habitat (Fig. 3).

Plate 1 Some common butterflies of the study area. 1. *Hypolimnas anthedon* (Variable eggfly); 2. *Vanessa cardui* (Painted lady); 3. *Junonia hierta* (Yellow pansy); 4. *Junonia oenone* (Blue pansy); 5. *Papilio demodocus* (Citrus swallowtail); 6. *Vanessa abyssinica* (Abyssinian admiral); 7. *Papilio dardanus* (African swallowtail); 8. *Papilio nireus* (green-banded swallowtail); 9. *Eurema desjardinsii*; 10. *Catopsilia florella* (African emigrant); 11. *Belenois aurota* (Pioneer white); 12. *Phalanta phalantha* (Common leopard).

Table 2 Checklist of butterflies recorded from the study area.

Family name	Common name	Scientific name	Frequency occurrence in different habitats	
			Forest	Mosaic
Nymphalidae	Natal acraea	*Acraea natalica* (Boisduval, 1847)	10	0
Nymphalidae	Large spotted Acraea	*Acraea zetes* (Linnaeus, 1785)	5	0
Nymphalidae	Forest glade nymph	*Aterica galena* (Brown, 1776)	0	12
Nymphalidae	Wanderer	*Bematistes aganice* (hewiston, 1852)	5	8
Nymphalidae	Green-veined emperor	*Charaxes candiope* (Godrat, 1824)	10	0
Nymphalidae	Savannah charaxes	*Charaxes etesipe*(Godrat, 1824)	5	0
Nymphalidae	Demon charaxes	*Charaxes etheocles* (Cramer, 1777)	4	0
Nymphalidae	Lesser blue charaxes	*Charaxes numenes* (Hewiston, 1859)	10	6
Nymphalidae	Widespread forester	*Euphaedra medon* (Linnaeus,1763)	8	13
Nymphalidae	Ethiopian Forester	*Euphaedra neumanni* (Rothschild & Jordan, 1902)	12	0
Nymphalidae	Common forest queen	*Euxanthe eurinome* (Hubner, 1819)	4	0
Nymphalidae	Guinea fowl butterfly	*Hamanumida daedalus* (Fabricus, 1775)	12	8
Nymphalidae	Variable eggfly	*Hypolimnas anthedon* (Doubleday, 1845)	15	20
Nymphalidae	Golden pansy	*Junonia chorimene* (Guérin-Méneville 1844)	12	0
Nymphalidae	Blue pansy	*Junonia oenone* (Linnaeus 1758)	20	0

Nymphalidae	Blue Argus	*Junonia orithya* (Linnaeus, 1758)	9	0
Nymphalidae	Common club-dot sailer	*Neptis agouale* (Pierre-Baltus, 1978)	8	0
Nymphalidae	Common leopard	*Phalanta phalantha* (Drury, [1773])	23	12
Nymphalidae	Yellow pansy	*Junonia hierta* (Fabricius, 1798)	12	0
Nymphalidae	Little commodore	*Junonia sophia* (Fabricius, 1793)	0	9
Nymphalidae	Soldier pansy	*Junonia terea* (Drury, 1773)	14	6
Nymphalidae	Abyssinian admiral	*Vanessa abyssinica* (Felder & Felder, 1867)	9	0
Nymphalidae	Painted lady	*Vanessa cardui* (Linnaeus, 1758)	20	0
Pieridae	Pioneer white	*Belenois aurota* (Fabricius, 1793)	40	10
Pieridae	African common white	*Belenois creona* (Cramer, 1776)	15	0
Pieridae	African veined white	*Belenois gidica* (Godart, 1819)	20	0
Pieridae	Raffray's white	*Belenois raffrayi* (Oberthür 1878)	5	0
Pieridae	False dotted border	*Belenois thysa* (Hopffer, 1855)	7	0
Pieridae	Crimson tip	*Colotis danae* (Fabricius, 1775)	20	20
Pieridae	African emigrant	*Catopsilia florella* (Fabricius, 1775)	12	9
Pieridae	Eastern pale clouded	*Colias erate* (Esper, 1805)	10	0
Pieridae		*Eurema desjardinsii* (Butler, 1876)	23	0
Pieridae		*Eurema regularis* (Butler, 1876)	30	25
Pieridae	Eastern Dotted Border	*Mylothris agathina* (Cramer, [1779]	36	21
Papilionidae	African swallowtail	*Papilio dardanus* (Brown, 1776)	20	10
Papilionidae	Citrus swallowtail	*Papilio demodocus* (Esper, 1798)	12	40
Papilionidae	green-banded swallowtail	*Papilio nireus* (Linnaeus 1758)	5	25
Lycaenidae	Red-clover blue	*Actizera stellata* (Trimen, 1883)	40	21
Lycaenidae	Grass jewel	*Freyeria trochylus* (Freyer, 1845)	50	0
Lycaenidae	Pea blue	*Lampides boeticus* (Linnaeus, 1767)	60	30
Lycaenidae	Tiny grass blue	*Zizula hylax* (Fabricius, 1775)	43	23
Hesperiidae	Striped policeman	*Coeliades forestan* (Stoll, 1782)	3	5
Hesperiidae	Orange-spotted	*Zenonia zeno* (Trimen, 1864)	2	0
Hesperiidae	Mountain sandman	*Spialia spio* (Linnaeus, 1764)	0	10

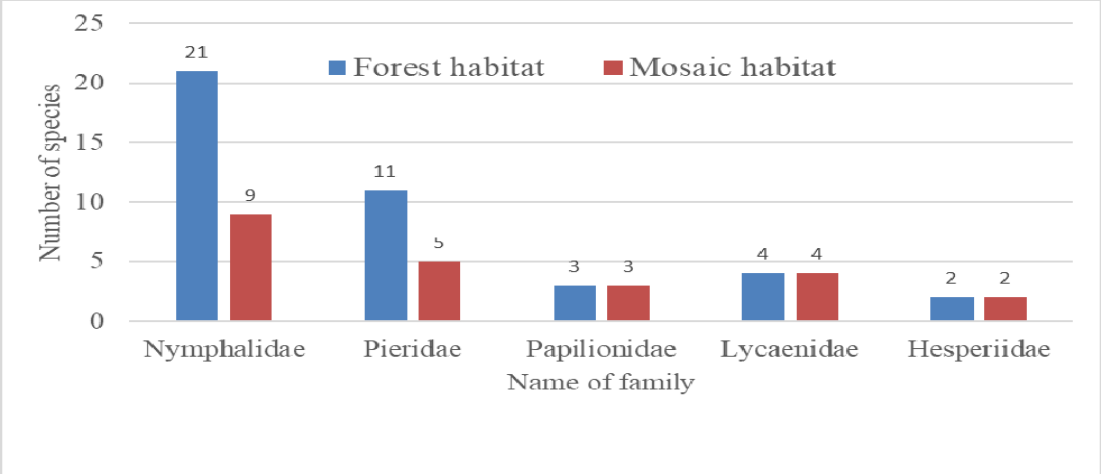

Fig. 1 The diversity of butterfly families across the forest and mosaic habitats.

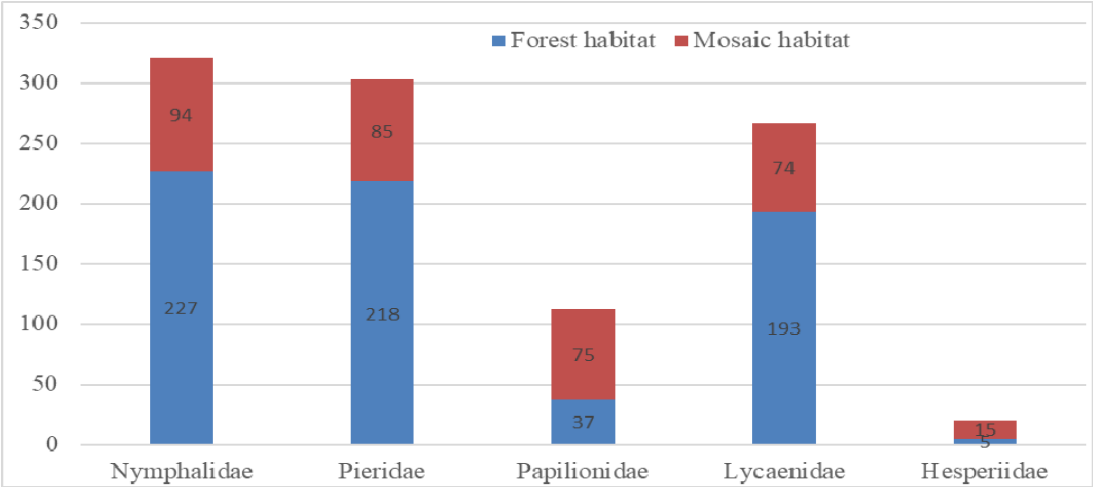

Fig. 2 The abundance of butterfly families across the forest and mosaic habitats.

Table 3 Selected diversity indices of different habitats of Gozamnn Woreda.

Diversity indice	Forest habitat	Mosaic habitat
Species	41	22
Individuals	680	343
Simpson_1-D	0.96	0.94
Shannon_H	3.46	2.97
Evenness_e^H/S	0.77	0.88
Margalef	6.14	3.60
Equitability_J	0.93	0.96
Fisher_alpha	9.59	5.24

The biodiversity indices of butterfly species and individuals in the two different habitats of Gozamen woreda were calculated and given in Table 4. The Simpson diversity indices were higher in the forest habitat (0.96) than in the mosaic habitat (0.94). The evenness index of butterflies was higher in the forest habitat (3.5) than in the mosaic habitat (3). The evenness and equitability index of butterflies varied by habitat, with the mosaic habitat having the highest, with 0.88 and 0.96 respectively, compared to the forest habitat, with 0.77 and 0.93 respectively.

Accumulation curves express the number of new species recorded in every successive sampling (Figure 4). Curves for mosaic habitat showed an increase until the 200th individual captured and then it remains more or less constant, meaning there were no further new species recorded. Curves for forest habitat showed an increment until the 300th individuals captured and remained more or less constant since there was no new species recorded (Fig. 4).

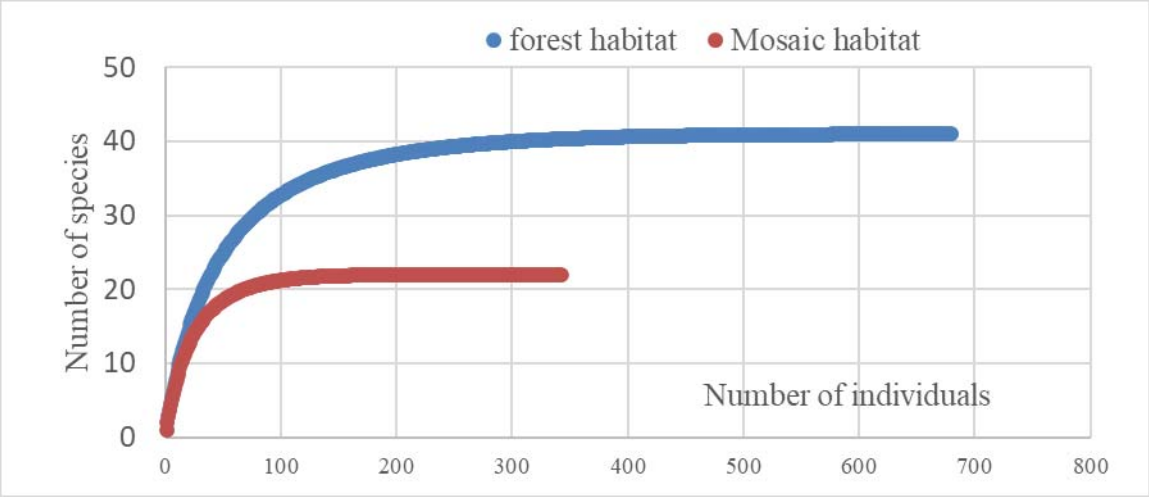

Fig. 3 Individual refraction curve of butterfly species from two different habitats of Gozamen woreda.

4 Discussion

In this study a total of 44 butterfly species belonging to five families and 1,023 individuals were recorded from the two habitat. The number of species recorded from the current study area is about 11% of the total species recorded from the total butterfly species of Ethiopia (426 species) and all five families recorded from Ethiopia are recorded from the current study (Tujuba et al., 2019). The number of taxa/species recorded from the current study area is lower than the butterfly species reported from the Jimma highlands of Ethiopia, which has 64 butterfly species(Norfolk et al., 2017) and butterfly species diversity (59) reported from the Menagesha-Suba State Forest and Gullele Botanical Garden (Jemal and Patharajan, 2018). One possible reason for this is that the current study was carried out for only one month, a shortage of time as butterflies are seasonal due to their life cycle (Serrat et al 2015; Van Swaay et al., 2015). The other possible reason for the low diversity of butterflies is that the current study area is one of the areas where agricultural activities are practiced more and results in habitat fragmentation, as butterflies are sensitive to environmental changes (Thomas, 2005; Koh, 2007; Warren et al., 2021). The results of the current study area were higher than the butterfly diversity reported from the West Shewa zone (19 species) (Gorbunov, 2017) and the butterfly species reported from the Middle Afromontane Area of Northwestern, Ethiopia (11 species) (Wale and Abdella, 2021).

Of the collected species of butterflies, 65% were recorded from the forest habitats of Gozamen woreda and the rest, 35%, were documented from the mosaic habitat. In the present study, all families recorded from

Ethiopia were represented and the family Nymphalidae dominated with respect to species richness and number of collected individuals. This is due to the fact that Nymphalidae species are widely distributed, inhabit a wide range of ecological niches, feed on a diverse range of plants (which are generalists), and have a great diversity of species in different parts of the world (Hamm and Fordyce, 2015). Previous studies from different parts of Ethiopia reported the same results (Norfolk et al., 2017; Jemal and Patharajan, 2018; Jenber and Getu, 2020; Wale and Abdella, 2021). The number of individuals of butterflies was also different in both habitats, such that 680 of the total of 1023 butterflies, accounting for 64.5% of the total, were found in the forest habitats and the rest of 343 butterflies, accounting for 34.5% of the total, were recorded in the mosaic habitat. Based on diversity, the calculated biodiversity index and the Shannon diversity index were higher in forest habitats than in mosaic habitats. Many studies found similar outcomes (Natuhara et al., 1999; Bobo et al., 2006; Yang and Gratton, 2014; Van Halder, 2017). Forest habitats are less degraded than mosaic habitats and as habitat loss has been demonstrated to have a strong negative influence on biodiversity, forests have more species diversity than mosaic ecosystems (Van Halder, 2017).The data demonstrated that habitats differed when rarefaction curves were used to represent the recorded new species at each survey.

Finally, this study can also be used as a foundation for future investigations and further research on insect biodiversity, especially those that are important in pollination, should be carried out.

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References

Andrade C. 1998. Use of butterflies like bioindicators of habitat type and their biodiversity in Colombia. Revista de la Academia Colombiana de Ciencias Exactas, Fisicas y Naturales, 22(84): 407-421

Bobo KS, Waltert M, Fermon H, Njokagbor J, Mühlenberg M. 2006. From forest to Farmland: butterfly diversity and habitat associations along a gradient of forest conversion in Southwestern Cameroon. Journal of Insect Conservation, 10(1): 29-42

Bonebrake TC, Ponisio LC, Boggs CL, Ehrlich PR. 2010. More than just indicators: a review of tropical butterfly ecology and conservation. Biological Conservation, 143(8): 1831-1841

Dangles O, Casas J. 2019. Ecosystem services provided by insects for achieving sustainable development goals. Ecosystem Services, 35: 109-115

Duara P. 2014. Effectiveness and importance of butterflies as pollinators to the flowers of Ixora coccinea. International Journal of Research Studies in Biosciences, 2(11): 71-74

Gorbunov OG. 2017. On the pierid butterflies of the West Shewa zone (Ethiopia) (Lepidoptera: Pieridae). Ethiopian Journal of Biological Sciences, 16: 95-147

Hamm CA, Fordyce JA. 2015. Patterns of host plant utilization and diversification in the brush‐footed butterflies. Evolution, 69(3): 589-601

Horn HS. 2003. Butterflies as bioindicators. American Scientist, 91(6): 565-568

Jemal A, Patharajan S. 2018. Butterflies as indicator taxa of ecological disturbance at Menagesha-Suba State orest, central Ethiopia. Indicators, 10: 11

Jenber AJ, Getu E. 2020. Studies on butterflies' diversity in relation to habitat and season at Gulele Botanical Garden in Central Ethiopia: implications of a protected areas for in-situ conservation of a biological entities. SINET: Ethiopian Journal of Science, 43(2): 64-76

Koh LP. 2007. Impacts of land use change on South-east Asian Forest butterflies: a review. Journal of Applied Ecology, 44(4): 703-713

Legal L, Valet M, Dorado O, Jesus-Almonte JMD, López K, Céréghino R. 2020. Lepidoptera are relevant bioindicators of passive regeneration in tropical dry forests. Diversity, 12(6): 231

Lepidoptera in GBIF Secretariat. 2019. GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei. Accessed via GBIF.org on 2021-02-22

Natuhara Y, Imai C, Takahashi M. 1999. Pattern of land mosaics affecting butterfly assemblage at Mt Ikoma, Osaka, Japan. Ecological Research, 14(2): 105-118

Norfolk O, Asale A, Temesgen T, Denu D, Platts PJ, Marchant R, Yewhalaw D. 2017. Diversity and composition of tropical butterflies along an Afromontane agricultural gradient in the Jimma Highlands, Ethiopia. Biotropica, 49: 346-354

Nugent J. 2018. INaturalist. Science Scope, 41: 12-13

Parmesan C. 2019. Butterflies as bioindicators for climate change effects. In: Butterflies. 541-560, University of Chicago Press, USA

Powell JA. 2009. Lepidoptera: moths and butterflies. In: Encyclopedia of Insects. 559-587, Academic Press, USA

Rader R, Bartomeus I, Garibaldi LA, Garratt MP, Howlett BG, Winfree R, et al. 2016. Non-bee insects are important contributors to global crop pollination. Proceedings of the National Academy of Sciences of USA, 113(1): 146-151

Ratnasingham S, Hebert PD. 2007. BOLD: The barcode of life data system. Molecular Ecology Notes, 7(3): 355-364

Regier JC, Mitter C, Zwick A, Bazinet AL., Cummings MP, Kawahara AY, Mitter KT. 2013. A large-scale, higher-level, molecular phylogenetic study of the insect order Lepidoptera (moths and butterflies). PloS one, 8(3): e58568

Robinson N, Armstead S, Deane Bowers M. 2012. Butterfly community ecology: the influences of habitat type, weather patterns, and dominant species in a temperate ecosystem. Entomologia Experimentalis et Applicata, 145(1): 50-61

Serrat A, Pons P, Puig–Gironès R, Stefanescu C. 2015. Environmental factors influencing butterfly abundance after a severe wildfire in Mediterranean vegetation. Animal Biodiversity and Conservation, 38(2): 207-220

Syaripuddin K, Sing KW, Wilson JJ. 2015. Comparison of butterflies, bats, and beetles as bioindicators based on four key criteria and DNA barcodes. Tropical Conservation Science, 8(1): 138-149

Tanda AS. 2021. Why insect pollinators are important in crop improvement. Indian Journal Entomology, e20370

Thomas JA. 2005. Monitoring changes in the abundance and distribution of insects using butterflies and other indicator groups. Philosophical Transactions of the Royal Society B: Biological Sciences, 360(1454): 339-357

Tujuba TF, Sciarretta A, Hausmann A, Abate GA. 2019. Lepidopteran biodiversity of Ethiopia: current knowledge and future perspectives. ZooKeys, 882: 87

Van Dyck H, Van Strien AJ, Maes D, Van Swaay CA. 2009. Decline in common, widespread butterflies in a landscape under intense human use. Conservation Biology, 23: 957-965

Van Halder I. 2017. Conservation of butterfly communities in mosaic forest landscapes: effects of habitat quality, diversity, and fragmentation. Doctoral dissertation, Université de Bordeaux, France

Van Swaay C, Regan E, Ling M, Bozhinovska E, Fernandez M, Marini-Filho OJ, Underhill L. 2015. Guidelines for standardised global butterfly monitoring. Group on Earth Observations Biodiversity

Observation Network, Leipzig, Germany. GEO BON Technical Series, 1: 32

Wale M, Abdella S. 2021. Butterfly diversity and abundance in the Middle Afromontane Area of Northwestern Ethiopia. Psyche: A Journal of Entomology, 2021

Warren MS, Maes D, van Swaay CA, Goffart P, Van Dyck H, Bourn NA, et al. 2021. The decline of butterflies in Europe: Problems, significance, and possible solutions. Proceedings of the National Academy of Sciences, 118(2)

Wikipedia contributors. 2021. Gozamin. In: Wikipedia, The Free Encyclopedia. https://en.wikipedia.org/w/index.php?title=Gozamin&oldid=1060869287. Accsess on 2022-1-5

Woodhall S. 2020. Field guide to Butterflies of South Africa. Bloomsbury Publishing, South Africa

Yang LH, Gratton C. 2014. Insects as drivers of ecosystem processes. Current Opinion in Insect Science, 2: 26-32