

The abundance and diversity of grasshopper communities in relation to elevation and land use in Malang, Indonesia

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Abstract. *Leksono AS, Yanuwadi B, Afandhi A, Farhan M, Zairina A. 2020. The abundance and diversity of grasshopper communities in relation to elevation and land use in Malang, Indonesia. Biodiversitas 21: 5614-5620.* Ecological factors include interactions of the community members with numerous biotic and abiotic factors such as temperature, humidity, precipitation, light intensity, and seasonality show an altitudinal gradient. Most grasshopper species play a role as herbivores and are a good source of protein for other animals such as amphibians, small reptiles, birds, and small mammals. This study aimed to analyze variations in the abundance, richness, and diversity of grasshopper species along an altitudinal gradient. This research was conducted in five locations in Malang District, East Java, Indonesia, namely Bantur, Sumber Pujung Lawang, Pujon, and Poncokusumo. Grasshopper sampling was carried out by the sweeping method using an insect net. Sweepings were carried out on four plots with each plot size of 2 x 10 m². Sampling was conducted four times from June to August 2020. The data were analyzed using the Shannon Wiener index (diversity analysis) and the Bray-Curtis index. The differences between locations were tested by one-way analysis of variance. Land use was analyzed by ArcGIS, using Landsat imagery 8. The abundance of grasshoppers had a significant negative correlation with elevation. That correlation was positive to species richness and diversity of grasshoppers. That with species diversity was significant, while that with species richness was not significant. The greatest abundance of the grasshopper was found in the middle elevation in Lawang (19.39 ± 2.12). In contrast, the highest species richness and diversity were found in the highest elevation in Poncokusumo (richness = 15.75 ± 1.60 and H' = 2.58 ± 0.11). Land use variation was not significant on abundance, species, richness, and diversity of grasshoppers. Interestingly, the high similarity of the grasshopper compositions in low elevation habitats was detected, indicating that land use in the low land area was remarkable. The abundance of grasshopper had a significant positive correlation with temperature but negatively correlated with humidity. There was no significant correlation among species richness, species diversity with temperature and humidity.

Keywords: Diversity, elevation, Malang District, Orthoptera

INTRODUCTION

Grasshoppers belong to the order Orthoptera and family Acrididae and are part of the biotic components with an important role in the ecosystem (Culliney 2013). Most grasshopper species play a role in the herbivory process in the ecosystem and are known to be a good source of protein for other animals such as amphibians, small reptiles, birds, and small mammals; therefore, their scarcity may hinder the trophic structure in an ecosystem (Soliman et al. 2017). Grasshoppers are also an important bio-indicator because of their specific habitat preferences and sensitivity to any changes in their habitat (Fartmann et al. 2012; Adu-Acheampong et al. 2016; Terra et al. 2017; Löffler et al. 2019). Of the insect group, apart from ants and butterflies, the orthoptera group includes grasshoppers, suitable for use as indicators in open habitats. Studies have shown that grasshoppers can exhibit changes in landscape quality. The number of grasshopper species in the grasslands increases with habitat heterogeneity, which is interrelated with patch size (Schirmel et al. 2010).

At the habitat level, the species richness and abundance of Orthoptera are driven by land use and the vegetation structure, and the influence of abiotic factors. Therefore, conservation management of the Orthoptera should primarily focus on increasing habitat heterogeneity and habitat quality in patches (Löffler and Fartmann 2017). Some grasshoppers act as herbivores on cultivated land so that they have the potential to become pests, for example, the locust.

The grasshopper community is greatly influenced by human activities, both in grassland and forest (van Klink et al. 2015; Ngoute et al. 2020). Agricultural livestock practices have intensified, culminating in the year 2000 in 26% of the terrestrial biome being used for livestock production as pasture or fodder crops (Gerber et al. 2010). This may pose a threat to grasshopper diversity through overgrazing, plowing, and habitat loss and fragmentation (Fahrig 2003; Latchininsky et al. 2011). Grazing thus has a large impact on a global scale due to agricultural intensification (increased stocking rates), agricultural

abandonment, and changes in wild herbivore assemblages (Donlan et al. 2006). However, species responses to landscape fragmentation are difficult to predict because they are highly dependent on dispersal capacity and the propensity to traverse inappropriate habitat patches (Blanchet et al. 2010; DiLeo et al. 2010; Lange et al. 2010).

There have been many studies on aspects of grasshopper diversity and abundance (Sirin et al. 2010; Adu-Acheampong et al. 2016; Prakoso 2017). Other studies have evaluated the distribution of orthoptera in relation to elevation (Sirin 2010; Mol and Zeybekoglu 2013). Generally, orthoptera is able to occupy a variety of habitats from low elevations to mountainous regions. Several species belonging to subfamily Gomphocerinae were collected in Black Sea Regions under three distribution range between 200 and 2460 meters above sea level in 175 different localities in Black Sea Regions (Mol and Zeybekoglu 2013). However, none of these studies did the map and specifically test the relationship between grasshopper abundance and diversity with abiotic factors and land-use diversity. This study aims to analyze variations in the abundance, richness, and diversity of grasshopper species at along an altitudinal gradient.

MATERIALS AND METHODS

Study area

This research was conducted in five study sites (Bantur, Sumberpucung, Lawang, Pujon, and Poncokusumo) in Malang District, East Java, Indonesia (Figure 1). Each site consisted of four plots. Sampling was conducted four times in the morning (07.00-10.00), June-August 2020 (represent the dry season). Grasshopper sampling was carried out by the sweeping method using insect nets on the grasslands with a plot size of 2 x 10 m². Obtained grasshoppers were put in a bottle containing 70% ethanol. The process of grasshopper specimens identifying was carried out at the Laboratory of Animal Diversity, Department of Biology, Faculty of Mathematics and Natural Sciences, Brawijaya University. The specimens were sorted, dried, and then pinned, prior to species-level identification. Small specimens were kept in alcohol, while the big ones were stored in an insectarium. Grasshopper specimens were identified based on Borror et al. (1989) supported with other studies such as Willemse (1930, 1965, 2001), Kalshoven (1981), Rentz (1991), Johnson (2008), and Tan (2012; 2017). Aerial abiotic data (temperature and humidity) were recorded during each sampling event using a digital Digital Thermohygrometer (XON MED™ HTC-2), while light intensity was recorded using a Digital Lightmeter (Krisbow™).

The data was analyzed using the Shannon Wiener index (diversity analysis), and the Bray-Curtis index. The differences between locations were tested by one-way analysis of variance. Land use was analyzed by ArcGIS, using Landsat imagery 8. The analysis was carried out on a circular area with a diameter of 1 km with land use criteria referring to the Indonesia National Standard. The relationship between abundance, diversity with abiotic

environmental factors, and land use was analyzed with the Pearson correlation. Statistical tests were performed using Excel and SPSS® version 20 (SPSS Inc. Chicago, IL, USA).

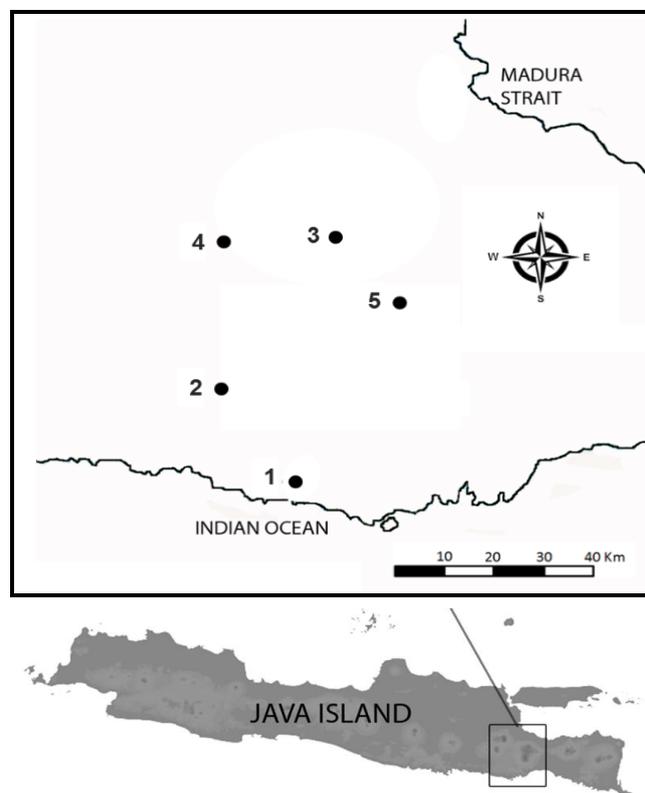


Figure 1. Location of five study sites in Malang District, East Java, Indonesia. 1. Bantur; 2. Sumberpucung; 3. Lawang; 4. Pujon; 5. Poncokusumo. (Modified from Leksono et al. 2017)

RESULTS AND DISCUSSION

Results

This study obtained 1,810 individual grasshoppers belonging to 30 species and three families. The most dominant species was *Alloteratura* sp. (24.36%), followed by *Phlaeoba fumosa* (13.43%), *Atractomorpha crenulata* (10.17%), *Oxya japonica* (8.29%), and *Acrida turrita* (7.85%) (Table 1). On the other hand, 23.3% of the collected species has narrow distribution (exist in only one location). These consisted of *Acromantis gestri*, *Ambivia undata*, *Oxya chinensis*, *Tagasta marjinella*, *Traulia azureipennis*, *Trilophida annulate*, and *Xenocatantops humilis* (Table S1). The distribution of species showed a cluster pattern at certain locations. *Alloteratura* sp., *Oxya japonica*, *Apalacris varicornis* tend to occupy low to moderate elevation habitats, whereas *Acrida turrita* tends to be abundant in medium elevation habitats. The distribution was categorized as local when the spatial distribution ranges from 1-10 km (Hortal et al. 2010).

Table 1. Number of individual dominant grasshopper species among five study sites

Species	Bnt	Sbp	Lwn	Pjn	Pnc	Total	%
<i>Alloteratura</i> sp. (***)	152	134	155	0	0	441	24.36
<i>Phlaeoba fumosa</i> (ns)	78	53	46	39	27	243	13.43
<i>Atractomorpha crenulata</i> (ns)	24	38	63	35	24	184	10.17
<i>Oxya japonica</i> (**)	67	30	32	0	21	150	8.29
<i>Acrida turrita</i> (**)	26	13	40	63	0	142	7.85
<i>Pseudoxya diminuta</i> (ns)	4	0	17	20	35	76	4.20
<i>Apalacris varicornis</i> (*)	30	24	4	0	11	69	3.81
<i>Chorthippus biguttulus</i> (ns)	0	0	18	21	11	50	2.76
<i>Asiophlugis thaumasia</i> (ns)	0	14	8	17	10	49	2.71
Miscellanies	48	92	63	41	162	406	22.43
Total	429	398	446	236	301	1810	100

Note: Bnt: Bantur; Sbp: Sumberpucung; Lwn: Lawang; Pjn: Pujon; Pnc: Poncokusumo; code inside parenthesis (* = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$ ns = not significant).

Table S1. List of species and its total abundance

Species	Bnt	Sbp	Lwn	Pjn	Pnc	Total
<i>Alloteratura</i> sp.	152	134	155	0	0	441
<i>Phlaeoba fumosa</i>	78	53	46	39	27	243
<i>Atractomorpha crenulata</i>	24	38	63	35	24	184
<i>Oxya japonica</i>	67	30	32	0	21	150
<i>Acrida turrita</i>	26	13	40	63	0	142
<i>Pseudoxya diminuta</i>	4	0	17	20	35	76
<i>Apalacris varicornis</i>	30	24	4	0	11	69
<i>Stenocatantops angustifrons</i>	0	0	18	21	11	50
<i>Asiophlugis thaumasia</i>	0	14	8	17	10	49
<i>Gesonula mundata</i>	9	0	17	0	22	48
<i>Valanga nigricornis</i>	14	12	15	0	7	48
<i>Phlaeoba infumata</i>	15	18	4	0	10	47
<i>Conocephalus fasciatus</i>	0	0	9	20	7	36
<i>Oxya chinensis</i>	0	28	0	0	0	28
<i>Tenodera australasiae</i>	0	11	0	0	13	24
<i>Sedulia specularia</i>	0	0	0	7	16	23
<i>Ceratocrania macra</i>	0	0	3	6	13	22
<i>Euconocephalus varius</i>	0	4	10	0	7	21
<i>Xenocatantops humilis</i>	0	0	0	0	20	20
<i>Traulia azureipennis</i>	0	0	0	0	15	15
<i>Trilophida annulata</i>	0	0	0	0	14	14
<i>Locusta</i> sp.	0	8	5	0	0	13
<i>Hierodula patellifera</i>	4	6	0	0	2	12
<i>Pteronemobius</i> sp.	0	0	0	4	7	11
<i>Locusta migratoria</i>	5	5	0	0	0	10
<i>Hierodula vitrea</i>	0	0	0	3	2	5
<i>Statilia maculata</i>	0	0	0	1	3	4
<i>Anchiale briareus</i>	0	0	0	0	2	2
<i>Tagasta marginella</i>	0	0	0	0	2	2
<i>Acromantis gestri</i>	1	0	0	0	0	1
Grand Total	429	398	446	236	301	1810

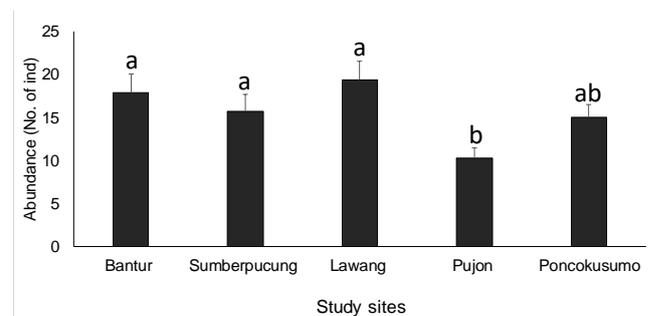
Land use variability surrounding the study sites

Landscape analysis showed that Bantur was dominated by paddy field (69.7%) and pasture land (15%). That in Sumberpucung was dominated by paddy fields (83%). Lawang was dominated by residential areas (35%), paddy field (22.4%), and cropland (22.2%). Habitat in Pujon was dominated by vegetable cropland (75.8%), while Poncokusumo was dominated by orchard (40%) and forest (48.11%) (Table 2).

Table 2. Land uses variation among five study sites

Land uses (%)	Bnt	Sbp	Lwn	Pjn	Pnc
Residential area	10	5.16	35	3	10
Paddy field	69.7	83	22.4		
Crop land	5		22.2	75.8	10
Pasture land	15				
Industrial area			5		
Orchard					30
Forest or vegetation area			9.55	17	48.11
Waterbody		10	0.46	0.32	0.19
Traffic area		1.2	3.83	1.53	1.2
Recreation area	0.3	0.64	1.56	2.35	0.5

Note: Bnt: Bantur; Sbp: Sumberpucung; Lwn: Lawang; Pjn: Pujon; Pnc: Poncokusumo

**Figure 2.** The Abundance variation of grasshopper among five study sites in Malang District, East Java, Indonesia

The abundance, species richness, and diversity across elevation and land use

The abundance of grasshopper varied among study sites. The greatest abundance of the grasshopper was found in Lawang (19.39 ± 2.12), while the lowest was in Pujon (10.26 ± 1.16). The highest species richness and diversity were found in Poncokusumo (richness = 15.75 ± 1.60 and $H' = 2.58 \pm 0.11$) (Figures 2 and 3), while the lowest was found in Bantur (richness = 8.25 ± 0.25 and $H' = 1.76 \pm 0.09$) (Figure 4).

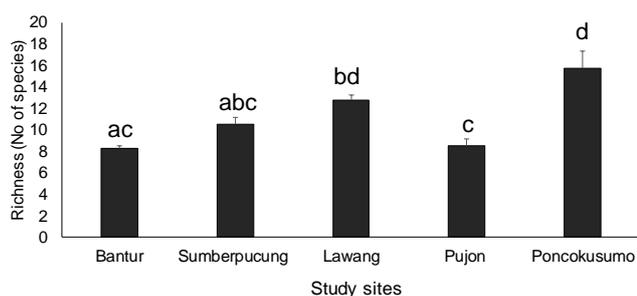


Figure 3. The species richness variation of grasshopper among five study sites in Malang District, East Java, Indonesia

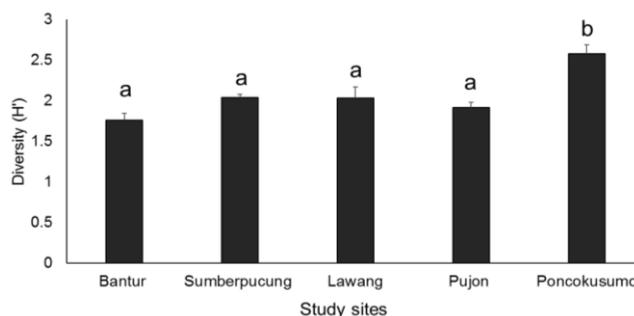


Figure 4. The diversity variation of grasshopper among five study sites in Malang District, East Java, Indonesia

There was a significant negative correlation ($P < 0.001$) between elevation and abundance. The correlation between elevation with both species' diversity and richness was positive. The correlation between elevation and species diversity was significant ($P < 0.05$) (Figure 5). The temperature was ranged from 21° to 30°C. The overall abundance had a positive correlation with temperature, and the correlation was significant ($P < 0.05$), while species richness and diversity were vice versa (Figure 6). Humidity was ranged from 60% to 73%. The overall abundance had a negative correlation with humidity, and the correlation was significant ($P < 0.05$), while species richness and diversity were vice versa (Figure 7). The correlation among species richness and diversity with temperature and humidity was not significant. The highest mean temperature was in low elevation while the lowest was found in high elevation. There were no significant correlations between land use characteristics and the abundance, species richness, and diversity of the grasshoppers.

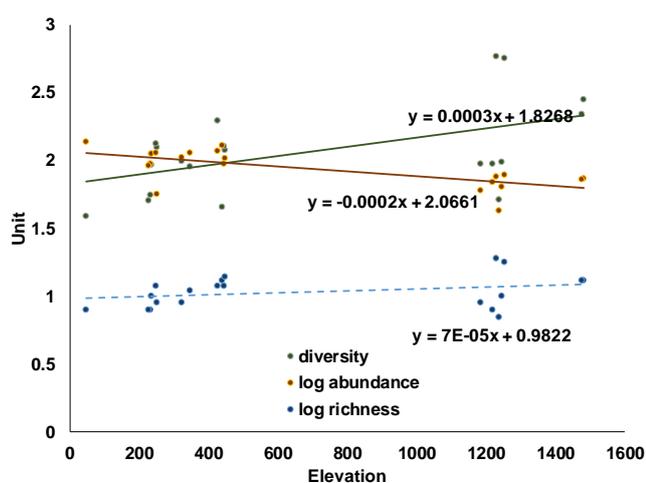


Figure 5. Correlations between elevation and grasshopper abundance, species richness, and species diversity

The grasshopper compositions were grouped into two clusters. The first was composed of Bantur, Poncokusumo, and Sumberpucung, and the second consisted of Pujon and Poncokusumo. The grasshopper compositions between Bantur and Sumberpucung were the most similar (75.9%). Those with a community in Lawang formed the first cluster with a similarity of 71.3% (Figure 8.A). This trend showed that the clustering was based on the elevation. This means that the composition of grasshoppers was influenced by the elevation factor. The high similarity of the grasshopper compositions in Bantur and Sumberpucung seems to relate to the land use composition. The land-use composition in Bantur and those in Sumberpucung was the most similar (75.9%) (Figure 8.B). In addition, the grasshopper compositions and land use composition between study sites were significantly correlated ($P < 0.01$).

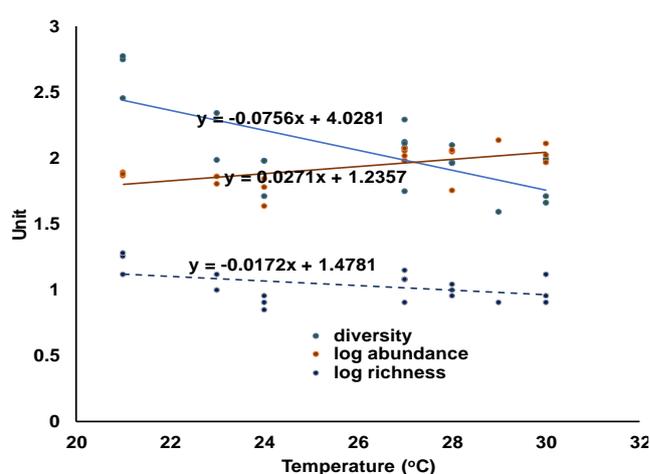


Figure 6. Correlations between temperature and grasshopper abundance, species richness, and species diversity

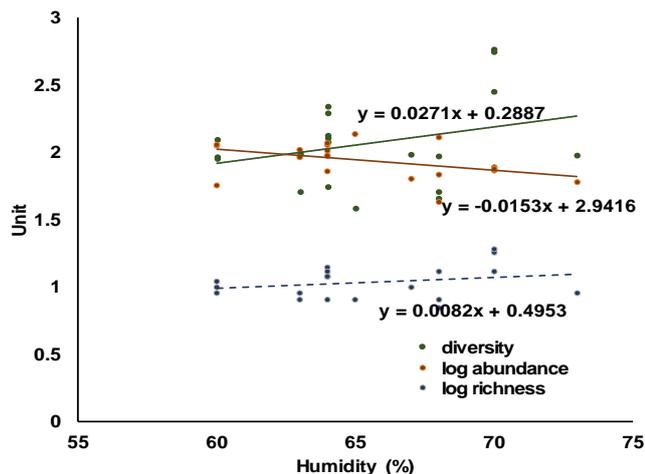


Figure 7. Correlations between humidity and grasshopper abundance, species richness, and species diversity

Discussion

This study showed that the grasshopper abundance varied among the study sites. This variation is influenced by environmental factors, including elevation, temperature, and humidity. This study indicated that land use had no effect on grasshopper abundance. According to the habitat, nine grasshopper species are common species such as *Alloteratura* sp., *Phlaeoba fumosa*, *Atractomorpha crenulata*, *Oxya japonica*, and *Acrida conica*. While, *Atractomorpha crenulata*, *Oxya hyla*, and *Hesperotettix viridis* are species commonly found in maize gardens. Furthermore, *Gesonula mundata* and *Valanga nigricornis* are common in plantation forests (Prakoso 2017). This study showed that the highest abundance of grasshoppers is found in middle elevations (400 m asl). The results of this study are supported by previous studies which state that species diversity and abundance of grasshoppers is highest in the medium lands and lower in the high and lowlands (Sirin et al. 2010). Differences in altitude, plant composition, steep nature, urbanization and livestock grazing, and latitude positions also contribute to the variation (Sirin et al. 2010).

Many factors can influence grasshopper species diversity, including resource availability, habitat structure, escape space, and predators (Joern 2004; Joern 2005). Five environmental factors, including the number of flower heads, disturbance intensity, altitude, humidity, and the cover of shrubs and trees in the wider plot area, significantly influenced the distribution pattern of the locust community, explaining 32% of the overall variance. The endemic grasshopper was strongly associated with flower headcount and humidity, whereas it was negatively related to disturbance intensity and shrub and tree cover. Humidity has a regulatory effect on the hatchery of grasshoppers and the seasonality of their life cycle. It is also important for species of conservation concern such as the endangered *C. lacustris* (Kati et al. 2006). Elevation, flower-heads abundance, low disturbance intensity, and plant species richness predict grasshopper species richness well, while the latter together with humidity predict plant

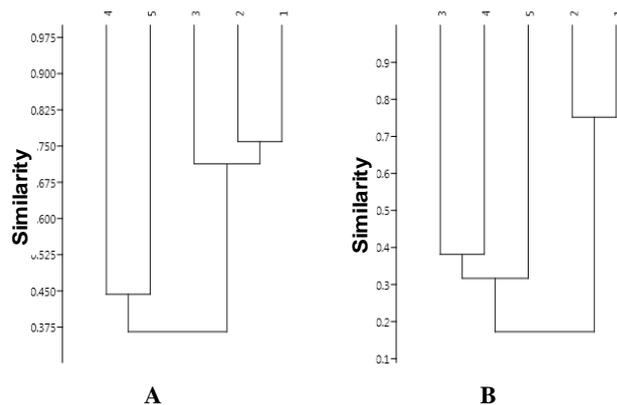


Figure 8. The similarity of grasshopper compositions (A) and Land use compositions (B) among study sites. 1. Bantur; 2. Sumberpucung; 3. Lawang; 4. Pujon; 5. Poncokusumo

species richness (Kati et al. 2012). A study on the species composition, diversity, abundance, and density of four rangelands types in China, showed that the greatest abundance of grasshoppers was found in mountain rangeland, while the lowest abundance of grasshoppers was caught in alpine shrublands (Sun et al. 2015).

This study showed that grasshopper abundance had no significant correlation with land use, but the composition had. The paddy fields exist in the lowland, while cropland and forest/vegetation areas exist in the highland. Previous research results indicated that grasshopper communities were not always associated with grassland habitats but also supported by herbaceous shrubs. The existence of this plant group supports the diversity of grasshoppers because it is associated with providing a larger source of food. Shrub and tree cover appears to be an important factor in establishing locust habitat, providing shelter, oviposition, and a source of food for some grasshopper species (Zografou et al. 2009). Many studies have examined the relationship between grasshopper communities' composition and vegetation patterns in grassland ecosystems worldwide (Joern 2005). Plant diversity often has a positive effect on grasshopper species diversity, but the relationship is sometimes inconsistent. In addition, the grasshopper diet can have an important impact on local plant abundance and community structure (Belovsky and Slade 2009). Grasshoppers are often the dominant native herbivores in grassland ecosystems worldwide, with economically devastating locust outbreaks frequently occurring in western North America (Branson et al. 2006).

Nevertheless, a number of significant associations between plant diversity and grasshopper diversity were found through regression analysis. The results were very different between years suggesting that plant species richness and diversity did not lead to a strong influence on grasshopper diversity metrics.

The pattern of variation in environmental factors, abundance, and species richness is also influenced by the relationship with orthopterofauna from adjacent areas (Jarčuška et al. 2019). Furthermore, management practices

such as livestock grazing and crop species composition are impacted by fire and then influence the species composition of grasshoppers (Joubert et al. 2016; Joern 2004). Plant species richness seems too crude to lead to accurate predictions of grasshopper species richness in this system, which is dominated by generalist grasshopper species (Branson 2010). Across all sites and grazing intensities, grasshopper abundance tended to be the lowest and diversity highest in plant communities with intermediate biomass and plant species richness (Hao et al. 2015).

The abundance and species diversity of grasshoppers varied along with an altitudinal gradient of land uses, while species richness did not differ significantly. Grasshopper compositions in low elevation have shown close similarity. This situation may associate with habitat composition. Temperature and humidity are among the important factor.

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