THE INFLUENCE OF FOREST CANOPY COVER ON FRUIT-FEEDING BUTTERFLY COMMUNITIES IN THE HUU LIEN SPECIAL-USE FOREST, LANG SON PROVINCE

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ABSTRACT

The alteration of tropical forest structures due to human activities can have negative impacts on various organism communities. The purpose of this study was to investigate how forest canopy cover affects the species composition and community structure of fruit-feeding butterflies in the karst ecosystems of the Huu Lien special-use forest, Lang Son Province. Three forest fragments with high (>80%), medium (50-80%), and low (<50%) levels of canopy cover were examined. We collected fruit-feeding butterflies using Van Someren-Rydon traps, with 30 traps deployed evenly across the three fragments from May 2022 to March 2023, recording 27 butterfly species of 557 individuals in total. The results indicated that the forest fragment with medium canopy cover had the highest species richness and diversity of fruit-feeding butterfly communities. Although most species were found in all three forest fragments, the Nonmetric Multidimensional Scaling (NMDS) analysis significantly separated the community structures of fruit-feeding butterflies among the three fragments. The two species, *Kallima incognita* Nakamura & Wakahara and *Stichophthalma fruhstorferi* Röber, were mainly found in the forest fragment with high canopy cover and were considered as indicator species for this forest type. This study demonstrated the impact of forest canopy cover on the structure of fruit-feeding butterfly communities and emphasized the importance of forest canopy cover in conserving and maintaining insect diversity in karst ecosystems.

Keywords: forest canopy cover, forest fragmentation, Fruit-feeding butterflies, karst ecosystems, the Huu Lien special-use forest.

1. INTRODUCTION

The fruit-feeding butterflies of the Nymphalidae family are often used to detect habitat changes and disturbance effects in tropical forests [1, 2]. They are mainly found in closed-canopy forests and play an important role in tropical food webs [3]. Due to their taxonomic and ecological knowledge and ease of sampling, these butterflies are well-studied in many tropical areas.

The impact of forest disturbances on the diversity of fruit-feeding butterflies in tropical regions has been studied, but the results have been inconsistent. While some studies have shown a decrease in species richness in secondary forests compared to primary forests [4], others have reported an increase in species richness in secondary forests [5], and some have found no differences in diversity [6, 7]. The butterfly communities are likely to be influenced by changes in the successional gradients of tree communities, as plants provide the primary source of biomass and physical structure in terrestrial ecosystems [8]. It is crucial to comprehend the diversity patterns of fruit-feeding butterflies as many species are specialized to specific vegetation structures [9].

Several general studies of butterfly communities in National Parks and Conservation Areas in Vietnam have recorded the species composition and diversity of fruit-feeding butterfly communities. For instance, Vu Van Lien et al. (2014) [10] identified 188 butterfly species, including 85 fruit-feeding butterflies, in three central regions, namely Dakrong Nature Reserve, Bach Ma National Park, and Ba Na-Nui Chua Nature Reserve. Vu Van Lien (2009) [11] conducted a comprehensive three-year investigation on the fruit-feeding butterfly community at Tam Dao National Park, recording 169 butterfly species. Hayes et al. (2009) [12] investigated changes in the species composition and diversity of fruit-feeding butterflies in Ba Be National Park, observing the high sensitivity of some community characteristics, such as the number and diversity of species, to different levels of forest habitat disturbance. However, as Hayes et al. (2009) [12] only examined insects at a single location with one level of disturbance (lack of replication), this study could not

provide precise conclusions about the effects of forest disturbance on insect biodiversity.

The Huu Lien special-use forest (Huu Lien) (21°37'–21°45'N, 106°19'–106°26'E) is located in Lang Son Province (North Vietnam). The total area of Huu Lien is 10,640 ha covering entire Huu Lien Commune and a part of Yen Thinh Commune of Huu Lung district (Lang Son Province). The landscape is dominated by limestone karst, with total area of 9,734 ha. Most of the limestone area (9,082 ha, 93%) are currently forests, located at an elevational range of 200–400 m above sea level (a.s.l.) [13]. The limestone karst is bisected by two flat valleys in the centre of the reserve, which run in a north-south direction. These valleys lie on an elevation of around 100 m (a.s.l.), while the highest summit in Huu Lien is Mount Kheng with a height of 638 m. Additionally Huu Lien contains freshwater ecosystems with two main streams, namely Buc and An, and the four lakes Giang Ca (125 ha), Deo Long (60 ha), Lan Dat (30 ha) and Lan Ty (19 ha) [14].

Several studies reported a high level of biodiversity in Huu Lien, with 794 vascular plant species, 57 mammal species, 23 reptile species and 14 amphibian species, of which, 31 plant species and 29 animal species are currently listed in the Vietnam Red Data Book [15]. Recently, the Huulien Tiger Gecko has been recently described from there, *Goniurosaurus huuliensis*, which is a microendemic for the region and already listed as Critically Endangered by the IUCN Red List [16].

Like most nature reserves in Vietnam, much of the natural forest area within Huu Lien, especially around settlements of ethnic minority communities has experienced strong disturbances, primarily related to clear-cutting for shifting agriculture. Consequently, Huu Lien is hosting a wide variety of habitat types. The purpose of this study is to investigate and provide the first data on the species composition and community structure of fruit-feeding butterflies, an important indicator group for environmental change, in the Huu Lien special-use forest. The results of the study will provide important scientific evidence for the management and conservation of insect diversity and ecosystems in Huu Lien.

2. RESEARCH METHODOLOGY

2.1. Research sites

The study was conducted in the Huu Lien special-use forest, located in Huu Lien commune (Huu Lung, Lang Son). The sampling sites were selected based on forest fragments with varying forest canopy covers, encompassing those with canopy covers above 80%, those with covers ranging between 50% and 80%, and areas with low canopy cover below 50%. These sites were all located at an altitude of about 200 meters above sea level and were at least 2 kilometers apart from each other.

2.2. Fruit-feeding butterfly sampling and identification

To investigate fruit-feeding butterflies, we utilized the Van Someren-Rydon trap. Ten traps were set up in each forest fragment to collect fruit-feeding butterflies. The trap had a diameter of 30 cm and a height of 110 cm, and was suspended 1-2 meters above the ground level. Fermented bananas were used as bait, as this has been found to attract a considerable number of the Nymphalidae butterfly family [17, 12]. After a five-day trap period, the fruit-feeding butterflies were collected from the traps and transported to the laboratory. They were then sorted and identified following Monastyrskii & Devyatkin (2015) [18]. The fruit-feeding butterflies were collected from each trap three times during the study period in June and August 2022, and March 2023. Traps were placed at 100-meter intervals, spaced evenly. The trapping period lasted for a total of 15 days.

2.3. Forest canopy cover

To measure forest canopy cover at each trapping site, we employed the quadrant-section method as described by Brower and Zar (1998) [19]. In brief, we marked a cross with the trap as the center point to divide each trapping site into four quadrants. Then, we estimated the forest canopy cover at each quadrant using the index proposed by Braun-Blanquet (1928) [20]. The index assigned values of 5 for canopy cover ranging from 75-100%, 4 for 50-75%, 3 for 25-50%, 2 for 5-25%, and 1 for 1-5%.

Figure 1. Van Someren-Rydon traps set up to collect fruit-feeding butterflies

2.4. Data analyses

The statistical analyses were conducted using the R software version 3.5.1 [21]. The completeness of the fruit-feeding butterfly sampling across the three levels of forest disturbances was assessed by utilizing species accumulation curves. To test for variations in species richness, abundance, and Shannon's diversity index among the different forest disturbances, we carried out both analysis of variance (ANOVA) and Tukey's post-hoc test. If necessary, log transformation of the dependent variables was performed prior to the ANOVA analysis to normalize the distribution of the data. The Shapiro-Wilk test was used to verify the normality of the data. Non-metric multidimensional scaling (NMDS) was performed to identify the structure of the fruit-feeding butterfly communities in the three forest disturbances. Bray-Curtis dissimilarities from a species relative abundance matrix were utilized for the NMDS. All the ordination plots were produced using the vegan package version 2.4-5 [22]. To identify the typical species of specific forest types according to Dufrene & Legendre 1997 [23], we conducted an indicator value analysis (IndVal) using the indicspecies package version 1.7.6 [24]. This analysis allowed us to determine the characteristic indicator species for each habitat. Species with significant IndVal exceeding 70% were considered to be indicative of the habitat.

3. RESULTS AND DISCUSSIONS

3.1. Results

3.1.1. Changes in species composition of fruit-feeding butterflies along the forest disturbance gradient

We recorded 27 fruit-feeding butterfly species from 557 individuals collected at three areas with different forest disturbance. The areas were categorized as those with high forest canopy cover (>80%), moderate forest canopy cover (50-80%), and low forest canopy cover (<50%) in the Huu Lien special-use forest, Lang Son (Table 1). Species accumulation curves, which estimated the number of fruit-feeding butterfly species using Chao's (1984) [25] at the three levels of forest disturbance, are shown in Figure 2. The species accumulation curves confirmed the effectiveness and completeness of the trapping method for investigating the butterfly community. The number of fruit-feeding butterfly species collected in these forest disturbances accounted for more than 90% of the estimated number of species according to Chao's (1984) [25].

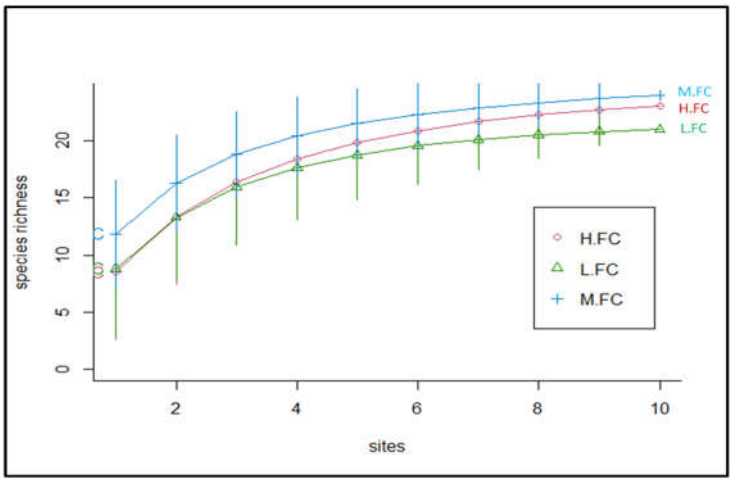

Figure 2. Species accumulation curves of fruit-feeding butterflies plotted across three levels of forest disturbance: high forest canopy cover (H.FC), medium forest canopy cover (M.FC), and low forest canopy cover (L.FC)

Table 1. Species composition of fruit-feeding butterflies recorded across three levels of forest disturbance: high forest canopy cover (H.FC), medium forest canopy cover (M.FC), and low forest canopy cover (L.FC)

	Forest canopy covers			Total
	H.FC	M.FC	L.FC	
Anthene emolus (Godart)	3	3	2	**8**
Ariadne ariadne (Linnaeus)	3	1	2	**6**
Elymnias malelas (Hewitson)	3	4	3	**10**
Elymnias patna (Westwood)	0	8	0	**8**
Euploea mulciber (Cramer)	2	3	0	**5**
Euthalia phemius (Doubleday)	1	0	2	**3**
Hypolimnas bolina (Linneaus)	2	0	0	**2**
Junonia almana (Linneaus)	0	4	0	**4**
Kallima incognita Nakamura & Wakahara	20	1	1	**22**
Melanitis leda (Linnaeus)	8	37	35	**80**
Melanitis phedima (Cramer)	7	16	12	**35**
Mycalesis annamitica Fruhstorfer	6	15	4	**25**
Mycalesis inopia Fruhstorfer	0	6	4	**10**
Mycalesis intermedia (Moore)	5	20	3	**28**
Mycalesis malsara Moore	8	11	4	**23**
Mycalesis mineus (Linnaeus)	20	27	7	**54**
Mycalesis perseoides (Moore)	12	19	21	**52**
Mycalesis sangaica Butler	0	4	0	**4**
Neptis hylas (Linnaeus)	5	9	3	**17**
Orsotriaena medus (Fabricius)	16	19	31	**66**
Penthema michallati Jane	0	7	0	**7**
Polyura athamas (Drury)	5	4	5	**14**
Rohana tonkiniana (Fruhstorfer)	7	0	3	**10**
Stichophthalma fruhstorferi Röber	23	2	2	**27**
Yasoda tripunctata (Hewitson)	2	5	5	**12**
Ypthima baldus (Fabricius)	2	1	1	**4**
Zemeros flegyas (Cramer)	1	5	15	**21**
Total	**161**	**231**	**165**	**557**

The non-metric multidimensional scaling (NMDS) analysis showed that the fruit-feeding butterfly communities were separated among the three levels of forest disturbance (Figure 3). The results of the Permutational Multivariate Analysis of Variance (PERMANOVA) indicated statistically significant differences in the community structure of fruit-feeding butterflies among these different forest disturbances (PERMANOVA, $F=12.37$, $p < 0.001$).

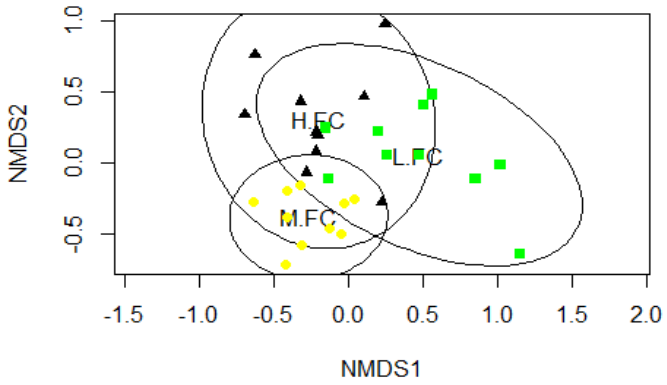

Figure 3. NMDS analysis indicated differences in the community structure of fruit-feeding butterflies among the forest disturbances: High forest canopy cover (H.FC, black), medium forest canopy cover (M.FC, yellow), and low forest canopy cover (L.FC, green)

3.1.2. Changes in the diversity of fruit-feeding butterflies along the forest disturbance gradient

The analysis of variance (ANOVA) revealed statistically significant differences in species richness ($F = 7.3$, $p < 0.01$), abundance ($F = 9.6$, $p < 0.01$), and Shannon diversity index ($F = 6.3$, $p < 0.01$) of the fruit-feeding butterflies among forest disturbances. The Tukey HSD analysis highlighted that areas with medium forest canopy cover exhibited the highest species richness, Shannon indexes, and abundances (Figure 4, Table 2).

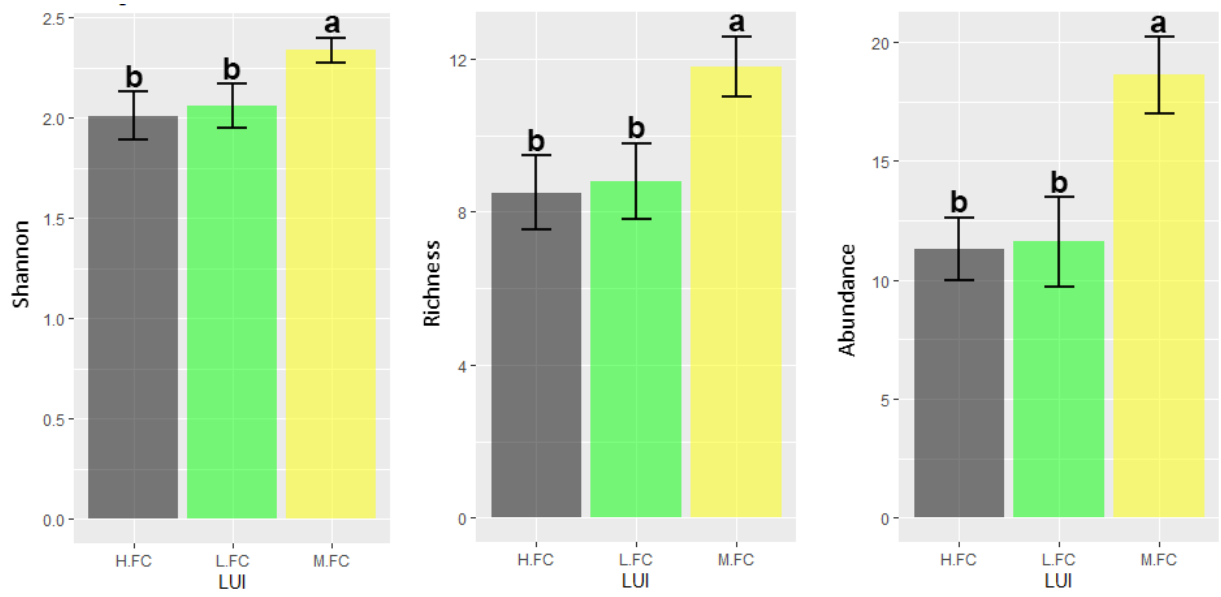

Figure 4. Error Bars illustrating changes in Shannon, richness and abundance of fruit-feeding butterflies across forest disturbances: High forest canopy cover (H.FC), medium forest canopy cover (M.FC), and low forest canopy cover (L.FC)

Table 2. Two-way Analysis of Variance (ANOVA) and pair-wise Tukey HSD test results for the number of species, individuals, and Shannon diversity index of fruit-feeding butterfly communities across different levels of forest disturbances: High forest canopy cover (H.FC), medium forest canopy cover (M.FC), and low forest canopy cover (L.FC)

Pair-wise test/ forest disturbance	F - value	*P* - value
Number of species (per trap)	F =7.3	**0.007**
M.FC – L.FC		**0.02**
M.FC – H.FC		**0.01**
L.FC – H.FC		0.06
Number of individuals (per trap)	F=9.6	**<0.001**
M.FC – L.FC		**<0.01**
M.FC – H.FC		**<0.01**
L.FC – H.FC		0.08
Shannon diversity index	F=6.3	**0.009**
M.FC – L.FC		**0.04**
M.FC – H.FC		**0.03**
L.FC – H.FC		0.07

3.2. Discussions

3.2.1. Species diversity of fruit-feeding butterflies in Huu Lien special-use forest

Research on fruit-feeding butterfly communities has been conducted in many protected areas and nature reserves in Vietnam, although the scope and intensity of these studies varied widely. Previous studies have typically focused on identifying the composition and distribution of fruit-feeding butterfly communities, with little evaluation of the effectiveness of sampling methods. For example, Vu Van Lien et al. (2014) [10] identified 188 butterfly species in central Vietnam during April to May 2013. Furthermore, the fruit-feeding butterfly community in Tam Dao National Park was investigated by Vu Van Lien (2009) [11] over three years (2002-2004), with 169 butterfly species recorded.

This study aimed to assess the effectiveness of Van Someren-Rydon traps for fruit-feeding butterfly sampling in the Huu Lien special-use forest, Lang Son. We deployed traps evenly across different levels of forest disturbances, allowing us to quantify species diversity, community structures, and the efficacy of the sampling method. We used Chao's model (1984) [25] to estimate the number of species, and we collected more than 90% of the estimated species. Our results showed that Van Someren-Rydon traps were highly effective for investigating fruit-feeding butterfly communities in this area. We identified 27 fruit-feeding butterfly species, reflecting a high level of diversity in the Huu Lien special-use forest.

Overall this study provided data on species composition and distribution of fruit-feeding butterfly communities according to different levels of forest disturbances, providing a basis for further research on the fruit-feeding butterfly communities in the Huu Lien special-use forest. While the initial results indicated a high level of species diversity in the fruit-feeding butterfly communities in forest habitats, additional butterfly species in other ecosystems and landscapes within this nature reserve require investigation in the future. Moreover, the present study highlighted the importance of assessing the efficacy of sampling methods and investigating butterfly communities across different forest disturbances to promote a comprehensive understanding of butterfly ecology. Our study contributes to the understanding of butterfly ecology in tropical forests and highlights the importance of assessing the efficacy of sampling methods.

3.2.2. Changes in community structure of fruit-feeding butterflies across different forest disturbances

Changes in the composition and structure of fruit-feeding butterfly communities across different habitats have been described in various studies [17, 26, 27]. Most studies have shown a high sensitivity of fruit-feeding butterfly communities to changes in the habitat. Our findings were consistent with previous studies, indicating differences in species composition, and species diversity among different levels of forest disturbances. Secondary forests are known to support high species diversity for many insect groups when natural forest areas decrease. This study provided evidence to support this argument, showing a high diversity of fruit-feeding butterfly communities in recovered secondary forests, even higher than in natural forests with high forest canopy cover. Two fruit-feeding butterfly species including *Kallima incognita* Nakamura & Wakaharaand *Stichophthalma fruhstorferi* Röber, were mainly found in secondary forests with high forest canopy cover, and are considered as indicator species (IndVal >70%) for this habitat. The forest type consists primarily of bamboo trees mixed with other tree species.

Although most fruit-feeding butterfly species (18 species) had a wide distribution, occurring at all three forest disturbances (Figure 5), their abundance (number of individuals) varied greatly between forest disturbances. This has led to changes in the community structure of fruit-feeding butterflies between forest statuses (Figure 3), which may affect the ecological functions of the fruit-feeding butterfly communities.

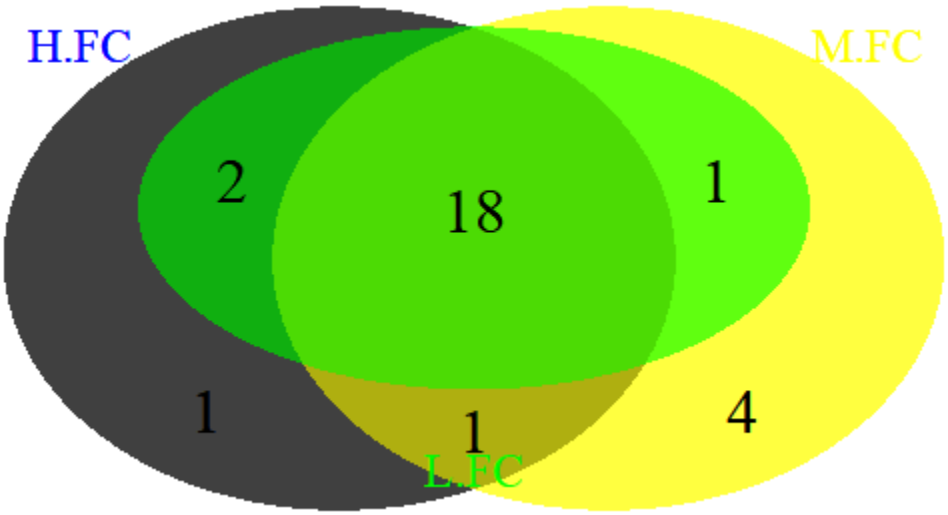

Figure 5. Venn diagram showing the number of fruit-feeding butterflies occurring in uniquely and in common in three levels of forest disturbances: High forest canopy cover (H.FC), medium forest canopy cover (M.FC), and low forest canopy cover (L.FC)

4. CONCLUSIONS

This study presents significant findings regarding the species diversity and community structure of fruit-feeding butterfly populations in the Huu Lien special-use forest in Lang Son. Through our study, we identified a total of 27 fruit-feeding butterfly species, which indicates a high degree of species diversity in the reserve. Additionally, our analysis unveiled noteworthy distinctions in the community structure of fruit-feeding butterflies within varying levels of forest disturbances, indicating the vulnerability of these communities to changes in their habitat. Notably, our findings indicated that secondary forests with moderate forest canopy cover displayed the highest levels of species richness, Shannon diversity indices, and population densities, which may hold crucial implications for ecological processes. Our study underscores the

importance of assessing sampling techniques and exploring butterfly communities across different forest disturbances to advance a comprehensive understanding of butterfly ecology. In the future, it is crucial to investigate fruit-feeding butterfly communities across other ecosystems and landscapes within the reserve to further enrich our knowledge of butterfly ecology in tropical forests.

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I would like to express my sincere gratitude to the Management Board of the Huu Lien special-use forestin Lang Son province for allowing me to conduct my field research on their site. The article presented here is the outcome of my basic scientific research task titled "Assessing the role of fruit-feeding butterfly communities as biological indicators in different habitats within Huu Lien special-use forest, Lang Son" (LN-QM-2022.3), which was carried out in accordance with Decision No. 526/QD-DHLN-KHCN issued on March 15, 2022, by the Rector of the Vietnam National University of Forestry.

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ẢNH HƯỞNG CỦA ĐỘ CHE PHỦ RỪNG TỚI QUẦN XÃ BƯỚM ĂN QUẢ TẠI RỪNG ĐẶC DỤNG HỮU LIÊN

Bùi Văn Bắc, Bùi Thế Đồi

Trường Đại học Lâm nghiệp

TÓM TẮT

Tác động của con người làm thay đổi cấu trúc rừng nhiệt đới có thể ảnh hưởng tiêu cực đến thành phần và cấu trúc của nhiều quần xã sinh vật. Nghiên cứu này được thực hiện để đánh giá ảnh hưởng của độ che phủ rừng đến thành phần loài và cấu trúc quần xã bướm ăn quả tại rừng nhiệt đới trên núi đá vôi thuộc Rừng đặc dụng Hữu Liên, Lạng Sơn. Các phân mảnh rừng được điều tra tương ứng với ba mức độ che phủ rừng khác nhau: cao (>80%), trung bình (50-80%) và thấp (<50%). Bướm ăn quả được thu thập bằng bẫy Van Someren-Rydon. Tổng cộng 30 bẫy được sử dụng và thiết lập đều trên ba phân mảnh rừng. Từ tháng 5 năm 2022 đến tháng 3 năm 2023, 27 loài bướm từ 557 cá thể đã được thu thập. Kết quả cho thấy quần xã bướm ăn quả tại khu vực rừng có độ che phủ trung bình có mức độ phong phú và đa dạng loài cao nhất. Mặc dù hầu hết các loài bướm ăn quả được tìm thấy ở cả ba phân mảnh rừng, phân tích đa hướng không gian (NMDS) cho thấy sự khác biệt rõ rệt trong cấu trúc quần xã bướm ăn quả giữa ba phân mảnh rừng. Hai loài *Kallima incognita* Nakamura & Wakahara và *Stichophthalma fruhstorferi* Röber được tìm thấy chủ yếu ở phân mảnh rừng có độ che phủ rừng cao và được xem xét là loài chỉ thị cho trạng thái rừng này. Nghiên cứu đã làm sáng tỏ ảnh hưởng của độ che phủ rừng đối với cấu trúc quần xã bướm ăn quả và nhấn mạnh tầm quan trọng của độ che phủ rừng trong bảo tồn và duy trì tính đa dạng sinh học côn trùng.

Từ khóa: Bướm ăn quả, độ che phủ rừng, hệ sinh thái núi đá vôi, phân mảnh rừng, Rừng đặc dụng Hữu Liên.

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