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Butterfly Diversity in a Rapidly Developing Urban Area: A Case Study on a University Campus

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Abstract: University campuses, as small and isolated areas of rapidly growing urban areas, can provide a unique opportunity for urban biodiversity research, conservation, education, and citizen science by monitoring assemblages of butterflies within their areas. We surveyed butterfly biodiversity in a rapidly developing urban area represented by the Chenggong Campus of Yunnan University in southwestern China using the Pollard walk method. In total, 3625 butterfly individuals belonging to 50 species, 35 genera, and six families were recorded in this survey. The results showed that the families Pieridae and Nymphalidae are the families with the highest species richness on the campus, and that the family Riodinidae contained the fewest species. *Pieris rapae* was the most common species, and seven species assessed by the IUCN Red List were recorded. Butterfly community structure varied across habitats and seasons on campus, and butterfly diversity was higher in spring and autumn than it was in summer and winter, as well as being higher in road habitats than in scenic habitats. Unavoidable urbanisation activities (construction, green space planning, etc.) may have influenced the composition and diversity of butterflies, and conserving urban butterfly diversity requires a balance between urban planning and habitat diversity. Finally, we encourage universities and research institutions to develop butterfly monitoring platforms for citizen scientists to participate in.

Keywords: biodiversity; lepidoptera; urbanisation; recent construction site; citizen science

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1. Introduction

Urban biodiversity reflects the complex relationship between cities, organisms, humans, and the environment, which serves as an excellent example of the state of urban ecological balance [1]. Different from traditional biodiversity research, cities need to focus on reconciling economic development with biodiversity conservation, while hoping that biodiversity will also bring economic and social benefits to them in a sustainable manner [2,3]. However, as urban sprawl and urban lifestyle intensifies around the world, primary habitats for wildlife within cities have become scarcer, and the connection between humans and nature is diminishing [4–6]. The loss of positive interactions between humans and nature would not only damage people's cognitive (ecological knowledge) and emotional relationships with nature (emotional connection to nature), but could also affect people's ability to experience, express concern for, benefit from, and take action to protect nature [7,8].

Recent studies have revealed that the impacts of the urban environment on biodiversity can occur on a very small scale, especially in areas with high greenspace coverage [9–11]. Exploring biodiversity on university campuses, smaller and isolated but important patches of urban landscape, has also received increasing attention [12]. Most Asian university campuses have physical boundaries (e.g., walls and fences) and are often viewed by researchers as "private gardens" in the urban area, and biodiversity patterns within campuses are therefore often of interest to some of the "masters (e.g., ecologists and conservationists)" [13,14]. Developing wildlife and community biodiversity experiences on university campuses can provide a unique opportunity for urban biodiversity research, conservation, and education [14,15]. This approach could increase citizens' connection to nature [16], promote their understanding and learning about the environment [17,18], help them gain ideal field experience of collecting biodiversity data while participating in biodiversity conservation at a small scale (their neighbouring environment) [19–21], and ultimately increase their sense of responsibility to protect nature [22–24].

Biodiversity research on Chinese university campuses is relatively limited, with the available ones mainly focusing on plants and birds [14]. Surveys of butterfly diversity in ecosystems are now an important tool with which to facilitate urban green space planning [25], land resource management, and ecosystem restoration [26,27], as well as developing citizen science [28,29]. The Chenggong Campus of Yunnan University is located in the Chenggong District of Kunming, Yunnan Province, China—an area with megabiodiversity where the Kunming-Montreal Biodiversity Framework was agreed upon recently [30]. The campus is covered by large areas of green spaces with a wide spectrum of garden plants, providing various habitats for certain butterflies and phytophagous animals [31]. However, current management such as construction, maintenance, and greening activities have been continuously disturbing the green spaces and secondary vegetation on the campus, affecting the survival and activities of urban-dwelling organisms in this ecosystem, including butterflies [11,32].

Butterflies are a group of conspicuous insects with great aesthetic, cultural, economic, and ecological value [22,33–35]. Furthermore, butterflies are very sensitive to environmental changes and easy to observe and identify in the field. Therefore, they are selected as key biodiversity indicators by many countries [34]. Moreover, when appreciating the charismatic wing patterns and elegant gliding behaviour of butterflies, the emotional bridge between humans and nature could be restored effectively [36–39]. However, such valuable butterfly assets on the university campus have long been neglected by teaching, training, management, and even biodiversity monitoring schemes [14,40–42]. This neglect has already created a substantial knowledge gap in modern biodiversity conservation, hindering effective urban planning and management in this aspect [43].

This research aims to unveil the current species assemblage and diversity of butterflies on a university campus in Kunming, China, and to understand how management and disturbances on the campus interact with butterfly populations and distribution. The findings of this research will firstly compensate for the lack of arthropod indicators on the campus and the missing biodiversity data in large-scale monitoring schemes, while providing eco-friendly methods for the future greening management. Furthermore, carrying out such a survey on the university campus would also increase public attention towards butterfly diversity and conservation among students, which would benefit the future development of citizen science for biodiversity conservation in Kunming.

2. Materials and Methods

2.1. Research Area

The Chenggong Campus of Yunnan University is located in the southeastern part of Kunming, Yunnan Province, China (Figure 1), covering a total area of 309.27 ha. The centre of the campus is located at 102.85° E and 24.83° N, with the highest elevation at 2001 m and the lowest at 1938 m. The overall elevation difference is less than 100 m, and forms a hill towards the middle of the field [44].

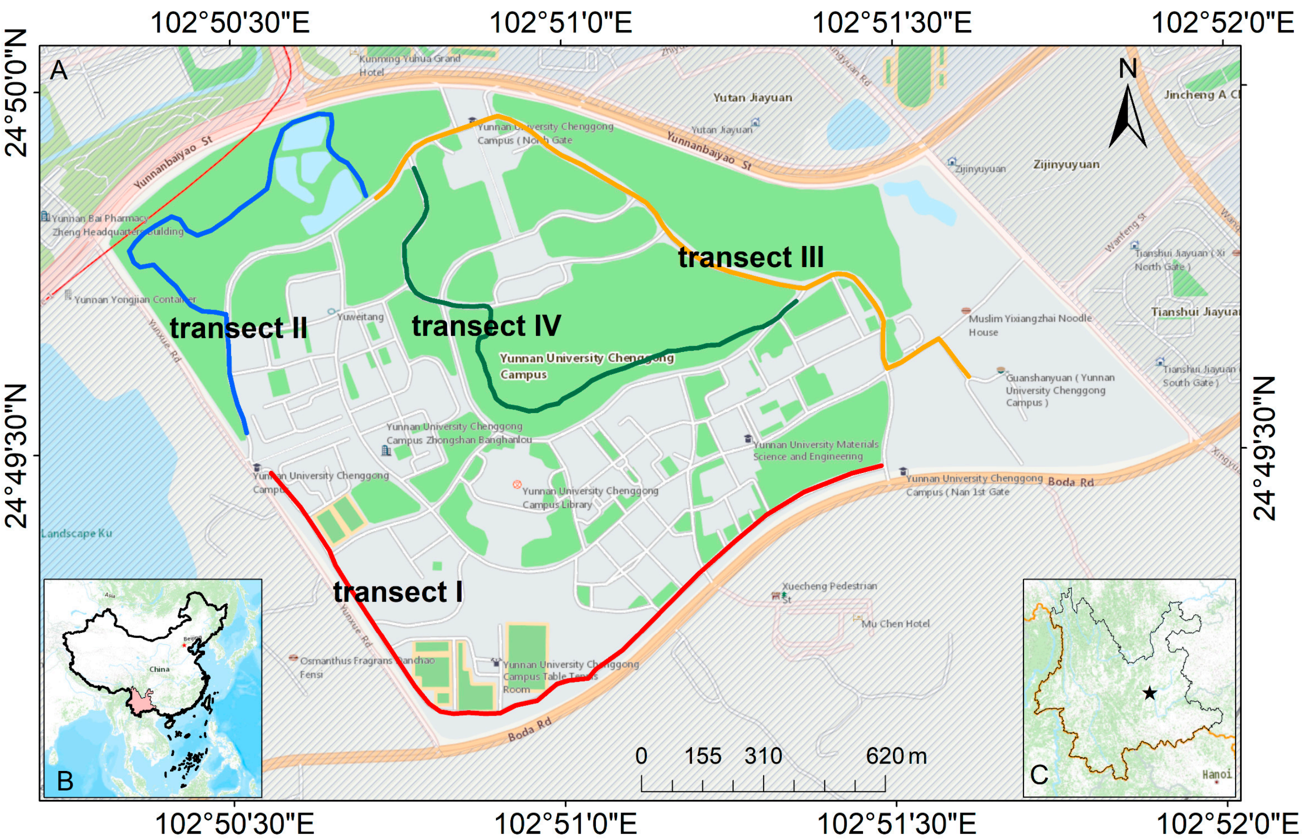

Figure 1. A map of the Chenggong Campus of Yunnan University and the setting of transects. (**A**) Map of the Chenggong Campus of Yunnan University, with green patches for green spaces, grey sections for constructed areas, and white lines for roads. The four transects are drawn in different colours: red for transect I; blue for II; orange for III; and dark green for IV; (**B**) country and province locations where the study area is located (the black border is the Chinese national boundary and the pink area is Yunnan Province; (**C**) the province where the study area is located, with a black asterisk indicating the location of the study area.

The construction of the campus started in 2006 with the conversion of agroecosystems into constructed areas, green spaces, water bodies, and bare land [45]. By 2018, the green spaces on the campus reached 129.13 ha, accounting for 41.75% of the campus' total area, and they are dominated by common urban greening plants, including *Cinnamomum camphora*, *Photinia glomerata*, *Cerasus cerasoides*, *Verbena bonariensis*, *Salvia rosmarinus*, *Lavandula angustifolia*, *Ligustrum japonicum*, *Oxalis debilis*, *Euphorbia peplus*, and *Vicia sepium*.

The area is a typical low-latitude plateau region with a mild climate characterised by small annual and large daily temperature ranges (Figure 2). During the past five years (2018–2022), the average temperature at the Chenggong Campus of Yunnan University has been 15.58 °C, with a maximum temperature of 31.50 °C and a minimum temperature of −5.00 °C. The average temperature in the coldest month (January) was 8.92 °C, while that in the warmest month (July) was 20.39 °C. Rainfall in the area is mainly concentrated between June and September, and the average monthly precipitation is greater than 100 mm. However, February, March, November, and December had much lower precipitation (less than 20 mm) (data sources: WheatA (http://www.wheata.cn (accessed on 20 March 2023)).

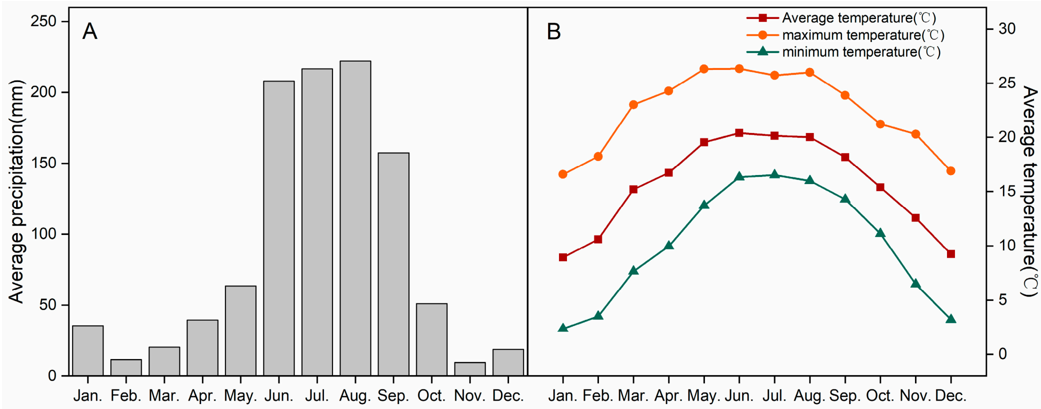

Figure 2. The monthly average precipitation (**A**) and monthly average temperature (**B**) for the past five years (2018–2022) for the area where the Chenggong Campus of Yunnan University is located.

2.2. Definition of Seasons

The definition and change of seasons is important for understanding the temporal dynamics of biodiversity, while biodiversity shifts can also reflect seasonal changes [46]. To better study the dynamics of butterfly diversity on the campus over the course of a year, we referred to *Division of Climatic Seasons* (GB/T 42074-2022) of China Meteorological Administration and Trenberth's climatic division criteria for the northern hemisphere using meteorological methods [47–49]. The survey used the meteorological division of seasons by months, with March to May, June to August, September to November, and December to February being defined as spring, summer, autumn, and winter, respectively.

2.3. Transect Settings

We employed the Pollard walk method to survey transects on the Chenggong Campus of Yunnan University [50,51]. The campus has a limited elevation change and a distinct urbanised character. Accordingly, we set four transects along the internal roads on the campus before the survey. Each transect is 2.5 m wide, and between 1.74 and 2.15 km long (Figure 1, Table 1).

Table 1. Distribution of butterfly monitoring transects and their habitat types on the Chenggong Campus of Yunnan University.

Transect	Start and End Coordinates	Transect Length/m	Elevation Range/m	Habitat Type	Type of Disturbance
I	102.856644, 24.827453 102.841152, 24.827718	2152	1952–1993	Campus road habitat	Human life disturbances: daily travel, physical activity, vehicular traffic, etc.
II	102.840729, 24.828334 102.843720, 24.833994	1735	1954–1955	Campus scenic habitat	Green pruning activities, pedestrian viewing, unscheduled building construction, etc.
III	102.843896, 24.833945 102.859606, 24.828714	2050	1955–1994	Campus road habitat	Human life disturbances: daily travel, vehicular traffic, etc.
IV	102.854640, 24.831672 102.844871, 24.834721	1745	1955–2001	Campus scenic habitat	Green pruning activities, pedestrian viewing, unscheduled building construction, etc.

The green spaces on the campus are divided into two types of habitats through four transects (Figure 3). Transects I and III represent the campus road habitat (RH), and the plant composition is mainly roadside trees and green shrubs, including *C. camphora*, *P. glomerata*, *Michelia chapensis*, *Cedrus deodara*, and *Celtis tetrandra*. This habitat plays a major role in student activity and vehicle traffic, and is susceptible to repeated disturbances from the daily peaks of student activities and traffic before and after classes. Transects II and IV represent the green spaces of the campus scenic habitat (SH), and are dominated by rose gardens, pear orchards, lavender gardens, and artificial scenic water bodies. These areas provide spaces for ornamental, recreational, ecological, and landscape functions, which are mainly disturbed by pedestrians, green maintenance, and unscheduled minor construction. The two types of habitats differ markedly in terms of plant species composition as well as the types and degree of disturbances.

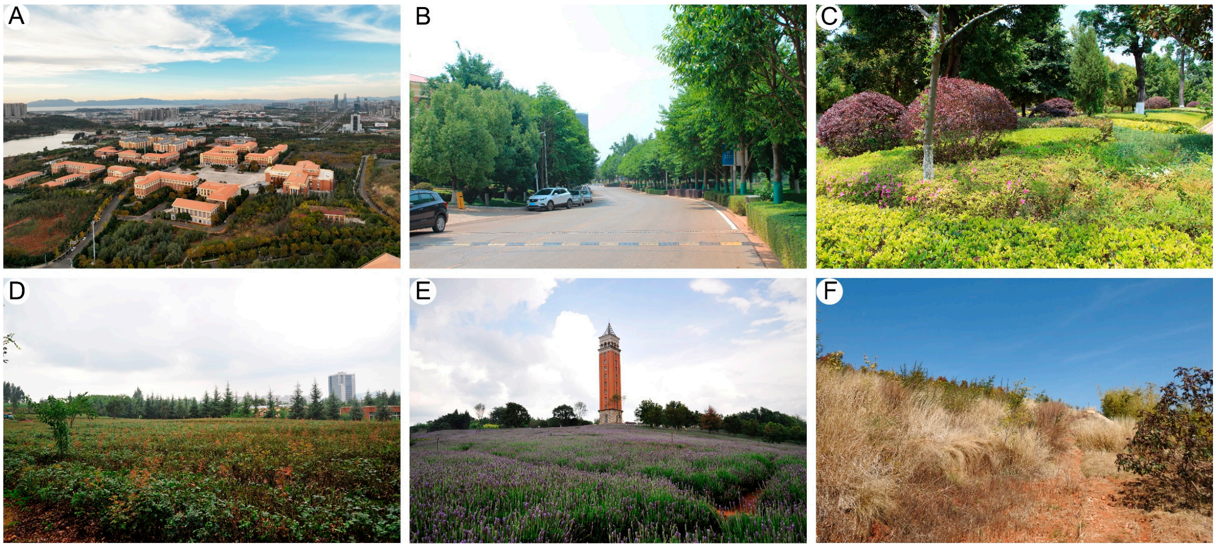

Figure 3. Landscape photos of habitat types. (**A**) Aerial view of a partial campus in a corner of the urban area; (**B**) campus road habitats that are susceptible to repeated disturbances from student activity and vehicle traffic; (**C**) a variety of plants comprising roadside greening; (**D**) a rose garden as a scenic spot; (**E**) a lavender garden on the campus that provides ornamental and recreational functions; (**F**) undeveloped wild land (now converted into green spaces for campus scenery) near the scenic site in 2022.

2.4. Butterfly Observation and Sampling

Multiple persons with interests in butterflies were invited to the observation task through online publicity and volunteer recruitment. Volunteers were led by the organisers through technical training in the field before the actual observation.

The approach was as follows: two persons formed an observation team, with one person carrying out observation and counting and the other recording and collecting specimens that could not be identified in the field. The observer should be a person with capacity in identifying butterflies. The two persons simultaneously maintained a speed of 1–1.5 km/h along the transect while recording the species and number of individuals within a 125 m^3 space, i.e., 2.5 m to the left and right of the observer, 5 m in front of them, and 5 m above them. It was important to note that the observers were required not to record the same butterfly repeatedly and any butterflies that flew up from behind. The recorders could use a camera (e.g., Nikon P900s and Canon 80D in this study) to record perching, nectaring butterflies, or net flying ones for identification. Those that could not be identified were counted, collected, and brought back to the laboratory for further identification. The counting criteria and data recording methods followed the Technical Guidelines for Biodiversity Monitoring—Butterflies (HJ 710.9-2014) [52], a standardised and effective method to produce comparative results, as well as to enhance citizen science in the university.

After training, the actual survey was conducted from October 2021 to October 2022, four times a month with a one-week interval between surveys. Each survey was carried out when the weather was sunny, and the wind speed was less than 40 km/h. The daily observation time was from 9:00 to 17:00, while extremely hot weather in summer was avoided.

2.5. Data Analyses

2.5.1. Species Assemblage and Conservation Status

The data recorded from the transects were imported into Microsoft Excel 2016 for summarisation, and the butterfly species and the number of individuals in different seasons and habitats were classified and organised. These results were visualised using chord diagrams between different butterfly species and seasons or habitats using the packages "circlize" [53] and "statnet" [54] of R 4.2.2 (http://www.r-project.org (accessed on 2 June 2023)) [55].

The conservation status of the butterfly species recorded in this survey was assessed with the IUCN Red List of Threatened Species (http://www.iucnredlist.org (accessed on 15 March 2023)) and *Chinese Species Red List (Volume 3): Invertebrates* [56]. The threatened levels were collated to provide clues for future assessment for the conservation of urban butterflies.

2.5.2. Diversity and Seasonal Dynamics

We used the Hill number, q, to compare the species diversity of butterfly communities on the campus. The Hill number, q (or effective number of species), integrates species richness and relative species abundance and is statistically more rigorous than other diversity indices [57–59]. Specifically, species richness (q = 0) focuses only on the presence or absence of species, counting species equally without considering their abundance. Larger values indicate greater species richness in a community. Shannon diversity (q = 1) is estimated as a proportional count of species abundance, and can be interpreted as the effective number of common species in the community. Simpson diversity (q = 2) is estimated from dominant species counts and reflects the effective number of dominant species in the community [60–62]. In this analysis, the species diversity of butterfly communities was estimated and visualised using 200 bootstrap replications and 95% confidence intervals (CI) using the packages "iNEXT" [63] and "ggplot2" [64] for R 4.4.2 [59,65]. When the confidence intervals (CI) overlaps, there is no statistically significant difference in the diversity index between butterfly communities. Furthermore, nonmetric multidimensional scaling (NMDS) based on Bray–Curtis distance and analysis of similarities (ANOSIM) and in the R package "vegan" [66] were used to assess differences in butterfly community structure between habitats and seasons. The datasets for running R analysis are available from the Supplementary Materials (Table S4).

The species and numbers of individuals of butterflies in different habitats change with the seasons [67]. Such changes in the butterfly community on the campus were visualised using line graphs in Origin 2018 to reflect seasonal changes in different butterfly families.

3. Results

3.1. Species Assemblage and Conservation Status

3.1.1. Species Assemblage

In total, 3625 butterflies were recorded over a cumulative period of 192 h. The sampled butterflies belonged to 50 species of 35 genera in six families (Table 2, Figure 4). Among the six families, Nymphalidae (14 genera and 17 species) and Pieridae (10 genera and 16 species) were the two most speciose families, accounting for 40.0% and 28.6% at the genus level, and 34.0% and 32.0% at the species level, respectively. Families Papilionidae (three genera and eight species) and Lycaenidae (four genera and four species) were far less speciose, while the family Riodinidae was the least (one genus and two species). In terms of the number of individuals, the greatest number of individuals was recorded in family Pieridae, with 2469 individuals, which accounted for 68.1% of the total sampled individuals, including the highest number of individuals of *Pieris rapae* (1308 individuals). The second was family Nymphalidae with 575 individuals, of which the most numerous species was *Ypthima baldus* (351 individuals), with only one individual recorded for *Polyura* *athamas*, *Dilipa morgiana* and *Callerebia polyphemus*. Lycaenidae and Papilionidae comprised 455 and 110 individuals, respectively; the highest number of individuals were *Lampides boeticus* (297 individuals) and *Graphium cloanthus* (71 individuals), respectively. The lowest number recorded was in the family Riodinidae, with only six individuals (0.2%) of *Dodona durga* (four individuals) and *Dodona ouida* (two individuals).

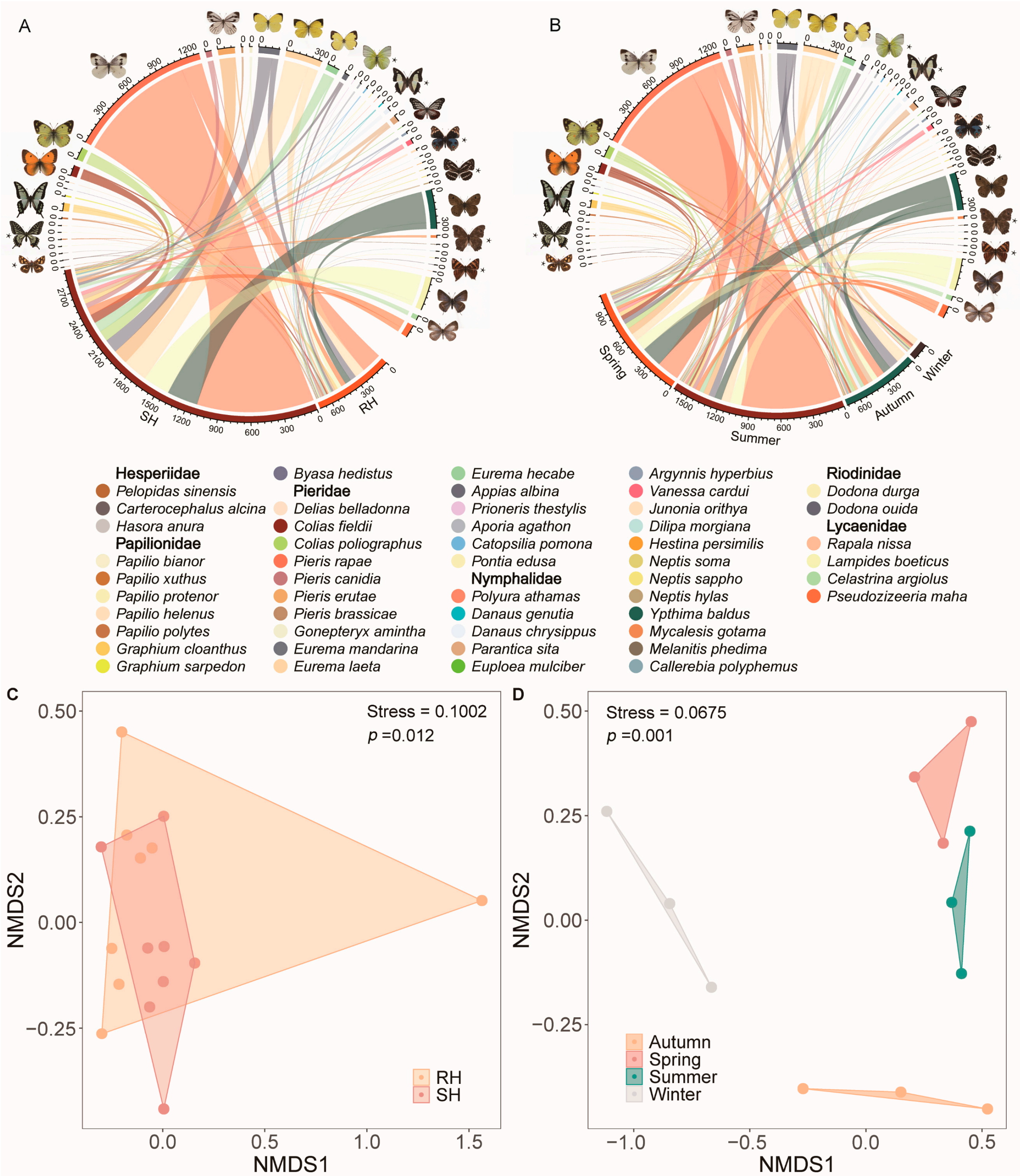

Figure 4. Habitat (**A**) and seasonal (**B**) associations of 3625 individuals of 50 butterfly species on the Chenggong Campus of Yunnan University, and nonmetric multidimensional scaling (NMDS) ordination of all sampling units indicating the relative differences in butterfly community composition

between habitats (**C**) and seasons (**D**). The presence of a link implies the distribution of that butterfly in a certain season or habitat. The width of the link between the butterfly species and each season or habitat shows the number of butterflies that were sampled in the associated season or habitat. The numbers in the upper half of the circle indicate the number of individuals of each butterfly species. The numbers in the lower half of the circle indicate the number of individuals sampled in each season or habitat. Abundant and rare (asterisk) species are shown through specimen photos. RH, road habitat; SH, scenic habitat. Spring, March to May; Summer, June to August; Autumn, September to November; Winter, December to February of the next year. Significance level: $p < 0.05$.

Table 2. The composition and proportion of butterfly communities in the family, genera, species, and individuals at the Chenggong Campus of Yunnan University.

Family	No. of Genera	Percentage	No. of Species	Percentage	No. of Individuals	Percentage
Hesperiidae	3	8.6	3	6.0	10	0.3
Papilionidae	3	8.6	8	16.0	110	3.0
Pieridae	10	28.6	16	32.0	2469	68.1
Nymphalidae	14	40.0	17	34.0	575	15.9
Riodinidae	1	2.9	2	4.0	6	0.2
Lycaenidae	4	11.4	4	8.0	455	12.6
Total	35	100	50	100	3625	100

3.1.2. Species Diversity

Our analysis showed that the family Nymphalidae (17.0 ± 5.4) had the greatest species richness, followed by family Pieridae (16.0 ± 0.4), while family Riodinidae had the lowest species richness (2.0 ± 0.2). Both Shannon and Simpson diversity indices reached the highest in family Pieridae followed by family Nymphalidae, with the lowest in family Riodinidae. However, the remaining families differed in Shannon and Simpson diversity indices. Specifically, the order of Shannon diversity index values was Pieridae > Nymphalidae > Papilionidae > Hesperiidae > Lycaenidae > Riodinidae, and that of Simpson diversity index was Pieridae > Nymphalidae > Hesperiidae > Papilionidae > Lycaenidae > Riodinidae (Table 3).

Table 3. Differences in species richness, Shannon diversity, and Simpson diversity between different families of butterfly species within the Chenggong Campus of Yunnan University (Mean ± SE).

Diversity Index	Species Richness	Shannon Diversity	Simpson Diversity
Hesperiidae	3.0 ± 0.5	2.6 ± 0.5	2.4 ± 0.6
Papilionidae	8.0 ± 1.4	3.4 ± 0.4	2.2 ± 0.2
Pieridae	16.0 ± 0.4	5.4 ± 0.1	3.2 ± 0.1
Nymphalidae	17.0 ± 5.4	4.6 ± 0.3	2.5 ± 0.2
Riodinidae	2.0 ± 0.2	1.9 ± 0.3	1.8 ± 0.4
Lycaenidae	4.0 ± 0.5	2.4 ± 0.1	2.0 ± 0.1

3.1.3. Conservation Status of Surveyed Species

The IUCN Red List Global Assessment included seven butterfly species found on the Chenggong Campus of Yunnan University, all of which were assessed as being of the Least Concern (LC) (Table 4), while the remaining 43 butterfly species are Not Evaluated (NE) as of yet. In comparison, the Regional Assessment of *Chinese Species Red List (Volume 3): Invertebrates* recorded three threatened species, including two Near-Threatened (NT) species, *Prioneris thestylis* and *Dilipa morgiana*, and one Vulnerable (VU) species, *Byasa hedistus*, recorded on the campus (Table 4); the remaining species are also Not Evaluated (NE) as of yet.

Table 4. List of butterfly species surveyed at the Chenggong Campus of Yunnan University that are evaluated in the IUCN Red List Global or *Chinese Species Red List*.

Family	Species	IUCN Global	China Species Red List
Papilionidae	*Graphium sarpedon*	LC	LC
	Byasa hedistus	LC	VU
Pieridae	*Prioneris thestylis*	NE	NT
	Eurema hecabe	LC	LC
Nymphalidae	*Dilipa morgiana*	NE	NT
	Junonia orithya	LC	LC
	Danaus chrysippus	LC	LC
	Vanessa cardui	LC	LC
Lycaenidae	*Lampides boeticus*	LC	LC

Note: LC, Least Concern; NT, Near-Threatened; VU, Vulnerable; NE, Not Evaluated.

3.2. Spatial Variation in Butterfly Community

3.2.1. Species Assemblage and Habitat Associations

Briefly, 39 species (717 individuals) were recorded in the road habitats, while 43 species (2908 individuals) were recorded in scenic habitats (Figure 4A, Table S2). *Pieris rapae* was the most abundant butterfly species in both habitat types, with 196 and 1112 individuals recorded, respectively. *Eurema laeta*, *E. mandarina*, and *Ypthima baldus* were also abundant in road habitats along with *P. rapae*. *Hasora anura*, *Pelopidas sinensis*, *Papilio protenor*, *Colias polyphemus*, and *Dodona durga*, which were only recorded in road habitats. In scenic habitats, *Y. baldus* (293 individuals), *Lampides boeticus* (257 individuals), and *E. laeta* (234 individuals) were among the most abundant species following *P. rapae*. Eleven species of butterflies were only recorded in scenic habitats, namely *Danaus chrysippus* (33 individuals), *Mycalesis gotama* (22 individuals), *P. brassicae* (16 individuals), *Delias belladonna* (4 individuals), *Melanitis phedima* (3 individuals), *Euploea mulciber* (2 individuals), *B. hedistus* (1 individual), *Hestina persimilis* (2 individuals), *Polyura athamas* (1 individual), *D. morgiana* (1 individual), and *Rapala nissa* (1 individual). Furthermore, NMDS analysis based on the Bray–Curtis distance matrix showed differences in butterfly community structure between road habitats and scenic habitats on the university campus (stress = 0.1002; p = 0.012. Figure 4C).

Photographic records showed that butterflies on the campus tend to rest on bushes, greening trees, or open spaces along roads. Flowers, either planted or wild, along roadsides are good nectar sources for butterflies. Gardens or water puddles near artificial water in scenic habitats are important areas for butterflies, providing environments for nectaring or puddling (Figure 5).

3.2.2. Differences in Habitat Diversity

Based on actual observed sample sizes, it is clear that there was no significant difference in species richness between scenic habitats (SH) and road habitats (RH). However, butterfly richness within both habitats was not saturated, and species richness would increase to some extent if there were additional observations (Figure 6A). In contrast, the Shannon and Simpson diversity curves both show that species richness in road habitats are significantly higher than those in scenic habitats (Figure 6B,C).

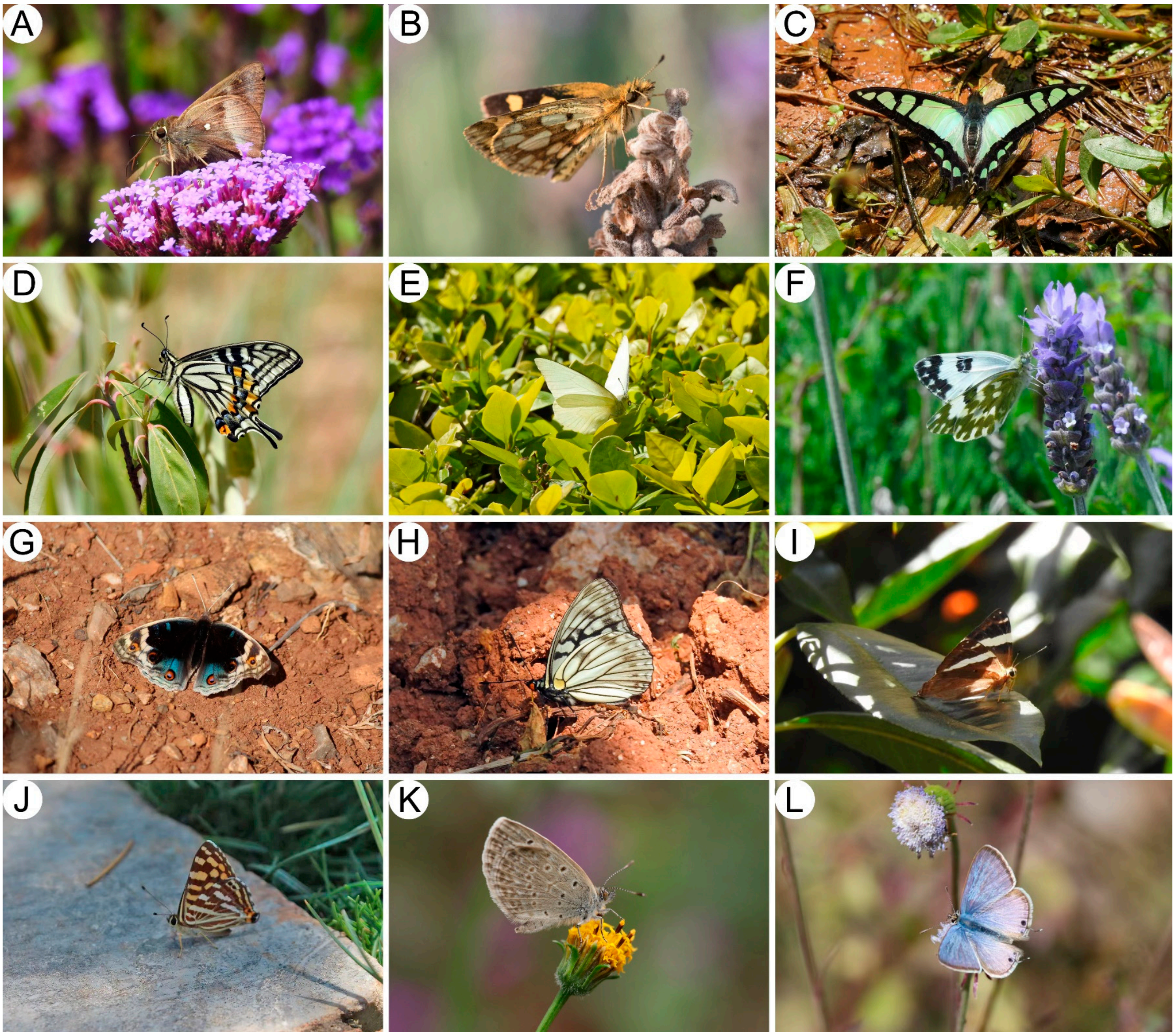

Figure 5. Field photographic records of adult butterflies on the Chenggong Campus of Yunnan University. (**A**) *Hasora anura* visiting *Verbena bonariensis*; (**B**) *Carterocephalus alcina* resting on *Lavandula angustifolia*; (**C**) *Graphium cloanthus* puddling in the wetlands beside the artificial lake; (**D**) *Papilio xuthus* resting on the leaves of *Cornus capitata*, a street tree; (**E**) *Appias albina* resting on *Ligustrum japonicum*, a greening shrub; (**F**) *Pontia edusa* nectaring on *Lavandula angustifolia*; (**G**) *Junonia orithya* puddling on earth; (**H**) *Hestina persimilis* puddling on earth beside the artificial lake; (**I**) *Dodona ouida* resting on the leaves of *Photinia glomerata*, a street tree; (**J**) *Dodona durga* resting alongside the road; (**K**) *Pseudozizeeria maha* nectaring on *Bidens pilosa*; (**L**) *Lampides boeticus* spreading its wings to bask while nectaring on *Crassocephalum rubens*.

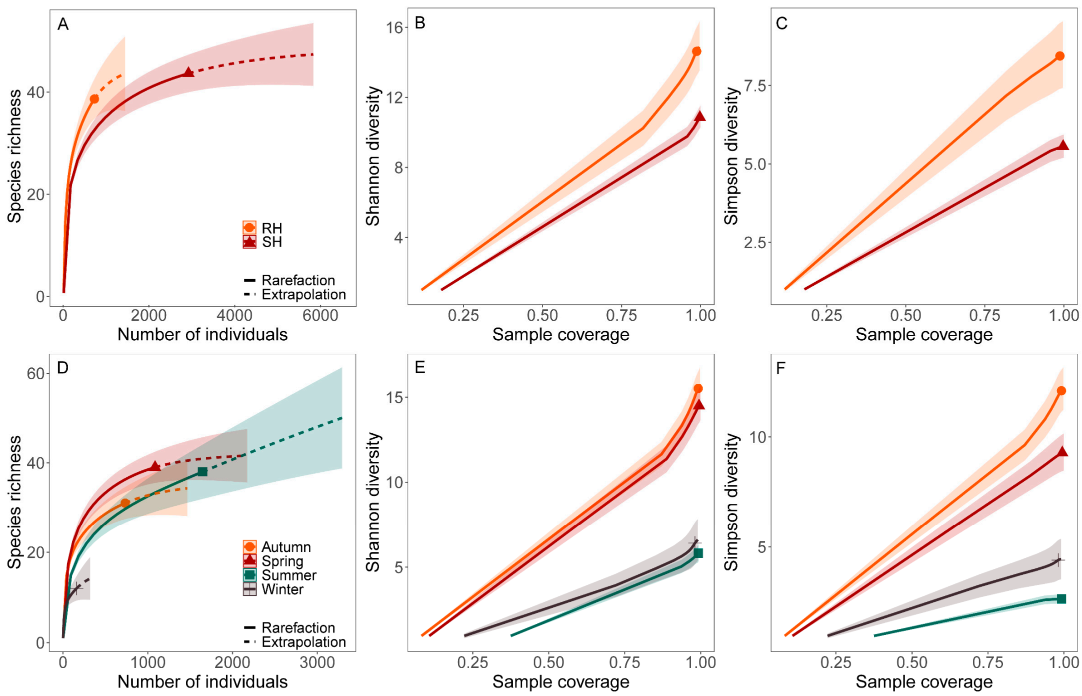

Figure 6. Estimated species richness, Shannon diversity, and Simpson diversity in different habitat types (**A**–**C**) and different seasons (**D**–**F**) through a sparse (solid curve), extrapolated (dashed curve) and corresponding 95% confidence interval (shaded area) based on the integrity of sample collection coverage. When the confidence intervals overlap, there is no statistically significant difference in the diversity index between the two habitats or seasons.

3.3. Temporal Variation in Butterfly Community

3.3.1. Species Assemblage and Seasonal Associations

The distribution and NMDS of butterfly species in different seasons showed that butterflies are active throughout the year on the Chenggong Campus of Yunnan University, and there were significant differences in butterfly community structure between seasons (stress = 0.0675, p = 0.001, Figure 4B,D, Table S2). Twelve species of butterflies were recorded in all four seasons, namely *P. rapae*, *P. erutae*, *E. laeta*, *E. hecabe*, *E. mandarina*, *C. poliographus*, *C. fieldii*, *Vanessa cardui*, *L. boeticus*, *Pseudozizeeria maha*, and *Junonia orithya*. In total, 1086 butterflies of 39 species were recorded in the spring, with the highest number of individuals being represented by *P. rapae* (223 individuals), followed by *Y. baldus* (205 individuals) and *L. boeticus* (117 individuals). *Appias albina* (44 individuals), *B. hedistus* (1 individual), and *D. morgiana* (1 individual) were only recorded in spring. In the summer season, 1646 butterflies of 38 species were recorded, and *P. rapae* (989 individuals) also reached the peak number, followed by *L. boeticus* (115 individuals). *H. anura*, *P. sinensis*, *P. protenor*, *C. polyphemus*, and *R. nissa* were only recorded in the summer, and they had less than five individuals. In autumn, the recorded butterflies totalled 733 individuals of 31 species, with *E. laeta* (101 individuals) being the dominant species. *D. genutia* (10 individuals), *M. phedima* (3 individuals), and *P. athamas* (1 individual) were only recorded in autumn. Only 160 butterflies of 12 species were recorded during the winter season. *E. laeta* (67 individuals) remained the dominant species, while *Colias fieldii* (20 individuals), *P. rapae* (19 individuals), and *C. poliographus* (15 individuals) were also more active. *P. maha*, *D. chrysippus*, and *V. cardui* were only recorded once during this season.

3.3.2. Differences in Seasonal Diversity

No significant statistical difference was detected in species richness between spring, summer, and autumn, despite the superficial differences between observation numbers. However, species richness in winter was significantly lower than that in the other seasons.

Species richness in summer and winter is not yet saturated and tends to increase (Figure 6D). Shannon diversity was significantly higher in spring and autumn than in summer and winter. However, there was neither a significant difference in Shannon diversity between spring and autumn, nor was there one between summer and winter. Simpson diversity was predicted to be the highest in autumn, followed by spring and winter, but the lowest in summer. Simpson diversity varied significantly between seasons.

3.3.3. Temporal Dynamics of Butterfly Communities

The number of individuals and species of different butterfly families on the Chenggong Campus of Yunnan University showed variation between seasons (Figure 7). Family Pieridae had more individuals than the other families in each season, and showed a unimodal pattern with a peak in summer. The family Nymphalidae showed a bimodal pattern, with higher numbers of individuals in spring and autumn than those in the summer and winter. The number of individuals in the families Papilionidae and Lycaenidae showed a left-skewed distribution, which was the highest in spring but declined in other seasons. For the number of species, families Pieridae and Papilionidae reached their highest level in spring, and then gradually decreased in other seasons, and family Papilionidae was not observed in winter. The number of species in families Nymphalidae and Riodinidae showed a bimodal pattern, with the highest peaks in spring and autumn. The species of families Hesperiidae and Lycaenidae showed a smaller unimodal pattern and reached their peaks in summer.

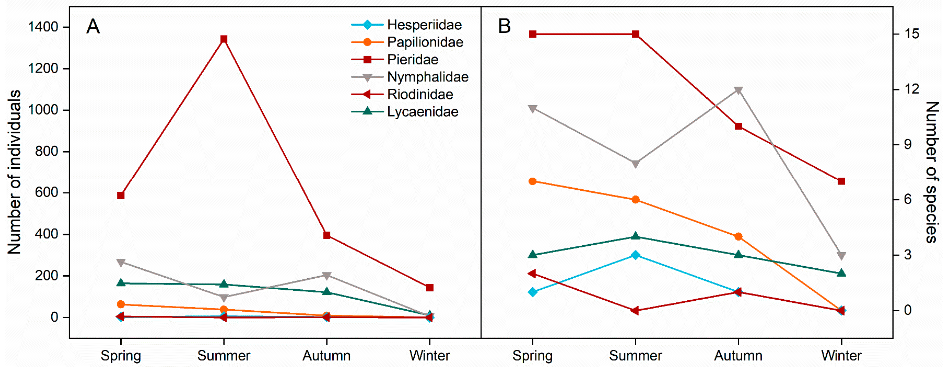

Figure 7. Dynamics of the number of individuals (**A**) and species (**B**) of different families of butterfly taxa in the Chenggong campus of Yunnan University in response to seasonal changes.

4. Discussion

4.1. Status of Urban/Campus Butterfly Composition

The capital city of Yunnan Province, Kunming, is not only rich in biodiversity but is also facing accelerating urbanisation due to the demands of development [68]. In this study, 50 species of butterflies belonging to 35 genera in six families were observed in a recently built university campus of Kunming, which is higher than the number of species in other Chinese universities (e.g., Southwest Forestry University [69], Jiangxi Normal University [70], Chongqing University [71], and Huaibei Normal University [72]). However, the number of butterfly species in this campus tended to be lower than that in other parts of Kunming City (e.g., Xishan Hill [73], Huanglong Qing Village [69], and Kunming city park [74]). Despite the differences in sampling time, the results of these studies showed one thing in common: families Pieridae and Nymphalidae were dominant in urban butterfly communities, and species of the family Riodinidae were also low in richness as it is the smallest butterfly family in Kunming. In addition to Kunming, butterfly surveys conducted in Wenshan [75] and Xichou of Yunnan Province [76], Huaxi of Guizhou Province [77], Taizhou of Zhejiang Province [78], Shenzhen of Guangdong Province [79], and Beijing City [80–82] showed similar trends, including that the composition of butterfly species varies due to geographical location and habitat type, but overall, families Pieridae and Nymphalidae had the greatest richness in urban areas.

At the species level, the majority of butterflies with IUCN threatened categories, such as *Byasa hedistus*, *Prioneris thestylis*, and *Dilipa morgiana*, are only occasionally observed in urban areas, even in urban parks with higher green coverage [74,83]. This may be due to their special habitat requirements and lower tolerance to human activities [84–86]. More data are required to assess the status of these taxa, including NE taxa in the future [87]. In comparison, species such as *Pieris rapae* are dominant not only in Kunming, but also in most other Chinese cities [88]. Similar species such as *Colias fieldii*, *C. poliographus*, *P. erutae*, *Eurema hecabe*, *Ypthima baldus*, *Pseudozizeeria maha*, and *Lampides boeticus* can always be found in other cities of China, with different degrees of dominance, indicating their tolerance to human activities [89].

Urban butterfly communities are usually composed of species that are adapted to the urban environment with higher mobility and lower habitat specificity [90–92]. However, with the rapid rate of urbanisation and increasing population, suitable habitats for butterflies will gradually contract, and the urban butterfly community may also face the problems of habitat degradation [93].

4.2. Urban/Campus Disturbance and Butterfly Diversity

Our analyses based on rarefaction and extrapolation revealed that butterfly species richness is highest in spring, but does not reach saturation in summer and winter. It reached its peak in summer only after the number of observations doubled. One possible explanation is that Yunnan University is located in the Central Yunnan Plateau, where a typical subtropical plateau monsoon climate prevails [94,95]. In winter, when most butterflies diapause stages as larvae or pupae, the lowest observation of adults appeared. As spring temperature rose, the activity of adult butterflies also increased and gradually reached its peak. However, during summer, the adult abundance declines again in most bivoltine or multivoltine species, since the first brood finishes their life history while the second brood is still in its immature stages [73]. Another possibility that the difference in suitability in urban habitats between different seasons is because some species may escape to nearby wild habitats to avoid an unfavourable environment in certain seasons [96–98]. Due to the presence of an urban heat island, higher winter temperature in urban areas could benefit certain butterflies. However, in summer, higher urban temperature may force butterflies to migrate to nearby, more hospitable suburban regions [99,100].

The results showed that the diversity indices (Shannon diversity and Simpson diversity) of the campus road habitat (RH) were higher than those of the scenic habitat (SH). On the one hand, weak disturbance and abundant flowering plants in areas with human activities can result in higher butterfly diversity [101,102]. However, the flora within the urban scenic habitat consists mainly of larger areas of ornamental plants, which are prone to management disturbances from ornamental demands (e.g., branch cutting, re-arrangements, and seasonal change) [82,103,104]. Moreover, scenic habitats are scattered (fragmented) in the campus landscape; species with higher dispersal capabilities, such as *Pieris rapae*, *Colias fieldii*, *C. poliographus*, and *Lampides boeticus*, could survive and dominate in similar urban areas or highly fragmented environments [10,90,105,106]. Furthermore, like that in the campus, urban green space management often leads to the unnecessary use of pesticides, which harms butterfly populations in these areas (Figure 8) [107,108]. Rational pesticide usage is therefore critical for sustainable urban development. On the other hand, Saarinen et al. found that butterflies and day-flying moths primarily inhabit the edges of open roads due to the availability of food and habitat provided by roadside green spaces [109]. Furthermore, roadside green spaces act as the ecotone for various habitats, playing an important role in species migration and settlement, leading to more opportunities to observe adult butterflies [109]. Several studies of insect diversity in urban areas (city parks, campuses, etc.) of China have shown that the improvement of the quality of green spaces (higher plant species richness and flower density) and the use of attractive native flowering plants can help reduce the negative effects of city expansion on pollinator diversity [14,82,88,110–112]. Therefore, treating urban scenic spots and roads as 'hotspots' for insect conservation and properly managing green spaces within them could be an effective way to benefit the survival of urban butterfly species [113,114].

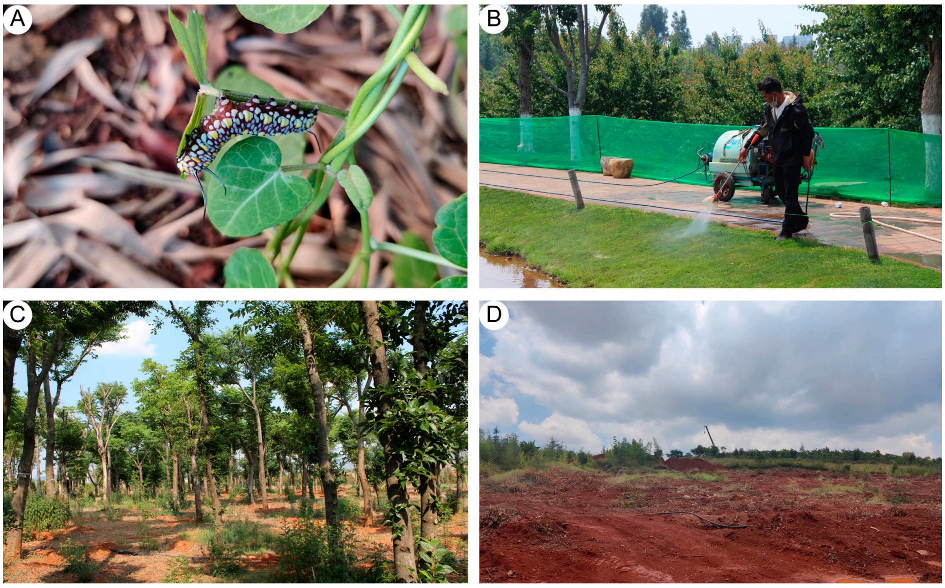

Figure 8. Examples of butterflies living in rapidly developing and frequently managed areas and green space on the Chenggong Campus of Yunnan University. (**A**) A larva of *Parantica sita* feeding on *Cynanchum* sp., which clings to *Pyracantha fortuneana* as greening shrubs; (**B**) management personnel spraying pesticides on a lawn; (**C**) Yunshan Hill as an unmanaged green space on the campus in May 2021; (**D**) the removal of vegetation on Yunshan Hill due to construction in July 2022.

Warren et al. suggested that the reasons for butterfly decline are similar in most European countries; habitat loss, degradation, and chemical pollution are the most commonly blamed factors [115]. In its course of rapid development over the past three decades, China may also have experienced similar situations. Construction, green space planning, and denser traffic networks would likely affect urban butterfly diversity and conservation [12,115]. Therefore, to enhance the conservation of urban butterflies, a certain proportion of primary vegetation and wild spaces in urban areas with local plant species is extremely necessary [79,116].

4.3. Citizen Science and Butterfly Biodiversity

Besides the 50 species of butterflies recorded from the transect survey, 26 additional species were observed on the campus through citizen science data collection (Figure 9, Table S1), reflecting the limitation to surveying efforts carried out by the research team alone within transects. Like biodiversity research in the wild, urban biodiversity research also requires an enormous workload to form solid background information; however, it is far from sufficient to have academic researchers work alone. To solve this limitation, citizen science is essential for investigating urban butterfly diversity on different scales [117]. Citizen science is a powerful approach to biodiversity, and many people can engage in future biodiversity conservation efforts [118]. Through citizen science projects, non-academic volunteers can assist scientists in collecting more data in a much longer time span and on a much larger geographical scale, which can also increase their knowledge and understanding of the biodiversity around them [119]. In the long term, the findings of these projects will not only contribute to biodiversity research, but also make conservation policies more efficient and accurate [118,120–122].

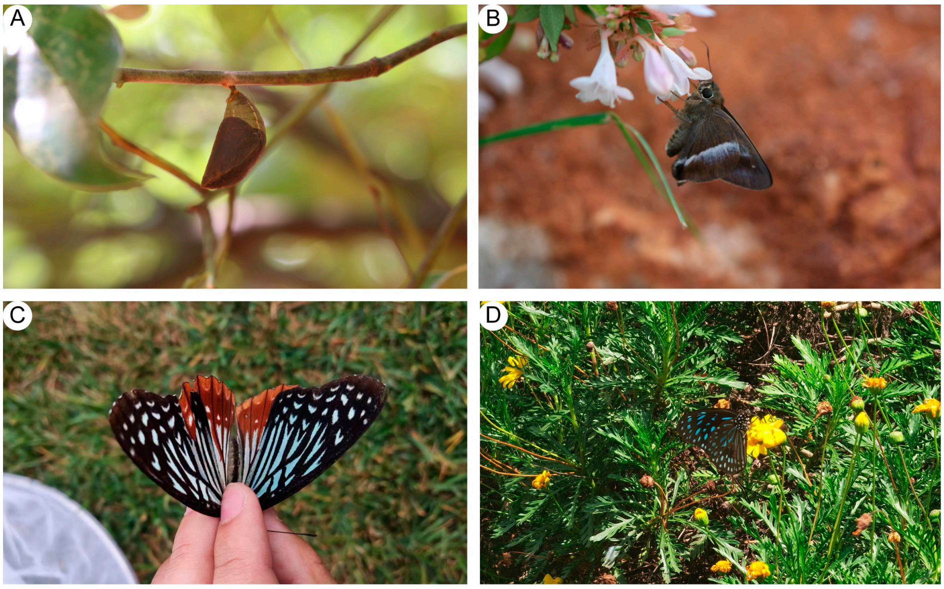

Figure 9. Photographs of a pupa and adults of butterflies recorded on the Chenggong Campus of Yunnan University by citizen science. (**A**) A pupa of *Polyura dolon* hanging on a camphor tree used as a roadside tree, photographed by Zhen-Bang Xu; (**B**) *Hasora vitta* visiting *Abelia* × *grandiflora* as a greening shrub along the roadside, photographed by Zhen-Bang Xu; (**C**) *Hestina nama* captured beside the greenhouse on the campus, photographed by Shi-Hao Lai; (**D**) *Tirumala septentrionis* visiting *Euryops pectinatus* as a greening shrub along the roadside, photographed by Rui-Cheng Xu.

Although citizen science in China has only started in recent years, a good start has been made in bird and plant monitoring. The China Birdwatching Record Centre (https://www.birdreport.cn (accessed on 7 June 2023)), Plant Science Data Center (https://www.plantplus.cn (accessed on 7 June 2023)), and the AiPlant smartphone app have been widely used in China [123–126]. However, there is still a large gap in citizen science for insect monitoring. Butterflies are one of the important environmental indicators; however, the monitoring of butterflies has not been effectively employed throughout the country [22,127], apart from the official "China BON-Butterflies" implemented by academia [128]. Establishing a monitoring network involving citizen science would be of great value for butterfly diversity research in China, as it would not only serve academia, but also benefit naturalists, ecologists, and conservationists [129].

5. Conclusions

Our research shows that on a university campus in a rapidly developing urban area, species of families Pieridae and Nymphalidae still maintain higher activity, and the campus is also a good overwintering refugium for some butterfly species. Butterfly community structure varies across habitats and seasons on campus. Campus road habitats have much higher butterfly diversity than scenic green spaces do, and butterfly diversity is higher in spring and autumn than in summer and winter. We encourage universities and research institutions to develop butterfly monitoring platforms for citizen scientists to participate in, which will be important for improving the efficiency of butterfly conservation in China.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/d16010004/s1. Table S1. List of butterflies in Chenggong Campus of Yunnan University (Up to October 2022); Table S2. Butterfly species and their abundance in the Chenggong Campus of Yunnan University in different seasons and habitats; Table S3. Diversity dataset after running it with the iNEXT model; Table S4. Raw datasets for R analysis; Code S1. R code for analysis and visualisation.

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