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Taxocenotic and Biocenotic Study of Lepidoptera (Rhopalocera) in Rucamanque: A Forest Remnant in the Central Valley of the Araucanía Region, Chile

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Additional information is available at the end of the chapter

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Abstract

Considering that butterflies (Lepidoptera: Rhopalocera) are sensitive to physical and climatic changes, e.g. of temperature, humidity and solar radiation, produced by disturbances in their habitat, a survey of this group was carried out in a small remnant of native forest (Rucamanque) in the central valley of the Araucanía Region of Chile. The object was to record the composition, abundance and diversity of Rhopalocera in grassland, forest and the ecotone between them during spring and summer. The study recorded 1190 individual butterflies belonging to 25 species, 18 genera, 8 sub-families and 4 families. The highest values of species richness and abundance were obtained in the summer, of 25 species and 953 individuals; in the spring, 9 species were recorded with a total of 237 individuals. The greatest diversity and homogeneity were found in the ecotone habitat ($H'=3.86$; $J'=0.88$; $\lambda=0.08$); the values for grassland were ($H'=2.73$; $J'=0.67$; $\lambda=0.23$) and for forest ($H'=2.55$; $J'=0.71$; $\lambda=0.23$); these environments being less diverse and more homogeneous. The greatest taxocenotic similarity was found between grassland and the ecotone (54%), and the least similarity appeared between the ecotone and forest (34%). The greatest biocenotic similarity was found between the ecotone and forest (48%), and the lowest correspondence was between grassland and forest (4.18%).

Keywords: biodiversity, fragmentation, Lepidoptera, Rhopalocera, Rucamanque

1. Introduction

The Lepidoptera first appear in geological history 50 million years ago. Most have mouth-pieces adapted for sucking, although some species lack these and others have mouths adapted for mastication [1–3]. They live up to great altitudes in mountainous, forest or grassland environments. Adults feed on the juices of flowers or on dew, although some species (none

resident in Chile) are attracted by putrefaction [4–6]. The Lepidoptera are the second most important order of pollinating agents, after the Hymenoptera, and may be sensitive to changes in vegetation and tree cover [5, 7]. Pollination is important for most species of flowering plants and has contributed to parallel evolution between plants and lepidopterous. It was due to the appearance of butterflies that flowers became more conspicuous and acquired increasingly attractive shapes, colours and smells [7].

The International Union for Conservation of Nature [8] states that habitat loss is the most important reason for the extinction of butterflies. In red lists of threatened species worldwide, the Lepidoptera are the next most threatened insect group after the Odonata (**Table 1**).

Butterflies are very sensitive to changes in temperature, humidity and solar radiation produced by disturbances to their habitat; inventories of their communities measuring their diversity, richness and chorological aspects therefore constitute a valid instrument for assessing their state of conservation and/or changes to the natural environment [10]. Due to their abundance, diversity, ease of handling in the field, spatial and temporal stability, and in general because their taxonomy is well documented, they are used as appropriate ecological indicators [10].

The lepidoptera have been divided [11] into *Jugatae* and *Frenatae* (Comstock, 1893); *Zeugloptera* (Chapman, 1916), *Monotrysis* (Borner, 1939) and *Ditrysis* (Borner, 1925); *Heterocera* (Boisduval, 1834) and *Rhopalocera* (Duméril, 1823). This work will consider only the latter group. The Heterocera (moths) have antennae of varying shapes, whereas the Rhopalocera (butterflies) have straight antennae ending in a small club, sometimes forming a hook, which makes them very easy to distinguish [4]. There have been few studies of the state of conservation of butterflies in Chile [12], and those that exist indicate that the Rhopalocera are poorly represented in the National System of State-Protected Wildlife Areas (SNASPE). Although central Chile is recognised as a world biodiversity hotspot, such studies are minimal in this zone and endemic species receive the least protection [13, 14].

Knowledge about conservation states is very scarce in Chile. There is a lack of data on the biology and distribution of most of the species described to date [15, 16]. Chilean species of the following genera are threatened: *Neomaenas* Wallengren, 1858; *Auca* Hayward, 1953; *Butleria*

Order	EX	CR	EN	VU	NT	DD	LC	Total
Coleoptera	16	10	16	27	3	0	0	72
Lepidoptera	27	8	39	130	45	35	19	303
Hymenoptera	0	3	0	139	7	1	1	151
Odonata	2	36	64	74	34	90	327	627
Orthoptera	2	8	8	50	0	2	0	74

Source: [9]. IUCN Red List 2007: Extinct (EX); critically endangered (CR); endangered (EN); vulnerable (VU); near threatened (NT); data deficient (DD) and least concern (LC).

Table 1. Principal groups of insects with threatened species.

Kirby, 1871; *Tatochila* Butler, 1870 and *Homoeonympha* C. & R. Felder, 1867. According to current knowledge, there are 169 butterfly species recorded for Chile, in 5 families [4] (**Table 2**).

Studies of Chilean lepidopterofauna may focus on taxocenosis or biocenosis [17–20]. In the Araucanía Region, a study done at Villarrica National Park [18] characterised the group at different altitudes; another survey was carried out on the Cerro Ñielol Natural Monument (Temuco) to obtain information for state-protected areas [17]; a third described the area of Budi Lake on the coast, which is considered a priority conservation site in the National Biodiversity Strategy [26]; and another was a study of Chilean Papilionoidea and Hesperioidea, including their flight periods [13].

Biodiversity is understood to mean the assemblage of genes, species, ecosystems and landscapes in a given space at any given moment, with their successive hierarchical interaction from genes to species, ecosystems and landscapes and vice versa [21].

Fragmentation is a dynamic process through which a habitat is reduced to small fragments or islands set in a larger area or matrix. The effect of this process is the formation of remnants of forest separated by a matrix of different kinds of vegetation or land use, the dynamics of which depend on factors occurring in the surrounding areas. It is one of the most recent causes of the impoverishment of biodiversity [21–24]. In the past, Chile’s central valley from the Malleco river (36° 30’ S) to 41° S was covered by park-type native forest in the north [25] and by other formations based on *roble* (*Nothofagus oblicua* (Mirb.) Oerst.) and other less abundant plant species. These forests were felled or burnt to clear land for arable farming and stock-rearing [26]. A few patches of the original Roble-Laurel-Lingue formation have remained almost unaltered, by decision of some landowners. Forests of this kind, very scarce

Superfamily	Family	Subfamily	Genus	Species	
Hesperioidea	Hesperiidae	Pyrginae	5	11	
		Hesperiinae	7	24	
Papilionoidea	Pieridae	Coliadinae	5	10	
		Pierinae	8	19	
	Papilionidae		1	1	
	Lycaenidae	Theclinae	13	30	
		Polyommatae	6	29	
	Nymphalidae	Danainae	1	1	
		Satyrinae	12	34	
		Heliconiinae	4	6	
		Nymphalinae	2	3	
		Libytheinae	1	1	
Σ	2	5	11	65	169

Source: [4].

Table 2. Diurnal lepidoptera present in Chile.

but ecologically and scientifically very important, are identified as Original Remnants [36]. Today, there are only two such patches of mature native forest—typical of the original vegetation—in Cautín Province in the central valley of the Araucanía Region: Cerro Ñielol and Rucamanque. The latter is the larger of the two, covering 435.1 ha, and has suffered less human impact, with some 209 hectares covered by primary forest. The Rucamanque remnant is included in the National Biodiversity Strategy as a national priority site with *Priority II (Important)*; its priority at the regional level of the National Strategy for the Conservation and Sustainable Use of Biodiversity is *Very High* [27]. Several studies have been carried out in the forest remnants of the Araucanía Region [28–30]; however, most deal with vegetation and very few with fauna. In view of the above, the purpose of this work is to report information on the taxonomic composition of butterflies (Rhopalocera) in Rucamanque, a forest remnant and priority conservation site.

The working hypothesis was: Considering the biotic and abiotic differences between forest, grassland and the ecotone, it is to be expected that the richness and abundance of Rhopalocera species will differ between them. The following General object was therefore proposed: To characterise the diurnal lepidopterofauna of Rucamanque, a forest remnant set in a fragmented ecosystem in the central valley of the Araucanía Region of Chile. The specific objects were: (1) to determine the taxa of diurnal lepidoptera associated with forest, grassland and ecotone environments in the Rucamanque forest remnant, determining diversity in forest, grassland and ecotone environments by community parameters and (2) to compare the taxocenotic and biocenotic similarities between the Rhopalocera of the different habitats in spring and summer using the Bray–Curtis similarity coefficient [31].

2. Materials and methods

2.1. Study area

Rucamanque (38° 39' S, 72° 35' W) (**Figure 1**), area 435.1 ha., is located 12 Km. NW of the city of Temuco, Cautín Province, Araucanía Region, Chile. Rucamanque forms part of the Huimpil-Ñielol range of hills. It consists of a ravine descending from NW to SE; the altitude at the foot of the ravine is approximately 200 m, and the sides climb to 550 m. The prevailing climate is wet temperate, with average annual precipitation of 1400 mm and mean temperature 12°C [31].

Field methods. A preliminary survey was done of the study area to decide on sampling areas in the three habitats: grassland (38°39'26"S, 72°36'21.72"W), ecotone (38°39'42.47"S, 72°36'18.96"W) and forest (38°39'44.56"S, 72°36'16.92"W). Specimens were sampled and recorded from the second half of September 2007 to the first half of April 2008. Sampling was carried out in the sampling area with a butterfly net on 1 day every 2 weeks (from 10:00 to 12:00, 14:00 to 16:00 and 18:00 to 19:00 hours).

The samples were recorded with capture number, habitat, activity and time, including photographs taken *in situ*. Individuals out of reach of the net were identified and counted with binoculars (7×50). Species were identified by comparison with examples from scientific collections in Temuco (Universidad de la Frontera) and Santiago (Natural History Museum, Juan

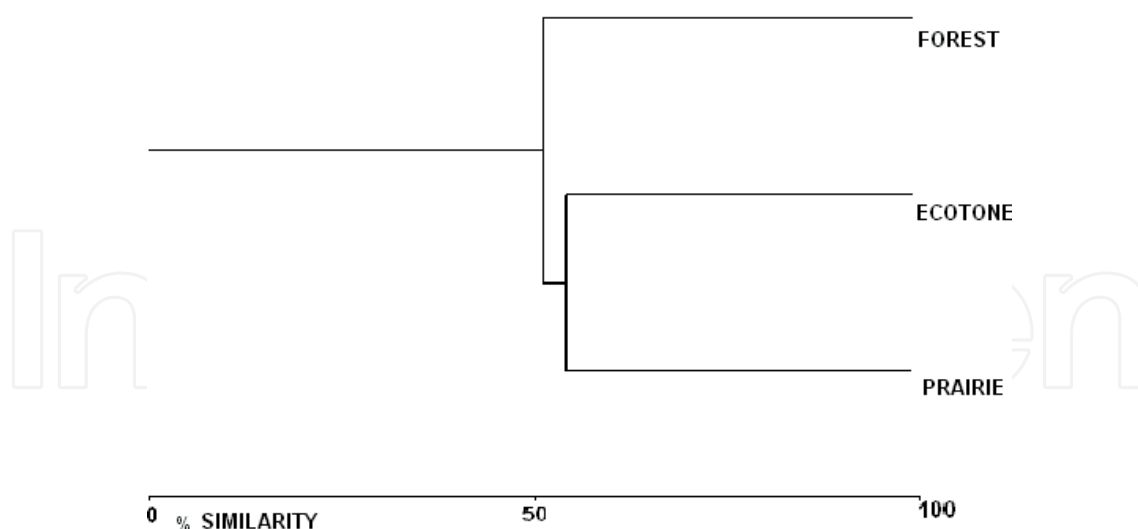


Figure 1. Taxocenotic similarity tree diagram for Rhopalocera in habitats sampled in Rucamanque, Araucanía Region.

Ignacio Molina Study and Publication Institute) and with the aid of keys [32]. The material was deposited in the Entomological Collection of the Faculty of Farming and Forestry Sciences of Universidad de la Frontera, Temuco.

Data analysis included a taxonomic list of the species present in the study area to determine the richness of species (**S**) and relative abundance (%) at the site to interpret the alpha diversity. Indices of diversity and abundance were obtained for each of the habitats sampled for both spring and summer seasons. The taxocenosis and biocenosis were indicated by the similarity index as proposed by Bray and Curtis [38] for all three habitats and two seasons studied (spring-summer). Tree diagrams were drawn for each result using the Biodiversity Pro programme. If the data did not fit a normal distribution, Friedman's non-parametric test was applied [34, 35].

3. Results

Taxonomic composition of species recorded. A total of 25 species was recorded among the samples (S). The families with the most representatives were the Hesperidae, Pieridae and Nymphalidae. The family with the smallest number of samples was the Lycaenidae (**Table 3; Figures 7 and 8**). A new distribution was established two species: *Eiseliana bicolor* (Philippi, 1859) (Lycaenidae) and *Neomaenas coenonymphina* Butler, 1881 (Nymphalidae).

Diversity in habitats sampled: The ecotone presented the greatest richness of species (21 in total) and an abundance of 376 individuals. The grassland and forest habitats presented lower richness of species, the poorest being the forest with only 12 species and an abundance of 361 individuals. This is reflected in the diversity values (H') for grassland, ecotone and forest—2.73, 3.86 and 2.55, respectively (**Table 4**). The habitat presenting distribution with the greatest homogeneity was the ecotone ($J' = 0.88$). Grassland and forest present similar values ($J' = 0.67$ and $J' = 0.71$ respectively). Dominance was strongest for species of the

SUPERFAMILY	:	HESPEROIDEA	
FAMILY	:	HESPERIIDAE	
SUBFAMILY	:	PYRGINAE	Burmeister, 1878
SPECIES	:	<i>Pyrgus notatus valdivianus</i>	(Philippi)
SUBFAMILY	:	HESPERIINAE	Barnes & Benyamin, 1926
SPECIES	:	<i>Butleria paniscoïdes paniscoïdes</i>	(Blanchard, 1852)
	:	<i>Butleria bissexguttata</i>	(Philippi, 1859)
	:	<i>Argopteron aureipennis</i>	(Blanchard, 1852)
	:	<i>Hylephila fasciolata</i>	(Blanchard, 1852)
	:	<i>Hylephila signata</i>	(Blanchard, 1852)
SUPERFAMILY	:	PAPILIONOIDEA	
FAMILY	:	PIERIDAE	Duponchel, 1835
SUBFAMILY	:	COLIADINAE	Swainson, 1827
SPECIES	:	<i>Colias vauthierii vauthierii</i>	Guérin, 1829
SUBFAMILY	:	PIERINAE	Swainson, 1940
SPECIES	:	<i>Mathania leucothea</i>	(Molina, 1782)
	:	<i>Pieris brassicae</i>	(Linné, 1758)
	:	<i>Tatochila autodice blanchardi</i>	(Butler, 1881)
FAMILY	:	LYCAENIDAE	Leach, 1815
SUBFAMILY	:	THECLINAE	Röber, 1892
SPECIES	:	<i>Strymon eurytulus</i>	Hübner, 1819
	:	<i>Eiseliana bicolor</i>	(Philippi, 1859)
FAMILY	:	NYMPHALIDAE	Swainson, 1837
SUBFAMILY	:	SATYRINAE	Boisduval, 1833
SPECIES	:	<i>Cosmosatyrus chilensis chilensis</i>	(Guérin, 1832)
	:	<i>Homoeonympha boisduvali pusilla</i>	(C. & R. Felder 1852)
	:	<i>Homoeonympha humilis</i>	(C. & R. Felder, 1857)
	:	<i>Neomaenas coenonymphina</i>	
	:	<i>Neomaenas janirioides</i>	Blanchard, 1852.
	:	<i>Neomaenas monachus</i>	(Blanchard, 1852)
	:	<i>Neomaenas poliozona</i>	(C. & R. Felder, 1867)
	:	<i>Auca pales</i>	(Philippi, 1859)

	:	<i>Elina montroli</i>	(Feisthamel, 1839)
	:	<i>Nelia nemyroides</i>	(Blanchard, 1852)
SUBFAMILY	:	HELICONIINAE	Swainson, 1887
SPECIES	:	<i>Yramea cytheris</i>	(Drury, 1773)
SUBFAMILY	:	NYMPHALINAE	Swainson, 1827
SPECIES	:	<i>Vanessa carye</i>	(Hübner, 1806)
	:	<i>Vanessa terpsichore</i>	Philippi, 1859.

Table 3. Systematic list of species of Lepidoptera—Rhopalocera recorded in Rucamanque.

Community parameters	Sampling stations		
	Grassland (E1)	Ecotone (E2)	Forest (E3)
Abundance (N)	453	376	361
Species richness (S)	17	21	12
Simpson's dominance index (λ)	0.23	0.08	0.23
Shannon-Wiener diversity index (H')	2.73	3.86	2.55
Theoretical maximum index (H' Max.)	4.09	4.39	3.58
Homogeneity (J')	0.67	0.88	0.71

Table 4. Community parameters analysed in Rucamanque.

grassland (*Colias vauthierii vauthierii* and *Hylephila fasciolata*) and forest (*Neomaenas monachus* and *Argopteron aureipennis*); the ecotone, which presented greater equity, as a result presented the lowest dominance $\lambda = 0.08$ (Table 4).

The greatest richness of species was recorded in summer, when 21 of the 25 species recorded in this study were reported, with an abundance of 953 individuals. Spring presented less diversity, with 17 species recorded and an abundance of 237 individuals.

The greatest homogeneity was found in the ecotone, in both spring and summer. This is reflected in the diversity (H') and homogeneity (J') obtained in each environment and season (Table 5).

Taxocenotic and biocenotic similarity. Regarding to the presence or absence of species in the habitats sampled (Table 6), *Pyrgus notatus valdivianus*, *Eiseliana bicolor* and *Cosmosatyris ch. chilensis* are found in grassland, *Pieris brassicae* is found in the ecotone, whereas species like *Mathania leucothea*, *Homoeonympha boisduvali pusilla*, *Neomaenas monachus* and *Vanessa carye* are found in all three habitats. The greatest number of shared species were shared between grassland and ecotone. The taxocenotic similarity between habitats is shown in Figure 1.

Community parameters	Spring 2007			Summer 2008		
	P	E	B	P	E	B
Total number of individuals (N)	136	59	42	317	317	319
Species richness (S)	8	6	3	15	21	12
Shannon-Wiener diversity index (H')	2.05	2.1	1.27	2.42	3.71	2.28
Theoretical H' index (H' Max.)	3	2.58	1.8	3.91	4.39	3.58
Homogeneity (J')	0.68	0.81	0.8	0.62	0.84	0.64

Table 5. Community parameters obtained in grassland (P), ecotone (E) and forest (B) in spring 2007 and summer 2008.

Species	Grassland	Ecotone	Forest
<i>Pyrgus notatus valdivianus</i>	P	A	A
<i>Butleria paniscoides paniscoides</i>	A	P	P
<i>Butleria bissexguttata</i>	A	P	P
<i>Argopteron aureipennis</i>	A	P	P
<i>Hylephila fasciolata</i>	P	A	P
<i>Hylephila signata</i>	P	P	A
<i>Colias vauthierii vauthierii</i>	P	P	A
<i>Mathania leucothea</i>	P	P	P
<i>Pieris brassicae</i>	A	P	A
<i>Tatochila autodice blanchardi</i>	P	P	A
<i>Strymon eurytulus</i>	P	P	A
<i>Eiseliana bicolor</i>	P	A	A
<i>Cosmosatyrus chilensis chilensis</i>	P	A	A
<i>Homoeonympha boisduvali pusilla</i>	P	P	P
<i>Homoeonympha humilis</i>	A	P	P
<i>Neomaenas coenonymphina ssp.</i>	A	P	P
<i>Neomaenas janirioides</i>	P	P	A
<i>Neomaenas monachus</i>	P	P	P
<i>Neomaenas poliozona</i>	A	P	P
<i>Auca pales</i>	P	P	A
<i>Elina montroli</i>	P	P	A
<i>Nelia nemyroides</i>	A	P	P
<i>Yramea cytheris</i>	P	P	A
<i>Vanessa carye</i>	P	P	P
<i>Vanessa Terpsichore</i>	P	P	A

Table 6. Presence (P) and absence (A) of Rhopalocera species recorded by habitat in spring 2007 and summer 2008 in Rucamanque, Araucanía Region.

Taxocenotic similarity matrix	Grassland	Ecotone	Forest
Grassland	*	54.16	34.48
Ecotone	*	*	51.16
Forest	*	*	*

Table 7. Taxocenotic similarity matrix for Rhopalocera in habitats sampled in Rucamanque, Araucanía Region.

Species	Grassland		Ecotone		Forest		Total	
	N	%	N	%	N	%	N	%
<i>Pyrgus notatus valdivianus</i>	3	0.66	0	0.00	0	0.00	3	0.25
<i>Butleria paniscoides paniscoides</i>	0	0.00	5	1.33	8	2.22	13	1.09
<i>Butleria bissexguttata</i>	0	0.00	35	9.31	40	11.08	75	6.30
<i>Argopteron aureipennis</i>	0	0.00	16	4.26	120	33.24	136	11.43
<i>Hylephila fasciolata</i>	126	27.81	0	0.00	2	0.55	128	10.76
<i>Hylephila signata</i>	22	4.86	4	1.06	0	0.00	26	2.18
<i>Colias vauthierii vauthierii</i>	164	36.20	39	10.37	0	0.00	203	17.06
<i>Mathania leucothea</i>	11	2.43	15	3.99	3	0.83	29	2.44
<i>Pieris brassicae</i>	0	0.00	6	1.60	0	0.00	6	0.50
<i>Tatochila autodice blanchardi</i>	9	1.99	2	0.53	0	0.00	11	0.92
<i>Strymon eurytulus</i>	2	0.44	2	0.53	0	0.00	4	0.34
<i>Eiseliana bicolor</i>	1	0.22	0	0.00	0	0.00	1	0.08
<i>Cosmosatyrus chilensis chilensis</i>	37	8.17	0	0.00	0	0.00	37	3.11
<i>Homoeonympha boisduvali pusilla</i>	30	6.62	37	9.84	1	0.28	68	5.71
<i>Homoeonympha humilis</i>	0	0.00	25	6.65	35	9.70	60	5.04
<i>Neomaenas coenonymphina ssp.</i>	0	0.00	32	8.51	16	4.43	48	4.03
<i>Neomaenas janirioides</i>	4	0.88	36	9.57	0	0.00	40	3.36
<i>Neomaenas monachus</i>	1	0.22	58	15.43	109	30.19	168	14.12
<i>Neomaenas poliozona</i>	0	0.00	11	2.93	2	0.55	13	1.09
<i>Auca pales</i>	17	3.75	6	1.60	0	0.00	23	1.93
<i>Elina montroli</i>	2	0.44	20	5.32	0	0.00	22	1.85
<i>Nelia nemyroides</i>	0	0.00	13	3.46	15	4.16	28	2.35
<i>Yramea cytheris</i>	4	0.88	9	2.39	0	0.00	13	1.09
<i>Vanessa carye</i>	18	3.97	4	1.06	10	2.77	32	2.69
<i>Vanessa terpsichore</i>	2	0.44	1	0.27	0	0.00	3	0.25
Σ habitats and study area	453	100.00	376	100.00	361	100.00	1190	100.00

Table 8. Absolute (N) and relative (%) abundance by species in the study area.

The taxocenotic similarity between the habitats sampled shows greater correspondence between ecotone and grassland, forming a nucleus; this nucleus corresponds to a lesser degree with the forest habitat (Table 7; Figure 1).

Grassland and ecotone present the highest abundances, with 453 and 376 individuals recorded, respectively (Table 8). In the forest, 361 individuals were recorded.

The most abundant species were *Colias v. vauthierii*, *Neomaenas monachus*, *Hylephila fasciolata* and *Argopteron aureipennis* with 203, 163, 128 and 122 individuals, respectively. Low abundance, not exceeding six individuals over the sampling period, was found in *Pyrgus notatus valdivianus*, *Mathania leucothea*, *Strymon eurytulus*, *Eiseliana bicolor* and *Vanessa terpsichore*.

Figure 5 shows the biocenotic similarity of the habitats studied. In general, the similarity between habitats is low; the highest correspondence exists between the ecotone and the forest, forming a nucleus with 48% similarity; however, these two environments together are more distant from grassland, which presents less similarity (Table 9; Figure 2).

The taxocenotic and biocenotic similarities differed between spring and summer, due to the larger number of species and greater abundances recorded in summer.

Spring presented a higher taxocenotic similarity nucleus (66%) between ecotone and forest. There was a high level of correspondence between grassland and ecotone (57%). The lowest correspondence was found between grassland and forest (Table 10; Figure 3).

Biocenotic similarity matrix	Grassland	Ecotone	Forest
Grassland	*	26.54	4.18
Ecotone	*	48.30	
Forest	*	*	*
Total study area	453	376	361

Table 9. Biocenotic similarity matrix for Rhopalocera in the habitats sampled in Rucamanque, Araucanía Region.

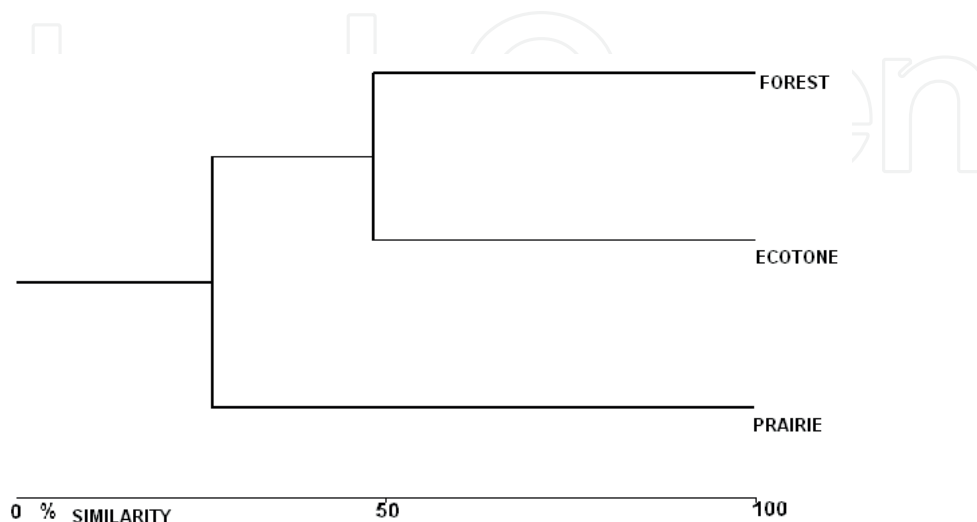


Figure 2. Biocenotic similarity tree diagram for Rhopalocera in the habitats sampled in Rucamanque, Araucanía Region.

Taxocenotic similarity matrix, spring 2007

	Spring-Forest	Spring-Ecotone	Spring-Grassland
Spring-Forest	*	66.67	18.18
Spring-Ecotone	*	*	57.14
Spring-Grassland	*	*	*

Table 10. Taxocenotic similarity matrix for Rhopalocera in Rucamanque, Araucanía Region, spring 2007.

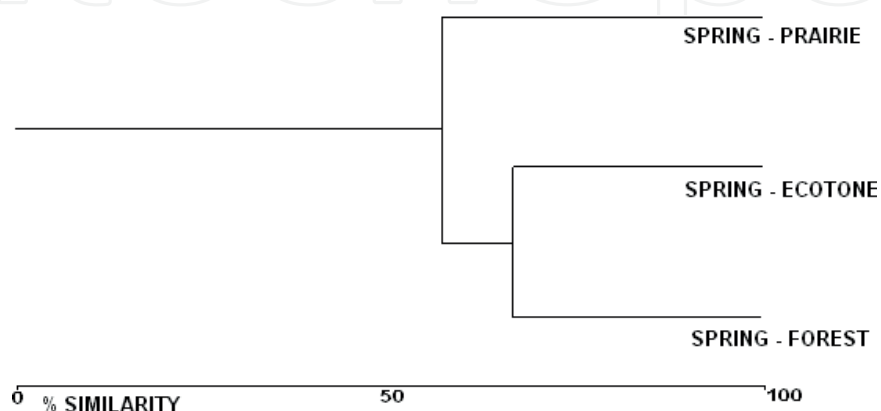


Figure 3. Taxocenotic similarity tree diagram for Rhopalocera in Rucamanque, Araucanía Region, spring 2007.

In summer, the taxocenotic similarity forms a single nucleus. There was no change in the percentages between ecotone and forest as compared to spring; however, there was an increase in correspondence between grassland-ecotone and grassland-forest. From this, we infer that the difference may result from records of “tourist” species observed primarily in the grassland environment, which seek cooler, more stable conditions during the heat of the day; as a result, they are sampled in environments to which they do not strictly belong or do not habitually visit (Table 11; Figure 4).

Biocenotic similarity in spring (Figure 5), strong correspondence is observed between the ecotone and the forest, forming a nucleus with 61% similarity, followed by grassland-ecotone with 23%.

In summer, the biocenotic similarity between the habitats is low, not exceeding 50%. The greatest correspondence is found in the nucleus which combines ecotone and forest, whereas the lowest similarity is between grassland and forest (Tables 12 and 13; Figure 5).

Taxocenotic similarity matrix, summer 2008

	Summer-Forest	Summer-Ecotone	Summer-Grassland
Summer-Forest	*	66.67	29.63
Summer-Ecotone	*	*	66.67
Summer-Grassland	*	*	*

Table 11. Taxocenotic similarity matrix for Rhopalocera in Rucamanque, Araucanía Region, summer 2008.

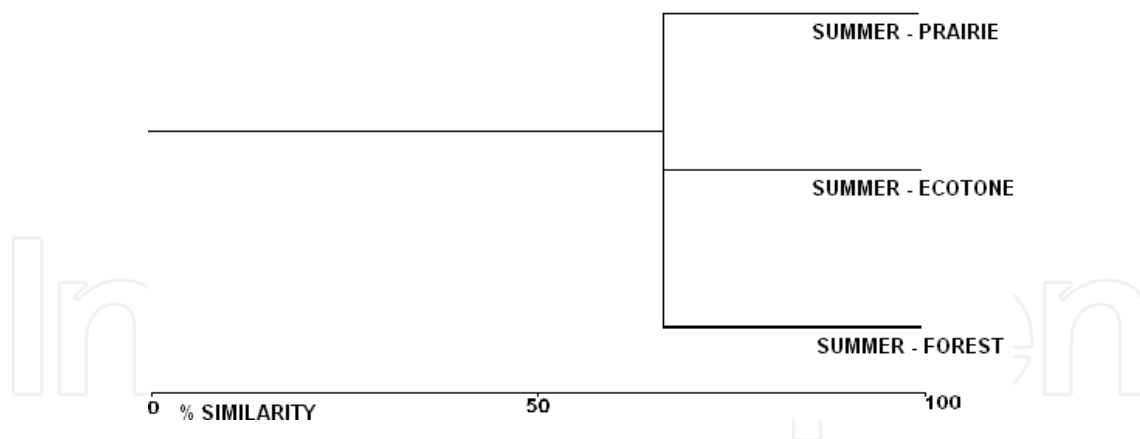


Figure 4. Taxocenotic similarity tree diagram for Rhopalocera in Rucamanque, Araucanía Region, summer 2008.

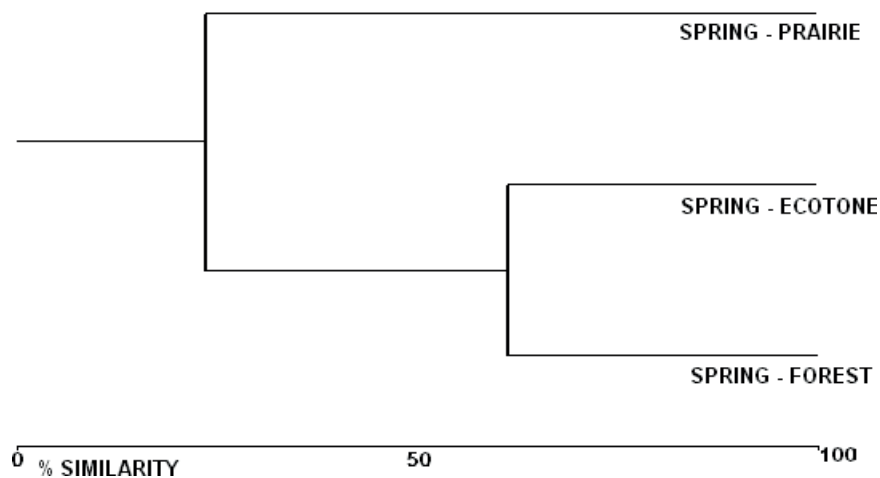


Figure 5. Biocenotic similarity tree diagram for Rhopalocera in Rucamanque, Araucanía Region, spring 2007.

Biocenotic similarity matrix, spring 2007

	Spring-Forest	Spring-Ecotone	Spring-Grassland
Spring-Forest	*	61.39	4.49
Spring-Ecotone	*	*	23.59
Spring-Grassland	*	*	*
Total study area	42	59	136

Table 12. Biocenotic similarity matrix for Rhopalocera in Rucamanque, Araucanía Region, spring 2007.

Statistical analysis with Friedman’s test (Spiegel, 2002) ($p \leq 0.05$) shows that the greatest significant difference is recorded between ecotone and forest, with a smaller similar difference between these two environments and grassland. This means finally that there is a difference between the environments studied (Figures 5 and 6).

Biocenotic similarity matrix, summer 2008

	Summer-Forest	Summer-Ecotone	Summer-Grassland
Summer-Forest	*	45.6	3.77
Summer-Ecotone	*	*	23.03
Summer-Grassland	*	*	*
Total study area	319	317	317

Table 13. Biocenotic similarity matrix for Rhopalocera in Rucamanque, Araucanía Region, summer 2008.

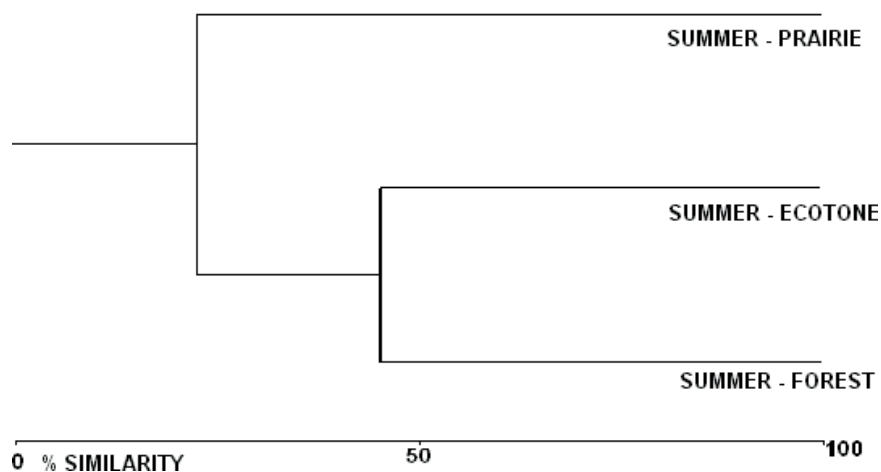


Figure 6. Biocenotic similarity tree diagram for Rhopalocera in Rucamanque, Araucanía Region, summer 2008.

The community parameters calculated and the Bray & Curtis similarity coefficient [33] denote these differences.

4. Discussion

From the data obtained in the study, we can indicate that the greatest richness of species is found in the ecotone, with 21 species; this habitat also presents the least dominance and highest equity in its population structure. It may be inferred that the least diverse habitat is forest, with only 12 species and the lowest homogeneity due to the presence of two dominant species: *Argopteron aureipennis* and *Neomaenas monachus*. Grassland presented greater diversity with 17 species; however, there were also two dominant species: *Colias vauthierii vauthierii* and *Hylephila fasciolata*, which together made up 52% of the population in this environment.

The absolute abundance, considering the whole sampling period, was highest in grassland with 453 individuals, followed by ecotone with 376 and finally forest with 361. These results agree with the results of Concha–Bloomfield et al. [21] in similar environments.

The differences in diversity between seasons result from abiotic factors [21], such as sunlight and stable temperatures, and biotic factors, such as the presence of flowers. These factors are neither stable nor predominant in spring or at least in early spring. According to Ollerton [8], the lepidoptera are in general the order of insects most closely associated with flowering plants and most dependent on flowers as a food source. This explains the greater richness of species recorded in the summer, when 21 of the 25 species recorded in the study area were observed.

There were marked differences between the abundances in different seasons. In summer, a total of 953 individuals was recorded, whereas in spring the total was 237—respectively 80.08 and 19.92% of the total individuals reported in the study. This difference may result from the better environmental characteristics, which favour hatching in the majority of species. Adults of 9 of the 25 species recorded in the study area were observed in flight in spring, with high dominance of a few species, such as *Hylephila fasciolata*, *Hylephila signata*, *Homoeonympha boisduvali pusilla* and *Homoeonympha humilis*.

In summer, the majority of species were observed in flight, with the greatest abundances in January and February. This observation appears to be characteristic of different altitudes and is related with good weather conditions, since in the same region, at an average altitude of 1345 m.a.s.l. Parada et al. [20] observed the largest number of specimens at this time of year. Abiotic factors like humidity and temperature, dependent on sunlight, and biotic factors like flowering, influence the hatching and establishment of the species found in Rucamanque during this season, corroborating [21].

Some species were only collected in one specific month during the sampling period: *Pyrgus notatus valdivianus* (January), *Butleria paniscoides paniscoides* (February), *Pieris brassicae* (March) and *Cosmosatyrus chilensis chilensis* (February). Likewise, there are species, such as *Pyrgus notatus valdivianus*, *Eiseliana bicolor* and *Cosmosatyrus ch. chilensis*, which are found exclusively in grassland, and *Pieris brassicae* recorded only in the ecotone. This may be because some species require a specific host plant for feeding or laying their eggs.

The taxocenotic similarity tree diagram indicates great similarity between grassland and ecotone, forming a nucleus of 54%; these two environments form a second nucleus at 51%. The lowest similarity, between forest and grassland, was 34%. These values are explained by the fact that grassland and ecotone share a large number of species, given the favourable environmental conditions present in these sectors such as greater amount of solar radiation and greater number of flowers. On the other hand, forest and grassland are exclusive home to some species, depending on their natural characteristics; these species tend to be more specific and less generalist.

The biocenotic similarity tree diagram indicates the existence of a similarity nucleus of 48% between ecotone and forest. The ecotone in turn has a similarity of 26% to grassland. Again, the environments with the lowest similarity are grassland and forest. The only slight differences between different habitats may be influenced by tourist species, which seek out more favourable environmental conditions when solar radiation is strong, and are recorded in the survey although they do not reside exclusively in this environment. This is a determining factor, since although the influence of environmental factors triggered by sunshine is higher in open areas [11], this migration may increase when the area has suffered greater alteration, as in the case of Rucamanque.



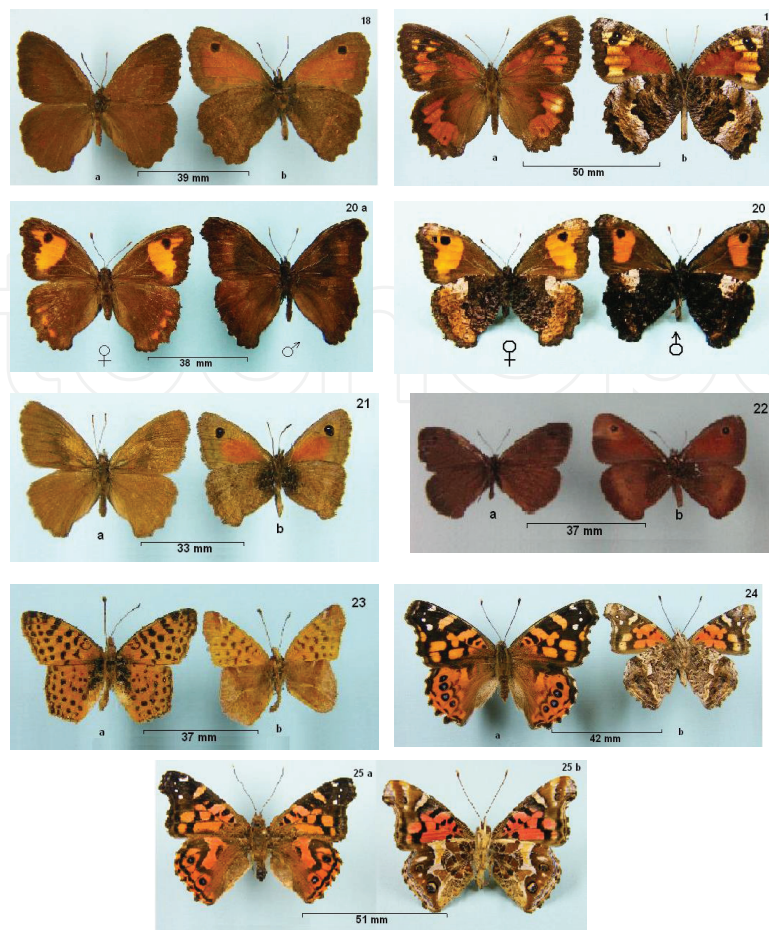


Figure 7. Dorsal and ventral views of the species recorded (adults): (1) *Pyrgus n. valdivianus* dorsal; (2) *Butleria p. paniscoides* dorsal; (3) *Butleria bissexguttata* dorsal and ventral; (4a) *Argopteron aureipennis* dorsal; (4b) *Argopteron aureipennis* ventral; (5) *Hylephila fasciolata* dorsal and ventral; (6) *Colias v. vauthierii* ♂ and ♀ dorsal; (7) *Hylephila signata* dorsal and ventral; (8) *Mathania leucothea* dorsal; (9) *Pieris brassicae* dorsal; (10a) *Tatochila autodice blanchardi* dorsal; (10b) *Tatochila autodice blanchardi* ventral; (11) *Strymon eurytulus* lateral; (12a) *Eiseliana bicolor* dorsal; (12b) *Eiseliana bicolor* ventral; (13) *Cosmosatyrus ch. chilensis* dorsal (a) and ventral (b); (14) *Homoonympha b. pusilla* dorsal (a) and ventral (b); (15) *Neomaenas coenonymphina* dorsal (a) and ventral (b); (17) *Neomaenas janirioides* dorsal and ventral; (18) *Neomaenas monachus* dorsal (a) and ventral (b); (19) *Elina montroli* dorsal (a) and ventral (b); (20a) *Nelia nemyroides* dorsal; (20b) *Nelia nemyroides* ventral; (21) *Auca pales* dorsal (a) and ventral (b); (22) *Neomaenas poliozona* dorsal (a) and ventral (b); (23) *Yramea cytheris* dorsal (a) and ventral (b); (24) *Vanessa carye* dorsal (a) and ventral (b); (25a) *Vanessa terpsichore* dorsal; (25b) *Vanessa terpsichore* ventral.

Turning to the taxocenotic similarity between seasons, in spring, there was greater similarity between ecotone and forest (66.67%), and these two environments together diverge from grassland in summer, which has a lower similarity. This occurs because the majority of the species recorded in grassland in spring are not shared, a large number being found exclusively in this habitat.

The biocenotic similarity does not present great differences. The greatest dissimilarity is found between forest and grassland; this is explained by the fact that these two environments share fewer species; however, spaces which have suffered intervention and disturbance have higher levels of light [14] causing a restructuring of the butterfly community around forest edges. This allows pioneer species to increase in the plant succession, increasing food resources.

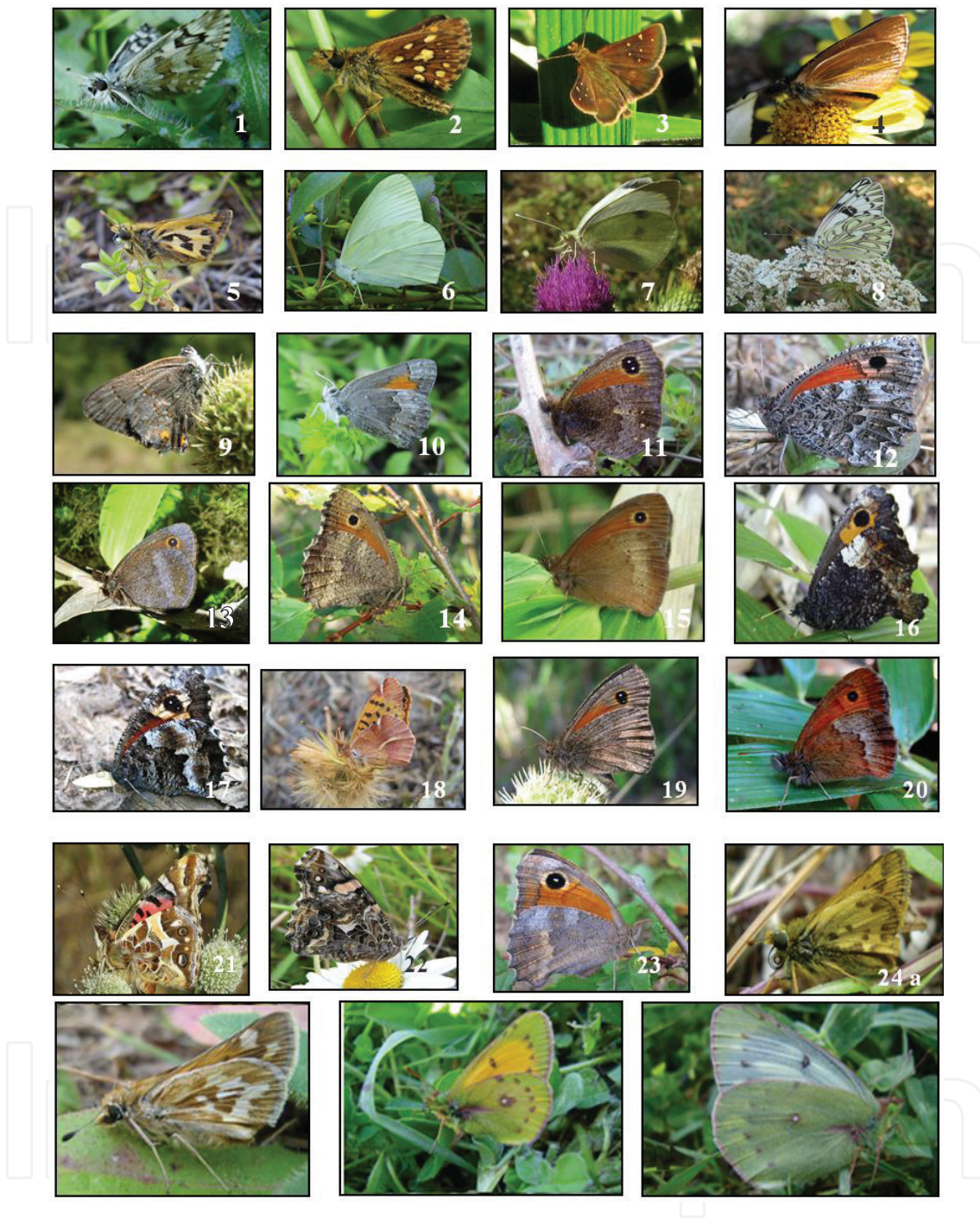


Figure 8. Photographs of Rhopalocera taken “in situ” at the Rucamanque site, spring 2007–summer 2008, on possible host plants: (1) *Pyrgus n. valdivianus* (Philippi) (Ea =); (2) *Butleria p. paniscoides* (Blanchard, 1852); (3) *Butleria bissexguttata* (Philippi, 1859); (4) *Argopteron aureipennis* (Blanchard, 1852); (5) *Hylephila fasciolata* (Blanchard, 1852); (6) *Mathania leucothea* (Molina, 1782); (7) *Pieris brassicae* (Linné, 1758); (8) *Tatochila a. blanchardi* (Butler, 1881); (9) *Strymon eurytulus* Hubner, 1819.; (10) *Eiseliana bicolor* (Philippi, 1859); (11) *Homoeonympha boisduvali pusilla* (C. & Felder); (12) *Cosmosatyrus chilensis chilensis* (Guérin, 1832); (13) *Homoeonympha humilis* (C. & R. Felder, 1867); (14) *Neomaenas monachus* (Blanchard, 1852); (15) *Neomaenas poliozona* (C. & R. Felder, 1867); (16) *Nelia nemyroides* (Blanchard, 1852); (17) *Elina montroli* (Feisthamel, 1839); (18) *Yramea cytheris* (Drury, 1773); (19) *Auca pales* (Philippi, 1859); (20) *Neomaenas coenonymphina* ssp.; (21) *Vanessa terpsichore* Philippi, 1859; (22) *Vanessa carye* (Hübner, 1806); (23) *Neomaenas janirioides* Blanchard, 1852; (24a) *Hylephila signata* (♂) (Blanchard, 1852). (24b) *Hylephila signata* (♀m) (Blanchard, 1852); (25a) *Colias vauthierii vauthierii* (♂) Guérin 1829.; (25b) *Colias vauthierii vauthierii* (♀) Guérin 1829.

Of particular interest in this study are the species *Eiseliana bicolor* (Philippi, 1859) and *Neomaenas coenonymphina* Butler, 1881, for which the distribution range must be extended. According to Ref. [4], the distribution of *E. bicolor* is from Atacama to the Bío-Bío. *N. coenonymphina* is an uncommon species supposedly found only in Chile's fifth region; it is associated with the graminid *Chusquea* sp. Kunth; this record is the more important as the species is considered to be threatened [17].

The forest remnant Rucamanque is the most pristine part of the Huimpil-Ñielol range of hills. It is therefore strange that the important indicator species *Eroessa chilensis* (Guérin, 1830) was not recorded and probably results from sampling errors.

In earlier studies in this area, Cerro Ñielol, close to the centre of Temuco, presented the same number of species [26]; it should however be noted that this study is 25 years old. Other studies reporting the diversity of Rhopalocera at different altitudes in the Araucanía Region [20, 26] indicate that the greatest diversity is found in the central valley and in forest remnants like Rucamanque, identified with the subtype name Original Remnants [36]. Paradoxically, this sector is suffering severe anthropic pressure, since although it is a priority site for conservation, it enjoys no legal protection as does the Cerro Ñielol Natural Monument.

The greatest diversity and levels of endemism for Rhopalocera are found in central Chile. This zone is recognised as a biodiversity hotspot, for both the endemism and richness of its vegetation [21]. This observation is also applicable to invertebrates, including insects, since plant diversity patterns are frequently good predictors of insect diversity patterns. The presence of certain species of Rhopalocera indicates that its host plants are present nearby [21].

The diversity of Rhopalocera present in the Rucamanque forest remnant is the more important because of the fragmentation process that is continuing in south central Chile (**Figures 7 and 8**).

The ecological characteristics of the Rucamanque remnant are still predominantly stable, despite fragmentation and the exotic plantations in the vicinity. They have allowed a great diversity of lepidoptera to flourish, including 50% of the species recorded for the Araucanía Region and 14% of the species recorded in Chile. According to Donoso [36, 37], forests of this kind are very scarce, but ecologically and scientifically very important. This explains the importance of this priority site for the conservation of biodiversity and the need to survey the micro and macrofauna in this sector.

5. Conclusions

- Study of the Rucamanque forest remnant produced a total of 25 species of Rhopalocera with a total of 1190 individuals recorded, representing 4 families and 18 genera of the order Lepidoptera. These 25 species represent 50% of the local lepidoptera and 14.79% of those recorded in Chile.
- The habitat where the greatest diversity of species was found was the ecotone, where 21 species were recorded representing more than 80% of all the species reported at the study site.

- The habitat presenting the least diversity was the forest with 12 species, 48% of all the species recorded in the study area.
- The seasonal diversity and abundance were stronger in summer, with higher values for species diversity and abundance in all three habitats sampled.
- The greatest numbers of species shared between habitats were 12 between ecotone and grassland and 11 between ecotone and forest. Grassland and forest presented the smallest number of shared species, only 4. The greatest taxocenotic similarity was found between ecotone and grassland, while forest presented the lowest similarity, diverging from these two habitats.
- The greatest abundance occurred in the grassland, with 453 individuals; the biocenotic similarity of grassland with ecotone and forest was low and the similarity between these two was higher. Although a larger number of species share the grassland and ecotone habitats, two species dominate the grassland assemblage, accounting for 64% of the population in this habitat, meaning that the other species are present in smaller numbers.
- New distributions were recorded for the species *Eiseliana bicolor* (Philippi, 1859) and *Neomaenas coenonymphina* Butler, 1881.
- Statistically significant differences were found in the three environments studied in Rucamanque, the greatest differences occurring between forest and grassland. The community parameters calculated and the Bray & Curtis similarity coefficient denote these differences.
- Recording the species diversity of the zoological group studied in forest remnants is of great importance, both for their ecological value and to take informed decisions in management and planning for conservation, study and tourism.

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