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Species densities and geographical distribution of Lycaenids on the Iberian Peninsula

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Introduction

Biogeographical studies dealing with the abundance of species started during the middle of the 19th century, centering mainly on latitudinal gradients.

Terentev (1963) and Simpson (1964) independently developed a rather simple technique for the analysis of the geographic variation of specific abundance. This method consists of the splitting of the geographical area under study into squares of equal size. The method was widely used by several authors in different parts of the world. Most of these deal with vertebrates due to the fact that the information on invertebrates is rather scarce.

On the Iberian Peninsula the technique has been used by Schall & Pianka (1977) who studied the distribution of the Spanish herpetofauna. Following the above authors, I have undertaken an analysis of the geographic distribution of the Iberian Lycaenids using the cartography given by Gomez Bustillo & Fernandez Rubio (1974).

The distribution maps have been compared with other distribution analysis such as those made by Manley & Allcard (1970) and Higgins & Riley (1980). I also took data from more detailed distributions both from a chorological as well as geographical point of view (Agenjo, 1944, 1965, 1967 ; Monserrat, 1974 ; Viejo, 1981 ; Gomez Bustillo & Arroyo Varela, 1982 ; etc.). Most of the details given by these authors are of scant meaning for an analysis of this type, which considers the distribution problem on a big scale. Thus I thought it better not to modify the data given by Gomez Bustillo & Fernandez Rubio (op. cit.), until further data of this type allow us to make a finer analysis in the future.

Three of the eight subfamilies into which Eliot (1972) divided the Lycaenidae are found on the Peninsula. The biology of the Iberian species is rather varied. Habitats range from high mountains down to typical lowland forests. Most are stenophagous in their larval phase. We find uni-, bi- and multivoltine species. Hibernation occurs in the egg, larval or pupal stage depending on the species. Most are sedentary, though others migrate. Some maintain rather close relationships with Formicidae and at all larval stages myrmecophilous organs are present. This fact undoubtedly allows them to tolerate the presence of these Hymenoptera much better than any other Lepidopteras. This advantage gives them a series of niches hardly avaible to any other insects.

In this work I intend to uncover the main factors ruling the geographic distribution of the species of the family Lycaenidae in the Iberian Peninsula.

Methods

The Iberian Peninsula has been divided into squares following the lines of geograhic parallels and meridians. The unit chosen has been one degree. We thus have 81 squares 1° of latitude times 1° of longitude.

The resulting network was superimposed on the maps of Gomez Bustillo & Fernandez Rubio (op. cit.) to calculate the abundance of species in each square. The abundance has been determined for the whole family (67 species) and for each of the three subfamilies, Theclinae (12 species), Lycaeninae (5 species) and Polyommatinae (50 species). The subfamily Polyommatinae has been subdivided into two groups, whether they belong (30 species) or not (20 species) to the *Polyommatus* genus group.

Once the abundance maps for the species had been constructed, I established the factors which, in my opinion, could govern the distribution. I chose 8 variables : three deal with the geographic placing of each square, namely latitude (*Lat.*), longitude (*Long.*) and distance from the Pyrenees (*Prdt.*). The other five refer to local conditions in each square : maximum altitude (*Hmax.*), minimum altitude (*Hmin.*), altitudinal difference (*Hdif.*), soil properties (*Sust.*) and "climatic irregularity" (*Clir.*).

Latitude and longitude have been measured in degrees. The range of these variables goes from 1 to 14 (longitude) and from 1 to 8 (latitude). The distance from the Pyrenees was likewise measured in degrees. All the squares which include this cordillera were taken as the origin and all received the 1 value. For squares placed diagonally the value of their hypotenuse was given. Values range from 1 to 10.6.

The values of altitude have been obtained from the corresponding sheets of the Military Map of Spain, scale 1 : 400,000 from the Geographic Service of the Army.

Maximum altitude represents the highest point of each square. It doesn't matter whether the same square has 1 or more than one points of similar altitude. Metres were taken as the unit of measurement. Range in this variable goes from 197 to 3.482 metres. Minimum altitude is the lowest point of the square considered. Also taken in metres, it ranges from 0 to 1,000 metres. The difference in altitude is that of maximum altitude minus minimum altitude. Its range goes from 197 to 3,082 metres.

Soil diversity has been introduced as an indirect indicator of botanical diversity. The latter can determine rather strictly the number of phytophagous species which a given square presents. I have assigned arbitrary values which reflect an approximate index of the plant diversity which each soil type supports. The squares with different types of soil are identified by the sum of the corresponding index. Thus the squares with silicic soil have been assigned value 1 ; argillaceous, both calcareous or silicic in origin 1.5 ; calcareous 2 ; silicic and argillaceous 2.5 ; silicic and calcareous 3 ; argillaceous and calcareous 3.5 ; and silicic, argillaceous and calcareous 4.5. Soil types have been taken from SOLE SABARIS (1952).

Climatic irregularity is a coefficient which reflects the unevenness of precipitation throughout the years. It is the quotient of the standard deviation and the mean of annual precipitation. The values have been taken from MONTERO DE BURGOS & GONZALEZ REBOLLAR (1974), where this concept is developed. Climatic irregularity is independent of the amount of precipitation. Being the unevenness of the precipitations the factor which best defines the mediterranean climate, this index reflects the mediterranean nature of the climate of each square.

After calculating the correlation coefficient of each one of these factors with the abundance of species, the analysis was repeated for the family as a whole and for each one of the groups into which the family was subdivided. Then, all the variables were submitted to a stepwise multiple regression analysis. In this case, the analysis was likewise carried out for the family as a whole and the constituting groups as well.

This type of analysis orders the variables as they absorb the residual variance which produce those introduced before them. The program automatically stops when the absorbed residual variance is not significant.

Results (Maps I and II ; Tables 1 and 2)

The maps show the results of the abundance of species. The results of the correlation analysis and the stepwise multiple regression analysis are shown on tables.

Maps I

Numbers of species in each square.
Columns on the right represent total numbers of species in each latitudinal band (N_1) and the mean value of these ($\bar{M}$)

10° 5° 0° 4°

44° 40° 36°

														N_1	$\bar{M}$
11	15	22	33	35	41	37	38	35						43	29.67
12	16	27	34	36	46	43	42	43	49	50	50	50	37	59	38.21
	23	33	30	20	23	32	36	29	31	41	47	51	38	54	33.39
	27	28	23	25	34	38	34	44	43	29				50	32.50
19	24	24	19	21	23	23	29	40	32					46	25.50
21	21	17	18	20	22	25	25	27	28	21				33	22.27
	18	18	20	22	25	38	31	29	22					40	24.78
			19	22	23	31	28							32	24.60

Ia: *Lycaenidae*

10° 5° 0° 4°

44° 40° 36°

														N_1	$\bar{M}$
4	4	4	7	8	9	9	10	10						10	7.22
4	4	5	8	8	10	9	10	10	9	9	9	11	8	12	8.14
	8	9	8	7	7	8	8	7	8	10	11	11	9	11	8.54
	9	9	9	8	8	7	8	8	8	6				10	8.00
7	8	8	7	6	6	6	7	8	8					10	7.10
7	7	6	6	6	6	6	6	6	6	5				7	6.09
	8	7	7	7	7	8	8	7	5					8	7.11
			7	7	7	8	8							8	7.40

Ib: *Theclinae*

	10°					5°					0°			4°	N_1	$\bar{M}$
44°	1	2	4	5	5	5	5	5	5						5	4.11
	1	2	5	5	5	5	5	5	5	5	5	5	5	5	5	4.43
		3	5	5	1	1	4	4	4	3	4	5	5	4	5	3.69
		5	5	2	3	4	4	3	3	3	2				5	3.40
40°	1	2	2	1	1	1	1	2	2	1					3	1.40
	1	1	1	1	1	1	1	1	1	2	1				2	1.09
		1	1	1	1	1	2	2	2	1					2	1.33
36°				1	1	1	2	2							2	1.44

Ic: *Lycaeninae*

	10°					5°					0°			4°	N_1	$\bar{M}$
44°	6	9	14	21	22	27	23	23	20						28	18.33
	7	10	17	21	23	31	29	27	28	35	36	36	34	25	42	25.64
		12	19	17	12	15	20	24	18	20	27	31	35	25	38	21.15
		13	14	12	14	22	27	23	33	32	21				35	21.10
40°	11	14	14	11	14	16	16	20	30	23					33	16.90
	13	13	10	11	13	15	18	18	20	20	15				24	15.09
		9	10	12	14	17	28	21	20	16					30	16.33
36°				11	14	15	21	18							22	15.80

Id: *Polyommatinae*

	10°					5°					0°			4°	N_1	$\bar{M}$
44°	3	4	6	12	13	15	12	13	12						16	10.00
	3	4	9	12	14	19	19	16	17	23	23	22	21	15	27	15.50
		6	10	9	6	9	13	15	11	12	17	18	20	15	22	12.39
		7	6	5	7	15	16	15	20	21	11				22	12.30
40°	5	7	6	5	8	9	9	13	19	15					20	9.60
	4	4	4	5	6	8	11	11	12	10	7				13	7.46
		4	3	5	7	9	17	12	11	8					17	8.44
36°				4	5	7	12	9							12	7.40

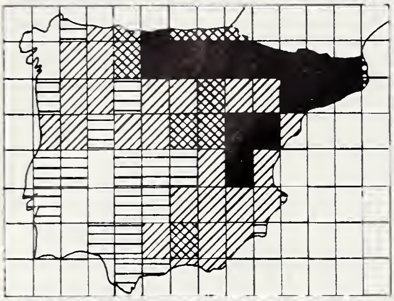
Ie: *Polyommatus*

	10°					5°					0°			4°	N_1	$\bar{M}$
44°	3	5	8	9	9	12	11	10	8						12	8.33
	4	6	8	9	9	12	10	11	11	12	13	14	13	10	15	10.14
		6	9	8	6	6	7	9	7	8	10	13	15	10	16	8.77
		6	8	7	7	7	11	8	13	11	10				13	8.80
40°	6	7	8	6	6	7	7	7	11	8					13	7.30
	9	9	6	6	7	7	7	7	8	10	8				11	7.64
		5	7	7	7	8	11	9	9	8					12	7.89
36°				7	9	8	9	9							10	8.40

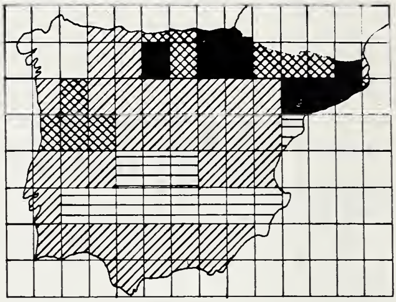
If: *Polyommatinae* excl. *Polyommatus*

Maps II

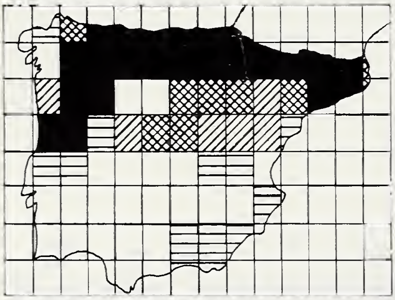
Species density gradients ; $\bar{M}$ mean, s standard deviation



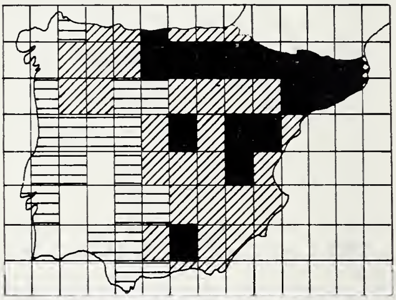
IIa : *Lycaenidae*



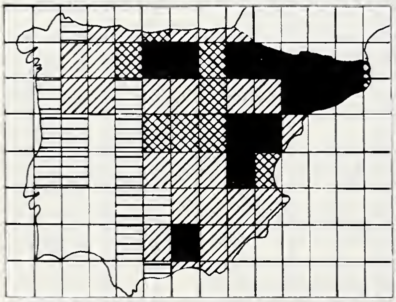
IIb : *Theclinae*



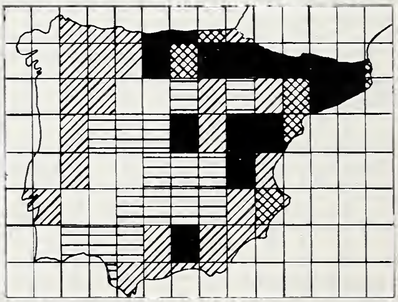
IIc : *Lycaeninae*



IId : *Polyommatinae*



IIe : *Polyommatus*



IIf : *Polyommatinae* excl. *Polyommatus*

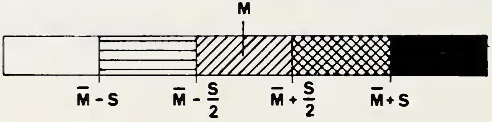


Table 1
Correlation coefficients between taxonomic group and variables, r

Taxonomic group	Lat.	Long.	Prdt.	Hmax.	Hmin.	Hdif.	Sust.	Clir.
Lycaenidae	0.43*	–0.69*	–0.81*	0.68*	0.29*	0.63*	0.32*	–0.36*
Theclinae	0.26	–0.43*	–0.53*	0.44*	0.10	0.44*	0.38*	–0.26
Lycaeninae	0.74*	–0.30*	–0.60*	0.53*	0.11	0.54*	–0.07	–0.64*
Polyommatinae	0.35*	–0.75*	–0.81*	0.68*	0.33*	0.61*	0.36*	–0.27
Polyommatus	0.38*	–0.75*	–0.84*	0.68*	0.40*	0.59*	0.36*	–0.29*
Polyommatinae excl. *Polyommatus*	0.24	–0.67*	–0.66*	0.58*	0.14	0.58*	0.31*	–0.20

Correlation significant: $^{*}P < 0.01$.

Table 2
Cumulative correlation coefficients, r
(Stepwise multiple regression analysis)

Taxonomic group	Step	Variable	Cumulative r
Lycaenidae	1	Prdt.	0.81
	2	Hdif.	0.88
Theclinae	1	Prdt.	0.53
	2	Sust.	0.60
	3	Clir.	0.64
	4	Hdif.	0.67
Lycaeninae	1	Lat.	0.74
	2	Hdif.	0.84
	3	Sust.	0.86
Polyommatinae	1	Prdt.	0.81
	2	Hmax.	0.88
	3	Long.	0.89
Polyommatus	1	Prdt.	0.84
	2	Hmax.	0.90
	3	Sust.	0.90
Polyommatinae excl. *Polyommatus*	1	Long.	0.67
	2	Hdif.	0.77
	3	Clir.	0.78

Discussion

The first thing one notices on the maps is that the latitudinal gradient is arranged so that maximum numbers of species are found on the northernmost latitudes while minima are located southwards.

On the tables, the highest correlation coefficients correspond to latitude, longitude and distance from the Pyrenees. This last variable on the north-east sector of the Peninsula is equal to latitude, in the north is assimilable to longitude, while in the remaining regions is a combination between latitude and longitude and has, therefore, a different meaning from the two variables each taken separately. It is, according to these coefficients, the most important factor affecting the distribution of species in this family. Furthermore, this is also seen if we consider the groups into which the family was subdivided instead of species numbers. In the multiple correlation coefficients these variables do not normally appear because distance from the Pyrenees absorbs the other two. The interpretation of this variable is complex. Its main characteristic is that these mountains represent the compulsory route for species of Euroasiatic origin. It is not, however, linked to the presence of a climate and/or vegetation of central european nature, which are better characterized by the values of latitude. Eurosiberian type vegetation occupies the northern strip and part of the western strip of the Iberian Peninsula.

The variables maximum altitude and altitudinal difference have always positive correlation indeces which rank second, in their values, to the three indeces mentioned above. They have been included because height differences are an indirect index of the number of different biotopes per square.

Maximum altitude considers the presence of high mountains and, therefore, squares with highest values of maximum altitude have climatology and vegetation comparable to european zones. In practice both variables are so similar that their correlation indeces become indistinguishable.

Minimum altitude is correlated to these last two and is of minimal significance. In the multiple regression coefficients maximum altitude and altitudinal difference absorb themselves mutually.

Climatic irregularity always shows negative values but there are marked differences among the different taxonomic groups which allow for a comparison to be established among the different groups adapted to the most extreme mediterranean climates (xerothermophilous).

The variable which includes soil diversity seems to be the least important one, though, naturally, a greater numbers of species correspond to higher diversity of soils.

Conclusions

1. Distance to the Pyrenees is the factor which best explains the distribution of species in this family. The gradient of species abundance from these mountains southwards seems to be due to the fact that most of the Iberian Lycaenids have an Euroasiatic origin.

2. The second factor in importance explaining species abundance is altitude. This could be due both to a higher absolute number of biotopes in these areas and to the fact that these zones are more similar to european habitats, which links with what has been said above.

3. Though there are a great number of species adapted to mediterranean type ecosystems, which are distributed throughout the oriental zone of the Iberian Peninsula, the number of species adapted to the most extreme mediterranean climates is very small.

4. Soil diversity plays a secondary role on the large-scale distribution of the species in this family.

5. The subfamily Lycaeninae within the Lycaenidae is the one that has the smallest proportion of species able to tolerate the most extreme mediterranean climates.

6. The subfamily Polyommatinae and, within it, the species which do not belong to the *Polyommatus* group, have the highest proportion of species adapted to mediterranean areas.

7. The rule of highest diversity of species as we decrease in latitude is not followed by this family in the Iberian Peninsula.

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Summary

This paper is an analysis of the geographical distribution of the Lycaenid species in the Iberian Peninsula estimated through species densities in areas of equal size.

The method pinpoints the two main factors governing the densities of these species as being the altitude and, interestingly, the distance from the Pyrenees. This fact emphasises the mainly Euroasiatic origin of the Iberian fauna of these lepidopteras.

Resumen

Se ha analizado la distribución geográfica de las especies de Licénidos en la Península Ibérica, mediante la estimación de la densidad en especies en áreas de igual superficie.

Mediante este método de análisis se ha podido constatar que los dos factores principales que influyen en la densidad de estas especies son la altitud, y de forma predominante, la distancia a los Pirineos. Esto pone de relieve el origen mayoritariamente Euroasíatico de la fauna ibérica de estos lepidópteros.

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