Belgian Journal of Entomology 2 (2000) : *111-124*

The geographic distribution and state of butterfly faunistic studies in Iberia (Lepidoptera Papilionoidea Hesperioidea)

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Abstract

Using a data base of chorological data from selected species of butterflies, the present state of faunistic studies of these insects was assessed in the Iberian Peninsula. The information was used to determine the geographic coverage of the existing data on UTM grids of different sizes. This enabled an estimation of the square size that is best suited for comparative work (e.g., estimation of biodiversity, or biogeographic inference), as well as an identification of relevant gaps, and the possible reason for their existence. Historical trends in the evolution in numbers of references, and in the amount of area covered by faunistic work, were used to estimate broad predictable trends in the faunistics of Iberian butterflies. It is concluded that less than 50% of the area has been covered by available faunistic reports, if the 10 × 10 km grid is taken as a reference. This figure improves as the grid scale increases, so that a minimum grid size of 50 × 50 km is recommended for the highest accuracy. The amount of faunistic effort, the number of endemic species, and the total number of butterfly species are correlated to each other. This suggests a pattern of "species diversity tracking" by lepidopterists, with faunistic effort being concentrated on areas that are *a priori* supposed to host a high species diversity (a conclusion that has to be regarded cautiously). Records from the past 200 years show that most faunistic progress is recent, and that historic data are geographically and quantitatively restricted. As a result, historical data may prove of limited use. Unless further work is undertaken to study those areas from which the present information is highly speculative, objective criteria to estimate butterfly biodiversity may be inapplicable at the local scale (e.g. below 50 × 50 km grid sizes).

Keywords : Portugal, Spain, biodiversity, biogeography, endemism.

Introduction

Faunistic studies represent an essencial tool for biodiversity assessment. Obviously, accurate information on the distribution of rare, endemic, or otherwise sensitive species is dependent on the existence of a satisfactory general faunistic knowledge. An efficient partition of natural geographic areas into smaller, operative units for biodiversity assessment or for related theoretical purposes (e.g., biogeographical analysis) will also depend on the accuracy of available chorological data. Thus, as stated by DENNIS & WILLIAMS (1995), *it is not possible to conserve what is not adequately mapped.*

The present work is to a large extent a result of the collection of data required by the project *"High Endemism Areas, Endemic Biota, and Conservation of Biodiversity in Europe"*. However, endemic species are not the main target in this study. Part of the activities undertaken during the project involved comparisons between species densities from different hexapod taxa. The present status of chorological data from different insect groups in Spain and Portugal is believed to vary within broad limits. Thus, one preliminary step consisted of determining a quadrat size that could ensure a reasonable coverage of the area under study. This had to be done in a relatively fast and economic way. The butterflies (superfamilies Papilionoidea and Hesperioidea) were selected for this purpose because these organisms are frequently assumed to enjoy a position of privilege in comparison to other terrestrial arthropods, in terms of the amount of attention paid by naturalists. This, in turn, led to the question: How accurate is the knowledge of butterfly geographic distributions in the Iberian peninsula?

An important amount of literature concerning European butterflies is available. Reliable species check lists exist for most European countries, and broad scale geographic distributions can be defined with reasonable accuracy for the Western Palaearctic (e.g. TOLMAN, 1997), as well as for several countries (e.g. HENRIKSEN & KREUTZER, 1982, GEIGER, 1987, EMMET & HEATH, 1989, FERNÁNDEZ-RUBIO, 1991, ABADJIEV, 1992-1995, BINK, 1992, HESSELBARTH *et al.*, 1995, PAMPERIS, 1995, TENNENT, 1996). More detailed distribution atlases are available for some countries, or some butterfly taxa (HEATH *et al.*, 1984, GONSETH, 1987, TAX, 1989, ESSAYAN, 1990, WILLIEN, 1990, REICHL, 1992). Relatively detailed chorologies such as 10 × 10 km UTM dot maps are useful for designation of areas of high diversity or high endemism (e.g. BAZ, 1991, VIEJO *et al.*, 1991, CASTRO PRAGA *et al.*, 1996), and species rarity (MUNGUIRA *et al.*, 1991). This requires that the study areas are homogeneously worked out: broad approaches may be succesfully performed using rough distributional data (e.g. DENNIS *et al.*, 1998), but criteria derived from such studies, or other general methods, will be inapplicable at the local scale whenever that objective data are missing.

The circum-mediterranean butterfly faunas are characterised by an important species diversity, as well as by a comparatively high number of endemic species (in terms of West-Palaearctic standards: MUNGUIRA, 1995). However, the progress of mapping programs in Mediterranean countries is slow (BALLETTO & CASALE, 1991). Paradoxically, the relatively rich literature on some Mediterranean countries, such as Portugal and Spain, suggests an increasingly accurate faunistic knowledge of their territories (MANLEY & ALLCARD, 1970; GÓMEZ BUSTILLO & FERNÁNDEZ-RUBIO, 1974; GÓMEZ BUSTILLO & ARROYO, 1981; FERNÁNDEZ-RUBIO, 1991; VIVES MORENO, 1994).

This study was thus directed to answer three main questions: First, what is the geographic distribution of the available faunistic reasearch on Iberian butterflies? Are there relevant gaps in the data?. Second, do such gaps enclose areas of potentially high species diversity? And, third, what is the minimum quadrat size that could be reliably employed in comparative biogeographic work using data from insects, or in order to determine areas of high endemicity or diversity, under the presumption that our knowledge of butterfly chorology is superior to those of other insect groups? In an attempt to identify consistent trends in Iberian butterfly faunistics, the evolution of the data during the last 200 years was also traced.

Materials and methods

1) Data sources and study area. The raw material consisted of presence/absence of species of the superfamilies Papilionoidea and Hesperioidea, in 10 × 10 km squares of the UTM grid system, from the Iberian Peninsula (in practice, the continental territories of Spain and Portugal). A crude estimate of the amount of work necessary to complete a fully comprehensive database for the whole fauna (more than 230 species: VIVES MORENO, 1994; KARSHOLT & RAZOWSKY, 1996) proved this activity to be out of the scope of the project. We thus relied primarily on bibliographic data, although these were complemented with information from public and private collections for species of restricted geographical range (all endemic ones, together with those recorded from less than 250 UTM 10 × 10 squares). Such collection sources included the Natural History Museum at Madrid, the scientific collection of the Sociedad Aranzadi at San Sebastián, the entomological collection at the authors Department, the collection of the Universidad Complutense de Madrid, and the private collection of Dr. F. Fernández-Rubio. The information concerning the Portuguese fauna was scarce enough to enable inclusion of the 131 species recorded from that country (details in GARCIA-PEREIRA *et al.*, 1999). For the Spanish data, a subset of species had to be chosen due to the amount of available material. The criteria for species selection were merely economic, and had to rely primarily on the accessibility of the sources to the authors. The sample consisted of 52 species of Nymphalidae Satyrinae (in fact, all the satyrines recorded form Spain and Portugal), 23 Lycaenidae, plus 16 additional species belonging to the Pieridae, Papilionidae, Nymphalidae, and Hesperiidae (full details, together with a preliminary approach, will be found in GARCÍA-BARROS & MUNGUIRA, 1999). This material was used to construct a database where each entry (row) contained data from one or more specimens including species name, date and site of collection, and the co-ordinates of the 10 × 10

km squares (UTM grid system) of collection sites. The operational database included more than 47,500 entries derived from 635 published references, concerning 188 butterfly species (130 in Continental Portugal, 91 in Continental Spain).

2) Area units. The 10 × 10 km UTM squares were used as basic operative area units (OAU_{10}). In order to estimate the geographic coverage of faunistic data under different scales, larger quadrats with sides of 20, 50 and 100 km in the UTM grid were employed (henceforth termed OAU_{20} - OAU_{100}). Such units were designed on the basis of the 100 × 100 km UTM grid. The UTM partition of the Iberian Peninsula is complicated by the presence of two compensation areas that produce OAU_{100} "squares" with less than 100 OAU_{10}. In such instances, adjacent subareas were fused to obtain roughly comparable OAU_{100} sq. Further, peripheral 100 km units contain small numbers of OAU_{10} sq. When this proportion was lower than 10% (that is, any OAU_{100} containing less than ten OAU_{10}), the subareal data were adscribed to the nearest large quadrat. The result of this modification can be appreciated comparing the quadrats in Figures 1 and 2.

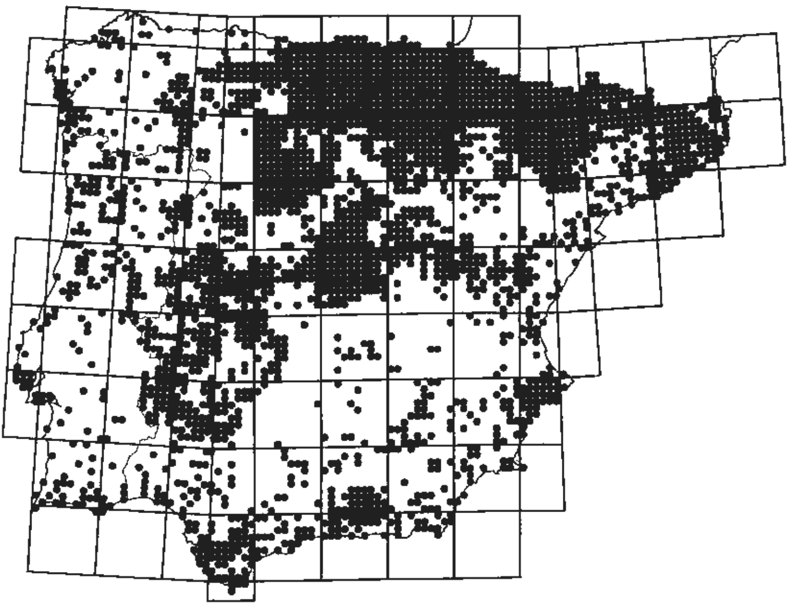

Fig. 1. Geographic distribution of faunistic information concerning Iberian butterflies (Papilionoidea and Hesperioidea). Dots represent 10 × 10 km squares (U.T.M. grid) referred to in any of the data sources (see text).

3) Faunistic coverage. This was measured as the percentage of area units that contain any record, at each *OAU* size. At the largest scale, coverage was also estimated as the percentage of OAU_{10} subunits for which faunistic data exist, in each OAU_{100}. The criterion for "presence" in a quadrat was rather optimistic: the presence of any species in one land unit was taken as evidence of faunistic knowledge, irrespective of the number of species, collectors, or references associated to that spot. Although the data from the Spanish territory are not exhaustive, the results are believed to be realistic. At least four of the satyrines are widespread across the whole of Iberia, and are believed to occur in no less than 90% of the area. Several of the other butterflies selected are in one or another way appreciated by collectors, or interesting for lepidopterists. This increased the likelihood that most of the sites recorded by us have, in fact, been prospected to a reasonable degree.

4) Size effects. As mentioned above, the surface of the largest area units (OAU_{100}) varied between ca. 1,000 and 12,000 km^2. To control for any statistical interdependence between species richness, or faunistic coverage, and the *OAU*'s actual area, the correlations between quadrat size and these variables were checked for in a first step. The largest quadrats (100 × 100 km) were used as area units in this, and the next steps of the analyses. Although this choice may be criticized for its low resolutive power, it guarantees conservative estimates and was supported by our own results (as detailed in the results section of this study).

5) Species densities. The total number of species in the OAU_{100}s was derived from the distribution charts given by FERNÁNDEZ-RUBIO (1991). Although these are broad-scale, presumptive distribution maps, the guide by FERNÁNDEZ-RUBIO (*op. cit.*) is reasonably updated to allow for estimates of species densities that are suitable for general purposes.

6) Endemic species densities. The number of butterfly species that represent true Iberian endemisms varies to some extent depending on taxonomic criteria. The next 15 species were selected: *Agriades pyrenaicus* (BOISDUVAL, 1840), *A. zullichi* (HEMMING, 1933), *Agrodiaetus ainsae* (FORSTER, 1961), *A. fabressei* (OBERTHÜR, 1810), *A. fulgens* (SAGARRA, 1925), *A. ripartii* (FREYER, 1830), *Aricia morronensis* (RIBBE, 1910), *Lysandra golgus* (HÜBNER, 1813), and *L. nivescens* (KEFFERSTEIN, 1851) (Lycaenidae), plus *Erebia gorgone* (BOISDUVAL, 1833), *E. hispania* (BUTLER, 1868), *E. lefebvrei* (BOISDUVAL, 1828), *E. zapateri* (OBERTHÜR, 1875), *E. palarica* (CHAPMAN, 1905), *E. sthennyo* (GRASLIN, 1850) (Nymphalidae, Satyrinae). Updated 10 × 10 km dot maps were produced for each of these species (not presented here). These served to estimate the number of endemics in the OAU_{100}s.

7) Historical trends. Finally, an approach to the historical evolution of faunistic coverage was attempted. For practical reasons this part of the study was restricted to the Nymphalid subfamily Satyrinae, and to the Spanish territory. For this purpose the cummulative amounts of faunistic coverage (pre-

sence/absence), were measured at 25-year intervals for the four *OAU* sizes. The cummulated number of literature references, and that of satyrine species added to the Spanish check lists, were plotted at similar time intervals. These data were graphically compared, based on the information recorded from ca. 550 published references relative to the 52 satyrine nymphalids (about 34,000 individual entries). Some further information on the references concerning Portugal is presented elsewhere (GARCIA-PEREIRA *et al.*, 1999).

Results

The spread of faunistic information across the Iberian territory, from the data described, is shown in Figure 1. The proportion of the total surface occupied is below 50% for the smallest quadrat size (OAU_{10}), in fact 39.5%. The figure improves for larger units areas: 70% for OAU_{20} and 100% for both OAU_{50} and OAU_{100}. The density of 10 × 10 occupied dots per large quadrat (OAU_{100}) is shown in Figure 2. The coverage of these units is 45.37% on average (s.d.=27.2). Only one fifth of the 100 km quadrats have been prospected to a level equal or above 75%, while the coverage is lower than 25% for almost a 30% of the 100 km quadrats.

The number of endemic species per 100 km square varied between 0 and 12 (mean=4.16, s.d.=3.89), while the total number of species in each square

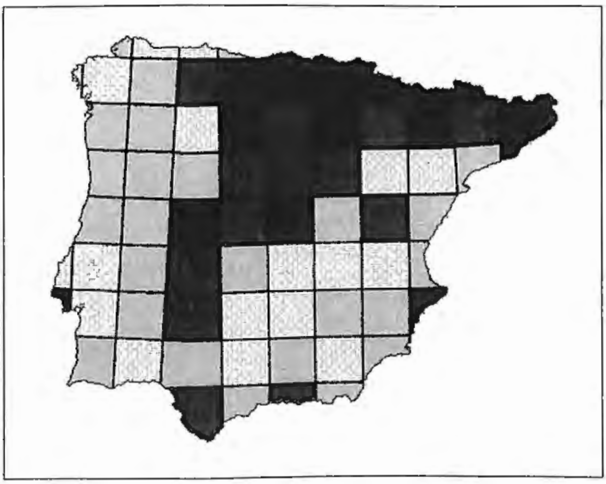

Fig. 2. Density of faunistic information relative to butterflies in Iberia, in large (ca. 100 × 100 km) area units (see text). The data are percentages of area coverage (number of 10 × 10 squares that contain any faunistic data, divided by the total number of such grid squares in a given area unit). The four degrees of intensity represent the quartiles of the frequency distribution (light to dark= low to high).

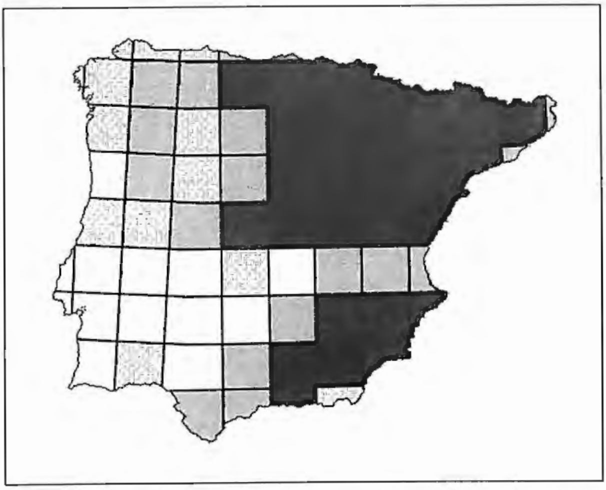

Fig. 3. Density of Iberian endemic butterflies. The four different intensities correspond to the four quartiles of the frequency distribution. Unshaded squares indicate absence of endemic species. Other details as in Figure 2.

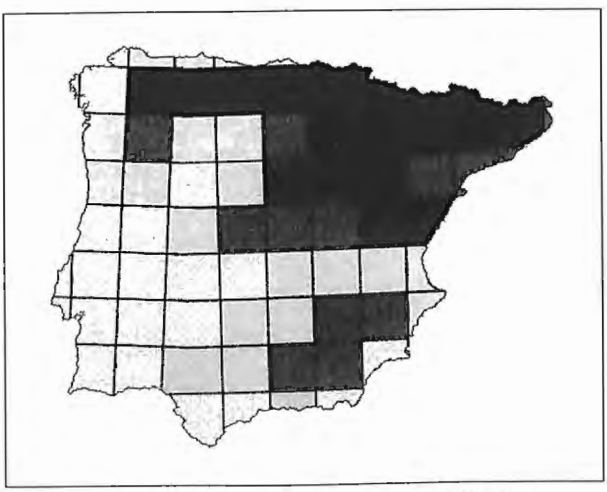

Fig. 4. Total species densities, based on updated hypothesized distribution maps. Details as in Figure 2.

ranked between 61 and 175 (108.78 on average, s.d.=27.01). The geographic distribution of these values is given in Figures 3 and 4. Testing the correlations between the values for the 100 × 100 km squares demonstrated significant relationships among the density of faunistic work, the total number of species, and the number of endemic species, as shown in Table 1 and Figures 5-7. There were positive correlations between the actual size of the operational units and the other variables. This "area effect" was evident for faunistic cove-

Table 1. Correlation matrix showing the relationships among the total numbers of species, the numbers of Iberian endemics, the degree of faunistic coverage, and quadrat area, for the largest area units (OAU_{100}) in Iberia. The number of area units is 74 in all instances.

	Faunistic coverage	Area	Number of endemics
Number of species	r=0.549 p<0.001	r=0.210 p=0.072	r=0.737 p<0.001
Faunistic coverage		r=0.512 p<0.001	r=0.510 p<0.001
Area			r=0.274 p=0.018

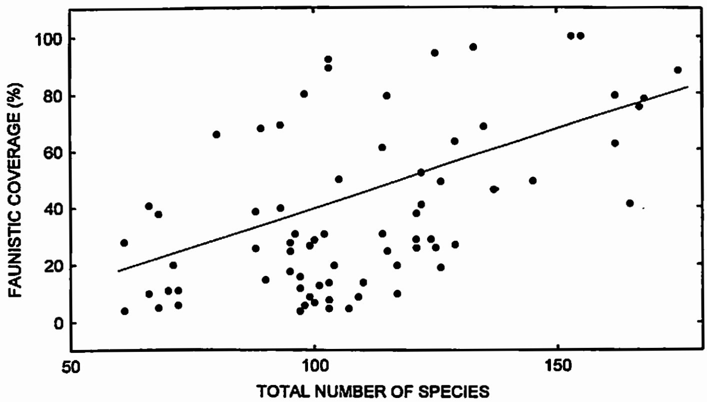

Fig. 5. Relationship between faunistic coverage (percent of 10 × 10 km squares for which data exist) and total species number, for large area units (approx. 100 × 100 km). The regression equation is faunistic coverage= -12.6 + 0.53(total number of species). See Table 1.

rage, but statistically non significant in the total number of species (which is not surprising, since hypothesized maps such as those taken as reference usually fill presumptive areas of occurence in spite of the actual lack of data from some of them). Correcting the effects of unequal area by taking residuals from regressions of the other variables on quadrat area produced no meaningful change in the direction of the correlations (results not given, see Figure 6).

The historical progression of faunistic coverages based on different quadrat sizes, as derived from our data, suggest coherent patterns: While the number of species recorded shows little increment after the first quarter of the present Century, the number of published references appears to be in an exponential phase of growth (see Fig. 8). The number of entries in the data base increases even at an even higher rate. This is probably due to a sharp growth of the

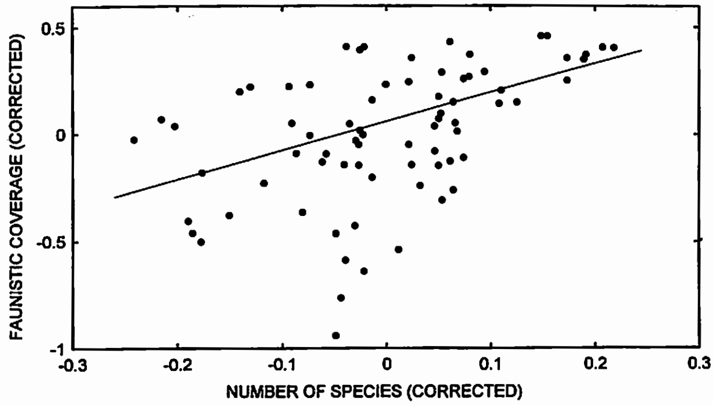

Fig. 6. Relationship between faunistic coverage and species density, after correcting both variables for the effects of unequal area of the quadrats. The values are the residuals from the regressions of each of the two variables on the surfaces of the area units, log transformed (r=0.462, p<0.001, n=74). The regresion equation for the X and Y variables is Y= 0.00 + 1.41(X).

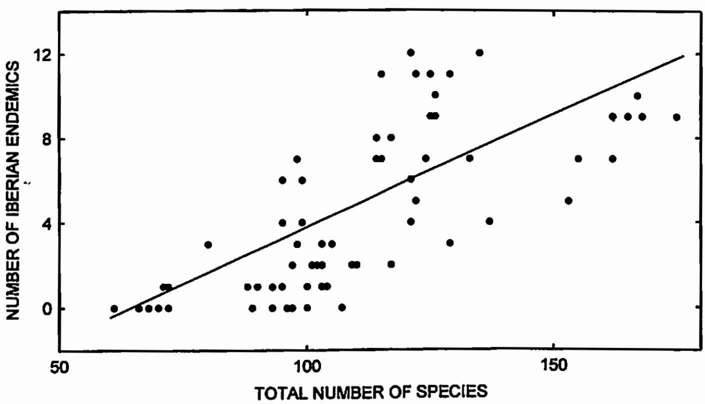

Fig. 7. Relationship between the density of butterfly species endemic to the Iberian Peninsula, and the total number of species per area unit. The regression equation is Number of endemic species= -7.46 + 0.11(total number of species).

amount of research being conducted and published at the regional and local scales. Reports of that kind frequently include quantitative data such as specimen counts. ..

The increase of faunistic coverage, based on the four quadrat sizes taken as reference, is illustrated in Figure 9. Full coverage has only very recently been reached, but this is true only at the largest grid scales (OAU_{50}, OAU_{100}). The coverage rate of increase relative to time can be broadly interpretated as logistic. At area unit sizes lower that 50 × 50 km, increase is approximately exponential. If the trends were to remain constant, full coverage of Iberia on a 10 × 10 km basis should be predictably achieved at some date in the first half of XXIst Century. The number of references, as well as the net coverage rate, show a very slight decrease after 1990. This might result from a trend towards a strong concentration of the results from faunistic research into regional atlases, that are produced at rather discontinuous rates.

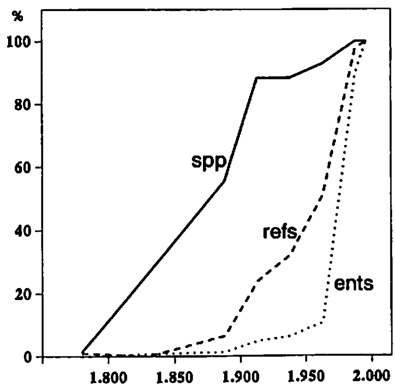

Fig. 8. Cummulative amount of published information on butterfly faunistics in Peninsular Spain. Data from Iberian Satyrinae (Nymphalidae), presented as percentages of the present (1997) figures. *Spp*= number of species, *refs*= number of biliographic references, *ents*= number of individual entries (rows) in the authors data base.

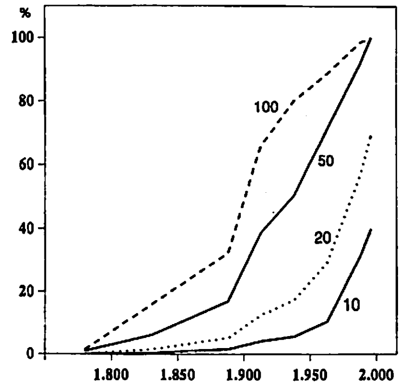

Fig. 9. Cummulative faunistic coverage of Peninsular Spain, based on Satyrine Nymphalids, for four quadrat sizes (quadrats are UTM grid squares with sides of 10, 20, 50, and 100 km).

Discussion and conclussions

While the progress of Iberian butterfly faunistics during the period 1900-1997 has been important, the amount of field work remaining to be done is still relevant. Local faunas (i.e., at grid side scales of 10 or 20 km) remain basically unknown across wide areas. Further, the geographical distribution of sampling effort is uneven, and this makes necessary a relatively large grid size (at least 50 × 50 km) for studies involving the whole Iberian peninsula.

To a large extent, the concentration of endemic species mirrors that of total species numbers. Two consequences follow: first, high-endemism areas are predicted to host high diversity of butterflies in general. Second, both total diversity and number of endemisms show strong concentration in certain parts of the Peninsula, namely the NE sector. MARTÍN & GURREA (1990) have demonstrated that latitude and longitude are the main parameters determining butterfly diversity in Iberia, since these two parameters alone account for a high proportion of the variance (>0.80) of species numbers in quadrats. Where only butterflies are involved, the coincidence between the densities of endemic and non endemic species has practical benefits for conservation purposes, facilitating the identification of diversity hot spots. However, the pattern of species density displayed by Iberian butterflies looks as "highly non-mediterranean". This may be due to a varied array of historical reasons that probably deserve theoretical attention, and has one practical consequence. Butterflies are often seen as flagship organisms in terms of biodiversity assessment and conservation, since they fit most of the properties required by indicator taxa, and enjoy higher popularity than other invertebrates (CORKE, 1992; NEW *et al.*, 1995; PEARSON, 1995). Their dominating present distribution patterns might well differ from those of other organisms, namely endemic mediterranean species. Using butterfly diversity alone as a tool in conservation strategies in the South and West of Iberia may represent a wrong strategy.

We are aware of the limits of the data used in this work. A more exhaustive data-base, e.g. one that covers extensive museum material from widespread species, would probably raise the figures relative to faunistic coverage by increasing the number of 10 × 10 km dots. However, most of the dots would not represent full species lists, but instead isolated records from one, or a few, representatives of local faunas. For instance, an assessment based on the butterfly fauna from Madrid Province (believed to be thoroughly documented: GÓMEZ DE AIZPÚRUA, 1987) demosntrated that the fit between existing data and results from new prospections in any given 10 × 10 km square was far from perfect, and that some amount of revission and updating is still needed (GARCÍA-BARROS *et al.*, 1998). Within this limits, the correlation between species diversity and intensity of faunistic effort per area unit is interesting. There are two ways to interpretate this result. The first one is that most lepidopterists have tended to visit those spots that were suspected to contain the highest numbers of butterfly species, a "diverstity tracking" behaviour. From this point of view, we might assume that existing data have high predictive value for species occurrence. This, in turn, may lead to the conclussion that there is not much to gain from investigating poorly covered areas. The latter may have unwanted effects since local faunistic data are often required for planning activities related to land use: in practice, the lack of faunistic data will be interpreted as an absolute absence of species. There is a second interpretation of the facts, however. Technically, the correlation between faunistic coverage and species density does not provide any evidence on the causal basis of the relationship between the two variables. In other words, it would be wise to conclude that highest intensity of prospection in some areas has artificially raised the number of species recorded from those regions. The bias might be important since, as noted before, species densities have been calculated after distribution maps that tend to smooth the actual gaps for all species. In conclusion, further prospection should never be discarded in areas that are insufficiently known.

Trends in the historical recording patterns suggest that Iberian butterfly faunistics are in full growth at present. Whether or not the trend remains will determine the probability of completing a detailed Iberian butterfly distribution atlas. However, only profound qualitative and quantitative change in social, political and scientific variables would enable production of wide scope censuses at grid sizes lower than 10 km in less than two or three decades. Because the documentation of trends, and not only the presence or absence of the organisms, are of interest (e.g., in connection with phenomena such as Global Climate Change: DENNIS, 1993, VAN SWAAY, 1995, PARMESAN, 1996), there is some risk that the amount of historical data accessible from Spanish and Portuguese collections remains too scarce to document any pattern, at a peninsular scale at least. These facts recommend that the advice given by Pyle *et al.* (1981) (*collect now*!) is kept in the minds of Portuguese and Spanish entomologists and research authorities for one or two more decades. While this picture is somewhat tinged by pessimism, the results still allow for more optimistic interpretations. After all, reliable documentation is available for wide areas and research activity proceeds at good rate, if the geographic extension of the countries involved is taken into account.

Funding

Parts of this study were funded by projects UE PL93-1917, DGICYT UE95-0038 (E. GARCÍA-BARROS, M.L. MUNGUIRA), and PRAXIS XXI/BD/9101/96 (P. GARCIA-PEREIRA).

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