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# CHANGES IN BUTTERFLY DIVERSITY IN THREE REFORESTED AREAS IN SPAIN

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**ABSTRACT.** Changes in butterfly diversity induced by reforestation were detected at three areas in central Spain with autochthonous forests and adjacent pine reforestations. The natural areas were pyrenean oak (*Quercus pyrenaica*) and holm oak (*Q. ilex*) forests, and the reforested areas were, respectively, stone pine (*Pinus pinea*), cluster pine (*P. pinaster*) and scots pine (*P. sylvestris*), and subject to different forestry management regimes. Reforestation with alien species causes a decrease in the number of butterfly specimens, the number of species, and the diversity index. These losses are minimal when the management of reforestations allows the recovery of undergrowth.

**Additional keywords:** conservation, diversity indices, forest management.

When comparing areas of natural vegetation to areas reforested with tree species differing from those previously present, it is generally assumed that the former are always richer in faunal diversity. Reforestations can be considered as rejuvenating elements for the ecosystems (Margalef 1980) and therefore as diversity simplifiers. However in spite of the great extent and importance of reforestations in many areas, studies on their actual influence are relatively scarce.

Reforestations are complex: many factors influence them, including site selection, local conditions or the plant species to be planted, the planting techniques used, and the subsequent utilization of the territory and its management and exploitation. According to studies made on this topic, decreases of diversity have been observed in microflora (Lozano & Velasco 1972), and in forest grassy plants, the number of individuals and species decreases compared to areas still retaining natural vegetation (Magurran 1988). In the soil fauna, diversity decreases in areas reforested with species different from those of the original forest, and is higher in the autochthonous forest (Bonnet et al. 1976, 1979, Arbea & Jordana 1985, Arbea 1987). Bird diversity is also greater in areas with natural vegetation than in reforestations (Batten 1976, Bongiorno 1982, Potti 1986, Avery & Leslie 1990), and these results agree with studies on rove beetles (Staphylinidae) (Buse & Good 1993) and large moths (Magurran 1985).

Planting with conifers has also affected butterflies, which are excellent bioindicators (Erhardt 1985, 1995, Erhardt & Thomas 1991) and a suitable group for exploring diversity topics. Although young conifer plantations can provide suitable habitat for many early successional species, the butterfly communities rapidly deteriorate after canopy closure. Allowing the canopy to close in the native British hardwood forest was extremely detrimental to woodland species (Robertson et al. 1995), and in blocks of mature conifers Robertson et al. (1988) found only five butterflies per km walked. The objective of this paper is to evaluate the effect on butterfly communities of the substitution of autochthonous species by pine plantations.

## MATERIALS AND METHODS

**Study sites.** Three areas in Spain that maintained their autochthonous tree vegetation and were adjacent to areas where the original vegetation had been replaced by pine reforestation were chosen for study: Valdelatas, Soto del Real, and Valsaín (see Table 1). The three areas with natural vegetation have well developed trees and nearly 100% tree cover. Although these forest areas are fragmented and altered, they can be considered, by their aspect and management, as representative of what is left of natural forest in flat or low mountain areas in the center of the Iberian Peninsula. Reforested areas also have mature trees, with a well developed canopy, although forest management is different in each one of them.

*Valdelatas:* This site is located near Madrid at an altitude of approximately 700 m, UTM (Universal Transverse Mercator) coordinates 30TVK48. According to Rivas-Martínez (1987), the climax vegetation of this area consists mainly of holm oaks, *Quercus ilex ballota* (Desf.) Samp. in Bol. and lusitanian oaks, *Q. faginea* Lam. There are some tall holm oaks (6–8 m), but part of the holm oaks are reduced to a bushy state (3–4 m tall) and constitute an impervious thicket at certain points. Lusitanian oaks are less numerous and scattered among the holm oaks. In this area there is a cleared reforestation of stone pine, *Pinus pinea* L. This reforestation is more than 60 years old, and though it was extensive many years ago, at present it is reduced due to roads and buildings. The total forested area is 250 ha, one half of which is covered by natural vegetation (*Q. ilex ballota*) and the other half by a reforestation with *P. pinea*. In the latter the trees are very separated from one another, have bulky trunks and great size (10–15 m tall). The canopy is closed, with little undergrowth. Both the natural and reforested areas are used periodically for sheep grazing.

*Soto del Real:* This site is located in Madrid, on the southern slope of the Sierra de Guadarrama, at an average altitude of 1200 m, UTM coordinates 30TVL31, and lies inside the Parque Regional de la Cuenca Alta del Manzanares. The original vegetation is a pyrenean oak forest (*Quercus pyrenaica* Willd.). The area is cleared as a result of extracting

TABLE 1. Characteristics of the sampled natural (NAT) and reforested (REF) areas.

| | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|
| | NAT | REF | NAT | REF | NAT | REF |
| Altitude | 700 m | 700 m | 1200 m | 1200 m | 1300 m | 1300 m |
| Vegetation | | | | | | |
| tree species | *Q. ilex* | *P. pinea* | *Q. pirenaica* | *P. pinaster* | *Q. pirenaica* | *P. sylvestris* |
| tree height | 6–8 m | 10–15 m | 8–12 m | 10–12 m | 10–14 m | 6–8 m |
| plantation age | | >60 yr | | ca. 40 yr | | ca. 30 yr |
| understory density | +++ | ++ | + | ++ | +++ | + |
| Management | | | | | | |
| cattle grazing | — | — | +++ | + | +++ | ++ |
| goats grazing | — | — | ++ | — | — | — |
| sheep grazing | ++ | ++ | — | — | — | — |
| cotting understory | + | ++ | +++ | + | — | ++ |
| charcoal production | — | — | ++ | — | — | — |

wood for charcoal production, leaving a mosaic of relatively open areas and closed thickets. Closed areas have young and large sized (8–12 m tall) trees and vegetation in the undergrowth, and the open areas have large trees and pastures. Most of the areas belonging to the pyrenean oak bioclimatic stage have been reforested with cluster pine *Pinus pinaster* Aiton. In adjacent zones, at higher levels than those of the sampling site, reforestations are made with scots pine, *P. sylvestris* L. Both the oak and pine forest are grazed at Soto del Real. In the oak forest, grazing is somewhat more intensive. The pine reforestation conserves more scrub than the adjacent natural zone of pyrenean oaks. Pine trees are quite near one another and they are very tall (10–12 m).

*Valsaín:* This site is located in the province of Segovia, on the northern slope of the Sierra de Guadarrama, at an altitude of 1300 m, UTM coordinates 30TVL12. This area also belongs to the pyrenean oak forest stage (*Q. pyrenaica*). This zone is grazed, and the pyrenean oak forest forms patches surrounded by pasture. The oaks, some of which are large (10–14 m tall), grow in these patches together with a variety of bushes, lianas and other components of the prickly border. The reforested zone here is a *Pinus sylvestris* forest. It consists of not very tall (6–8 m) pines about 30 years old. It is a closed formation into which daylight rarely penetrates. There is no undergrowth. Because of this management, the area is almost devoid of other vegetation. Cattle wander about the forest and graze in the clearings.

**Data recording and analysis.** Density of butterfly population was estimated using periodic walks along different previously established transects (Pollard et al. 1975, Pollard 1977, Rodríguez 1991, Pollard & Yates 1993). Two transects were set in each area: one in the reforested zone and the other in the natural vegetation zone. Transect length was fixed at 700 m, and covered at a slow and constant pace, so that the time spent on each was approximately one hour. Because butterflies typically prefer open areas, the transects were often routed through open areas within the forest. Rocky outcrops, cattle tracks and clearings were chosen in order to observe the highest possible number of butterfly species and individuals. All butterflies seen within 5 m on either side of the path were recorded. The surveyed area was therefore 0.7 ha in each transect. In every case the number and days of transect were the same for the natural and corresponding referested areas. Recording was only done on sunny, cloudless or almost cloudless days and at temperatures above 18°C. Specimens requiring special study for identification were taken to the laboratory (e.g., *Melitaea athalia*). These specimens are now part of the Autónoma of Madrid University Biology Department collection. Butterfly nomenclature follows Higgins (1975) and Higgins and Riley (1983), with minor changes. Agenjo (1975), Fernández-Rubio (1977) and Higgins (1975) have been followed to identify species by genitalic structure. The references used for plant taxonomy were Castroviejo et al. (1986, 1990).

Diversity was estimated by the Shannon-Weaver information index, H′ (Margalef 1980, Magurran 1988) as: $H' = -\Sigma (p_i \log_2 p_i)$, $\Sigma p_i = 1$, where $p_i$ is the ith species probability. The Shannon-Weaver information index was chosen becuase it is one of the most frequently used in ecology (Margalef 1980, Magurran 1988, Krebs 1989) and because its use is widespread in butterfly studies (Pinheiro & Ortiz 1992, Sánchez Rodríguez & Baz 1995). Evenness, J′, was calculated by dividing diversity by maximum diversity (Krebs 1989, Magurran 1988) as: $J' = H'/H'_{max}$. Maximum diversity was calculated as: $H'_{max} = \log_2 S$, where S is the number of species. Following Margalef's formula (Margalef 1980, Magurran 1988) richness, R′, was calculated as: $R' = S - 1/\ln(N)$, where S is the number of species and N is the number of specimens. Dominance, D′, was calculated using the Berger-Parker index (Magurran 1988) as: $D' = N_{max}/N$, where $N_{max}$ is the number of individuals of the most abundant species.

Two similarity indices were used to measure the similarity between two given samples: the Jaccard index and the Bray-Curtis index (Margalef 1980, Legendre & Legendre 1984, Krebs 1989). The qualitative Jaccard index considers only presence or absence data: $S_J = a/(a + b + c)$, where *a* is the number of species common to samples 1 and 2, and *b* and *c* the exclusive species from samples 1 and 2, respectively. The quantitative Bray-Curtis index takes into account the number of individuals of every species: $S_{BC} = 1 - (\Sigma \mid y_{i1} - y_{i2} \mid / \Sigma (y_{i1} + y_{i2}))$, where $y_{ij}$ is the number of individuals of species i in sample j. An agglomerate cluster analysis was also made from these indices using the single linkage clustering method (Krebs 1989).

## RESULTS

A total of 3033 specimens representing 53 species was recorded. The species and number of specimens of all reforested and natural vegetation areas are shown in Table 2. Figs. 1 and 2 show the variation in the number of species and specimens throughout the season in every sampling area. The largest relative number of butterflies was observed on the pyrenean oak forest in Valsaín (698 specimens in 10 samplings), followed by the pyrenean oak forest and the pine reforestation of Soto del Real (875 and 787 specimens, respectively, in 13 samplings). In Valdelatas, the number of records was much smaller: 319 on the pine reforestation and 212 on the holm oak forest in 11 samplings at each area. The Valsaín reforestation is remarkable for its low number of butterflies (only 142 butterflies in 10 samplings).

Among the 3033 butterflies observed 1785 were found in the natural vegetation zones and 1248 in the reforested areas. In Valsaín, a significant decrease in the number of butterflies on the reforested areas was observed ($p < 0.01$ by chi-square). In Soto del Real, both counts were similar, and the differences between natural and reforested areas were not significant (chi-square). In Valdelatas, more butterflies were found in the reforested area compared to natural area ($p < 0.05$, chi-square).

The highest densities and the greatest number of butterflies flying occurred in July at Valdelatas and Soto del Real (both in the southern slope of the Sierra de Guadarrama) and in August at Valsaín (in the northern slope of the Sierra de Guadarrama). Phenology differences were not found in the reforested areas when compared to those of the natural ones.

The diversity index (H′) ranged from 3.91 in the natural zone of Soto del Real, to 2.97 in the reforestation area of Valdelatas. Diversity was higher in the natural vegetation zones than in the reforestations at Valdelatas and Soto del Real, whereas at Valsaín the situation was reversed. Maximum diversity ($H'_{max}$) was highest in the oak forest of Soto del Real (5.43) and the lowest in the reforestation at Valdelatas (4.32). The three locations had larger index values for natural areas and smaller values for reforestations. R index values followed $H'_{max}$: the largest, 6.20, in the oak forest of Soto del Real, and the smallest in the pine reforestation of Valdelatas. R values were larger in the natural areas than in the reforestations. Evenness (J′) was highest in the holm oak forest at Valdelatas and the pine reforestation at Valsaín, and lowest in the pyrenean

TABLE 2. List of butterfly species recorded in the natural (NAT) and reforested (REF) areas. Sampling intervals: Valdelatas, 11 days; Soto del Real, 13 days; Valsaín, 10 days.

| | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|
| | NAT | REF | NAT | REF | NAT | REF |
| *Papilio machaon* | | | 1 | | | |
| *Iphiclides podalirius* | 2 | | 1 | 4 | 3 | |
| *Zerynthia rumina* | 3 | | 29 | 13 | 4 | |
| *Aporia crataegi* | 6 | 8 | 2 | 7 | 17 | 1 |
| *Pieris rapae* | 14 | 28 | 15 | 18 | 17 | 3 |
| *P. napi* | | | | 1 | 3 | |
| *Pontia daplidice* | 11 | 1 | 5 | 11 | | |
| *Anthocharis cardamines* | 1 | | 6 | 20 | | 2 |
| *A. euphenoides* | | | 1 | 7 | | |
| *Colias croceus* | 4 | 7 | 80 | 40 | 25 | |
| *Gonepteryx rhamni* | | | 14 | 25 | 14 | |
| *G. cleopatra* | | | | 1 | | |
| *Callophrys rubi* | | | | | 3 | |
| *Lycaena phlaeas* | 8 | 11 | 40 | 66 | 5 | 1 |
| *Heodes virgaureae* | | | | 1 | | |
| *H. tityrus* | | 2 | 2 | 1 | | |
| *H. alciphron* | | | 1 | 2 | 2 | |
| *Lampides boeticus* | | | | | 1 | |
| *Celastrina argiolus* | | | 1 | 1 | | |
| *Aricia cramera* | 4 | 4 | 11 | 1 | | |
| *Polyommatus icarus* | | | 6 | 6 | 2 | |
| *Limenitis reducta* | | | 2 | 1 | | |
| *Nymphalis antiopa* | | | 2 | 2 | | |
| *N. polychloros* | | 1 | 2 | 1 | | |
| *Inachis io* | | | 2 | 5 | 2 | |
| *Vanessa atalanta* | | | 1 | | 5 | |
| *Cynthia cardui* | | | 1 | | 6 | |
| *Aglais urticae* | | | 2 | | | |
| *Polygonia c-album* | | 1 | 1 | | | |
| *Pandoriana pandora* | 3 | 8 | 16 | 41 | 37 | 23 |
| *Argynnis paphia* | | | 1 | 3 | 1 | |
| *Mesoacidalia aglaja* | | | 7 | 7 | 6 | 1 |
| *Fabriciana adippe* | | | 1 | 7 | | 3 |
| *F. niobe* | 18 | 25 | 4 | 6 | 1 | |
| *Issoria lathonia* | | 2 | 37 | 55 | 38 | 2 |
| *Brenthis ino* | | | | | | 1 |
| *Melitaea cinxia* | | | 3 | 3 | | |
| *M. didyma* | | | 1 | 2 | 1 | |
| *M. athalia* | | | | 6 | | |
| *Euphydryas aurinia* | | | 35 | 41 | | 2 |
| *Hipparchia semele* | | | 2 | | 5 | 34 |
| *Neohipparchia statilinus* | 8 | 2 | 49 | 7 | 13 | 4 |
| *Brintesia circe* | 8 | 1 | 75 | 57 | 16 | 6 |
| *Pararge aegeria* | 2 | 6 | 6 | 1 | 4 | 1 |
| *Maniola jurtina* | 14 | 36 | 43 | 34 | 17 | 13 |
| *Hyponephele lycaon* | | | 1 | | | |
| *Pyronia cecilia* | 68 | 61 | 105 | 27 | 128 | 17 |
| *P. bathseba* | 6 | | | 1 | | |
| *Coenonympha pamphilus* | 1 | 1 | 51 | 7 | 29 | 14 |
| *Lasiommata maera* | 1 | | | | 1 | |
| *L. megera* | 6 | 1 | 2 | 5 | 7 | 2 |

TABLE 2. Continued.

| | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|
| | NAT | REF | NAT | REF | NAT | REF |
| *Melanargia lachesis* | 11 | 113 | 208 | 243 | 284 | 13 |
| *M. ines* | 13 | | | | | |
| Abundance (N) | 212 | 319 | 875 | 787 | 698 | 142 |
| Species (S) | 22 | 20 | 43 | 41 | 32 | 18 |
| Diversity (H′) | 3.63 | 2.97 | 3.91 | 3.90 | 3.21 | 3.37 |
| Evenness (J′) | 0.81 | 0.69 | 0.72 | 0.73 | 0.64 | 0.81 |
| Richness (R) | 3.92 | 3.30 | 6.20 | 6.00 | 4.73 | 3.43 |
| Dominance (D′) | 0.32 | 0.35 | 0.23 | 0.30 | 0.41 | 0.23 |
| Max. Diversity ($H'_{MAX}$) | 4.46 | 4.32 | 5.43 | 5.36 | 5.00 | 4.17 |

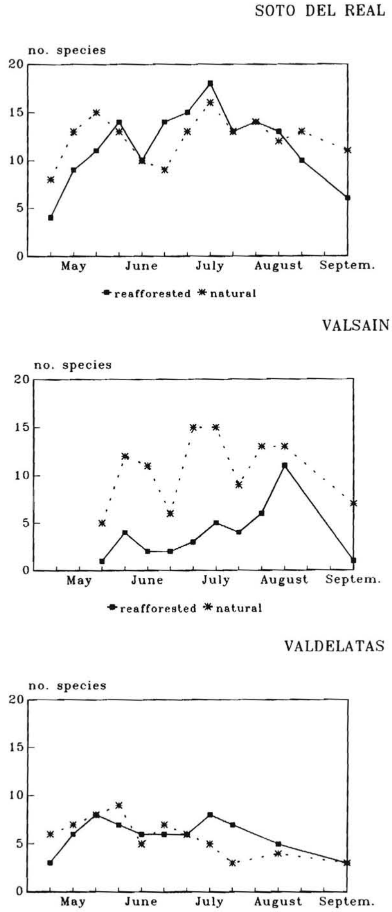


FIG. 1. Variation in the total number of butterfly species at three sites in Spain. Squares and solid lines refer to reforested areas, and stars and dashed lines to natural areas.

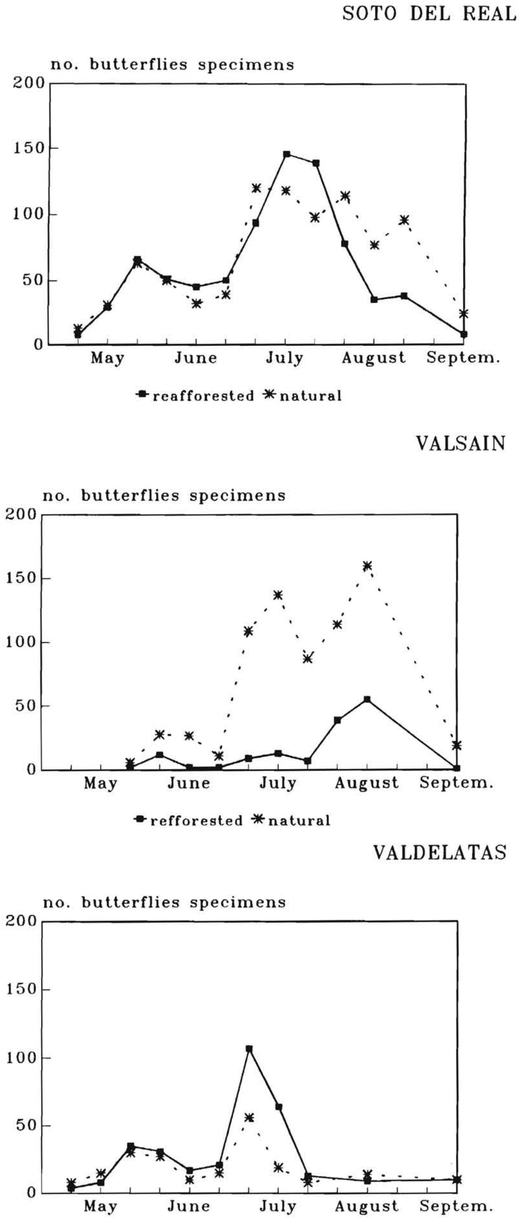


FIG. 2. Variation in the total number of butterfly specimens at three sites in Spain. Squares and solid lines refer to reforested areas, and stars and dashed lines to natural areas.

TABLE 3. Values of the Jaccard and Bray-Curtis similarity indices comparing natural (NAT) and reforested (REF) areas.

| | | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|---|
| | | NAT | REF | NAT | REF | NAT | REF |
| Jaccard | | | | | | | |
| Valdelatas | NAT | 1.00 | | | | | |
| | REF | 0.62 | 1.00 | | | | |
| Soto del Real | NAT | 0.41 | 0.47 | 1.00 | | | |
| | REF | 0.47 | 0.45 | 0.75 | 1.00 | | |
| Valsaín | NAT | 0.46 | 0.41 | 0.56 | 0.52 | 1.00 | |
| | REF | 0.48 | 0.52 | 0.42 | 0.40 | 0.43 | 1.00 |
| Bray-Curtis | | | | | | | |
| Valdelatas | NAT | 1.00 | | | | | |
| | REF | 0.56 | 1.00 | | | | |
| Soto del Real | NAT | 0.29 | 0.46 | 1.00 | | | |
| | REF | 0.26 | 0.43 | 0.72 | 1.00 | | |
| Valsaín | NAT | 0.34 | 0.48 | 0.67 | 0.65 | 1.00 | |
| | REF | 0.36 | 0.27 | 0.19 | 0.21 | 0.25 | 1.00 |

oak forest at Valsaín and the pine reforestation at Valdelatas. The Soto del Real oak wood and pine reforestation had intermediate J′ values. Dominance (D′) was highest in the pyrenean oak forest at Valsaín and the pine reforestation at Valdelatas, and smallest in the pyrenean oak forest at Soto del Real and the pine reforestation at Valsaín.

Table 3 shows values of the Jaccard and Bray-Curtis indices. The Jaccard index peaked at 0.75 at Soto del Real, so the maximum similarity found is that between the natural and the reforested areas at this location. The next highest value, 0.62, was between the natural and the reforested areas at Valdelatas, and the third highest, 0.56, between the natural areas at Soto del Real and Valsaín. Finally, 0.52 is the value between the reforestations at Valsaín and Valdelatas. Thus, the pine reforestation at Valsaín is not related either to its corresponding natural area nor to the other oak site in Soto del Real, but rather to the poorest area, the pine reforestation of Valdelatas. Similar clusters were obtained by other qualitative indices, like those of Sorensen or Czechanovski, Baroni-Urbani and Busner, which consider double absences (Margalef 1980, Krebs 1989), but these are not presented here.

The quantitative Bray-Curtis index produces similar results to the Jaccard, except for the Valsaín reforestation that is separated from all the other areas (Fig. 3). Figure 4 shows the ordered distribution of butterfly species frequencies in both reforested and natural sites. The lines of the reforested areas are always below those of the natural areas at Valsaín and Valdelatas.

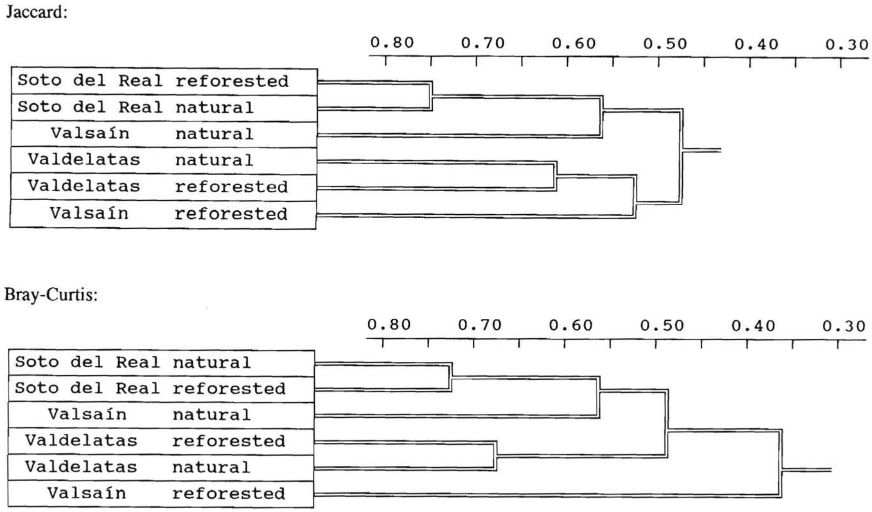


FIG. 3. Tree diagrams obtained from the Jaccard (qualitative) and Bray-Curtis (quantitative) similarity indices. Agglomerate cluster made by single linkage clustering.

## DISCUSSION

**Variation in butterfly density.** Among the three study locations, the number of butterflies at Soto del Real is similar in the reforested area in relation to the natural area. This may be because in the reforestation the undergrowth is maintained, and so its floristic richness is similar to that of the oak wood. At Valdelatas, greater butterfly density was observed in the pine reforestation, likely because this is an open area with abundant ruderal vegetation and flowers that are attractive, especially to vagile and opportunistic species such as *Pieris rapae, Maniola jurtina* and *Melanargia lachesis* (whose numbers spectacularly increase in the reforested zone). At Valsaín, a typical reforestation, the differences in butterfly densities between the natural and the reforested zones are pronounced, with a large decrease in numbers of individuals. This is reflected in the cluster obtained from the Bray-Curtis index, which takes into account the number of specimens in addition to species, and separates the pine reforestation at Valsaín from its corresponding natural area and from all the other areas. The other reforestations more nearly resemble their respective natural zones. Our results largely agree with those of Avery & Leslie (1990) for birds, Magurran (1985, 1988) for grasses and moths, Buse and Good (1993) for rove beetles (Staphylinidae), and Robertson et al. (1988) for butterflies, in which species numbers decrease in reforested areas.

In most cases, fluctuations in the number of specimens of certain spe-

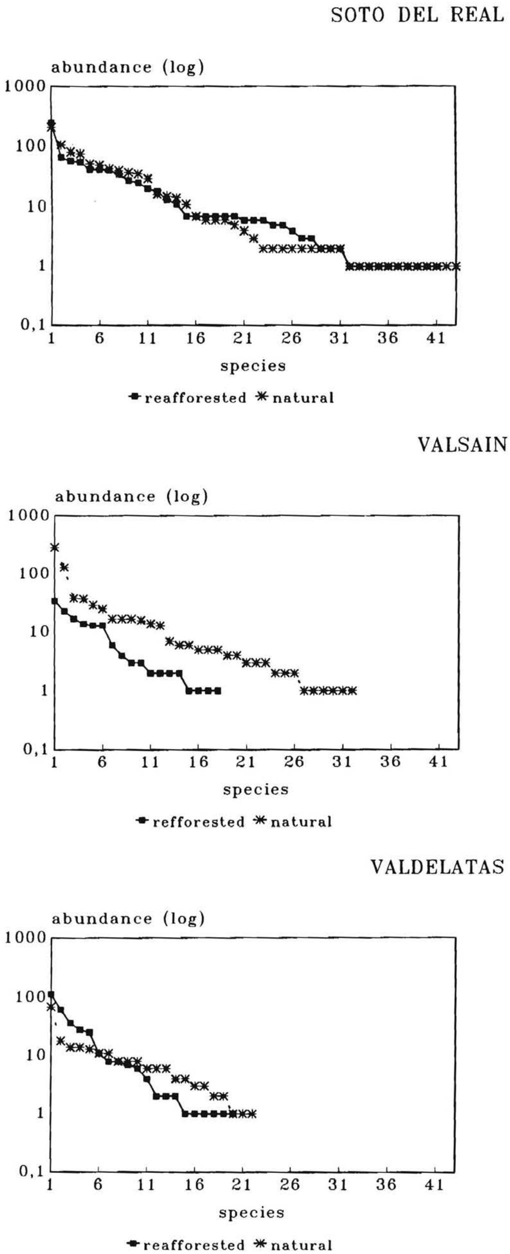


FIG. 4. Abundance plots for butterfly species at three sites in Spain.

cies were not attributable to reforestation. In the most abundant species with high quantitative changes (*Melanargia lachesis*, *Pyronia cecilia*), these can be attributed to the presence of clearings and pastures among the trees, regardlees of whether they are autochthonous or reforested.

**Changes in number of butterfly species.** The autochthonous forests had the largest numbers of species, with a total of 50, compared to 43 in reforestations. The total number of species recorded on all three sampling sites was 53. In Valdelatas, the autochthonous forest had a small number of species even though it is a climax forest. This is because the holm oak forests are poor in understory plants, with only 8 to 10 additional plant species (Izco 1984), and so the number of possible butterfly larval hostplants is diminished.

As with butterfly density, small differences were observed in the number of species in the natural areas compared to the reforestations at Soto del Real and Valdelatas (43 to 41, and 22 to 20, respectively), whereas large differences were seen at Valsaín (32 species in the natural area vs. 18 in the reforestation). This can also be attributed to the fact that the last area is strictly a forest plantation. Similarity clusters show these results graphically: according to the list of species and the Jaccard index, the most typical reforestation (Valsaín) is separated from its natural area, and is placed close to the poorest areas.

These results coincide with those of other authors (García-González 1988, Robertson et al. 1988, Avery & Leslie 1990, Buse & Good 1993). A decrease of the number of species was observed in the reforested areas, probably caused by a simplification and rejuvenation of the ecosystem, as pointed out by Margalef (1980).

**Diversity indices as indicators of change.** Considering the Shannon-Weaver index, the areas with the greatest diversity belong to Soto del Real, both the autochthonous and the reforested forest. The similar index values for the reforestation and the natural area can be considered normal. We noted earlier that Soto del Real is not used for wood extraction, and is an old pine reforestation. The accompanying vegetation of the pyrenean oak floor has regenerated and supports butterfly species characteristic of such areas. In contrast the pyrenean oak forest is being intensively grazed, and this has led to a convergence in the butterfly faunas of both areas. The sparse undergrowth in the pine reforestation at Valdelatas is probably responsible for decrease in diversity and number of species. At Valsaín, the autochthonous forest is cleared as a result of intensive grazing, and the reforested area is largely a monoculture of *Pinus sylvestris*. Paradoxically, the pine reforestation here shows a greater diversity than in the original oak forest. This is probably because some opportunistic species like *Melanargia lachesis*, whose caterpillars eat grassy plants, are very abundant in the oak forest clearings: of 698 specimens recorded, 284 were *M. lachesis*, and the H′ diversity index reflects this.

The Shannon-Weaver index takes into account the number of species and the relative numbers of each, but if we consider only the number of species, the oak forest has 32 species compared to 18 recorded in the pine reforestation. Likewise, the greatest $H'_{max}$ values are those of the autochthonous forests. Soto del Real still shows the largest diversity indices and Valdelatas the lowest, due to the scarcity of accompanying plant species in the oak forest. The Margalef returned similar results to $H'_{max}$ and, in contrast to the Shannon-Weaver index, maxima always corresponded to the natural areas, and the most pronounced differences were observed in the forests at Valsaín.

These results agree with those of Batten (1976), Bongiorno (1982) and Potti (1986) in birds; Bonnet et al. (1976, 1979), Arbea and Jordana (1985) and Arbea (1987) in Collembola; Buse and Good (1993) in rove beetles; and Magurran (1985) in moths. In general, diversity decreases in reforested areas, but such decreases are influenced by use and management subsequent to reforestation (Potti 1986, Avery & Leslie 1990, Buse & Good 1993).

The graphs of species abundances (Fig. 4) illustrate the differences between the three types of reforestation management studied. At Soto del Real, both lines start and end at similar points, and have similar slopes. At Valdelatas, the line corresponding to reforestation starts from a higher point and crosses the line corresponding to the natural zone. In this case, in a reforestation subject to light management there appears to be a decrease in diversity. At Valsaín, the slopes are parallel but the starting and ending points differ. In this reforestation managed to obtain high wood production yields, there is a loss both in the number of butterfly species and abundance.

In conclusion, these reforestations in Spain reduced Lepidoptera diversity compared to areas in which the autochthonous tree vegetation was preserved. The magnitude of the change in diversity depended on the nature of reforestation and on management practices. In reforestations where the undergrowth was conserved, diversities close to those of the original forest were reached.

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