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# Loss of biodiversity due to reafforestation in Central Spain (Lepidoptera Papilionoidea; Coleoptera Curculionidae; Collembola)

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### Abstract

The effect of reafforestation in the central region of the Iberian Peninsula has been studied in three different groups of organisms: butterflies, Curculionids and Collembola. To this end, three areas exhibiting autochthonous vegetation were chosen: Valdelatas (with *Quercus ilex*) and Soto del Real and Valsaín (with *Q. pyrenaica*). These locations had been respectively reafforested with *Pinus pinea*, *P. pinaster* and *P. sylvestris*. Differences were noted in the structure and composition of the arthropod communities studied. Comparisons were made of the numbers of individuals, the number of species, the Shannon-Weaver diversity index and the Margalef richness index. There were generally fewer species and individuals in the reafforestations than in the adjacent zones where the natural vegetation is conserved. The data also yielded lower values of the Margãlef index, which expresses the changes in the fauna provoked by the reafforestation better than the Shannon-Weaver index. From the point of view of conservation, the loss of diversity was less in those reafforestations where the understorey is maintained. In reafforested areas, populations were reduced and species with lower biological potential, usually those that were rare or endemic in such areas, tended to disappea. In reafforested areas, populations were reduced and species with lower biological potential, usually those that were rare or endemic in such areas, tended to disappear.

**Keywords** : conservation, diversity indices, endemism.

## Introduction

Modifications made to ecosystems alter their equilibrium to a greater or lesser extent. Reafforestation with foreign species following clearing or substitution of the original woodland are the causes of imbalances that are sometimes more damaging to biodiversity than the complete deforestation of the primitive vegetation. In the processes of deforestation the existing vegetation is replaced by more generalist species that were already present in the unaltered ecosystem, along with their associated cohort of animals. In reafforestations with exotic species unusual elements are introduced into ecosystems that the majority of animals are unable to consume, thereby cumulatively impoverishing the soil.

Reafforestations contribute to the reduction in species diversity with respect to natural resources (MAGURRAN, 1985), destroying the balance of the community of organisms, favouring opportunistic species and leading to a reduction in species richness (MARGALEF, 1991).

Biological diversity can be expressed synthetically in the form of diversity indices. Despite their limitations and the controversies that they engender (WOLDA, 1983), they are useful in that they allow us to describe and understand better the structure of communities. The variation in diversity index values indicates a change in the distribution of species abundance, which may alert us to the operation of detrimental processes (MARGALEF, 1991).

The aim of the current study is to investigate the effect of reafforestations with tree species distinct from the original ones on three groups of arthropods: butterflies, Curculionids and Collembola. All of these are valuable bioindicators of the habitat in which they are found (JORDANA *et al.*, 1987; MORRIS & RISPIN, 1987; GREENSLADE, 1992; GAMA *et al.*, 1994; ERHARDT, 1995; DEHARVENG, 1996; MARTÍN & FERRÍN 1998). The three groups differ markedly with respect to their size, ecology and dispersal capacity, for which reason their communities may respond differently to the same alteration, allowing the distinction of the effects of interventions in ecosystems as complex as those due to reafforestation.

## Materials and Methods

**Sampling sites.** - Three sites in the central region of Spain were studied: Valdelatas, Soto del Real and Valsaín. Each has a zone of reafforestation next to a zone in which the original arboreal vegetation is conserved. These areas are somewhat fragmented and altered but they may be considered to be representative of the current state of the autochthonous woodlands in the plains and medium altitude mountains in the central region of the Iberian Peninsular.

Site 1: Valdelatas, in the Province of Madrid. Altitude 700 m, in the mesomediterranean bioclimatic stage (RIVAS-MARTINEZ, 1987), U.T.M.: 30TVL31. The natural vegetation is holm oak, *Quercus ilex* (Desf.). The oaks may reach a height of 8m, although in many places they are shrub-sized. The reafforestation was with *Pinus pinea* L., the majority of which are more than 50 years old, while some are older than 60 years. The pines are not densely planted, and reach a height of 10-15 m.

Management: The natural woodland is subjected to moderate grazing; the understorey is dense and unmanaged. In the reafforested woodland there is moderate grazing and the understorey undergoes periodic cleaning.

Site 2: Soto del Real, in the Province of Madrid. Altitude 1200 m, in the supramediterranean bioclimatic stage (RIVAS-MARTINEZ, 1987) U.T.M. 30TVL31. The natural vegetation is oak, *Quercus pyrenaica* Wild. These oaks are 8-10 m high. Next to the original area there is a reafforestation of *Pinus pinaster* Aiton, with trees of 10-12 m in height that are approximately 40 years old.

Management: The natural woodland is subjected to grazing and production of charcoal, giving rise to a cleared woodland with a reduced understorey. Grazing is scarce in the reafforested zone and the understorey, not managed, is well developed.

Site 3: Valsaín, in the Province of Segovia. Altitude 1 300 m, in the supramediterranean bioclimatic stage (RIVAS-MARTINEZ, 1987). U.T.M.: 30TVL12. The natural vegetation is oak (*Q. pyrenaica*) and, along with the shrub border, is relatively well conserved. The oaks reach a height of 10-14 m. The reafforested zone is a dense, 30 year old plantation of *Pinus sylvestris* L., 6-8 m high. There is no understorey and the original vegetation is found only on rocky outcrops.

Management: The natural woodland is fragmented into patches separated by pastures where cattle graze, and its understorey is not managed. The reafforested woodland is periodically cleaned and totally lacks an understorey.

**Sampling.** - The sampling techniques used were chosen according to the group of arthropods studied.

For the butterflies, Pollard's transect method was employed (POLLARD, 1977; POLLARD & YATES 1993). Two 700 m transects were set up at each site, one in the natural zone and the other in the reafforested zone. They were periodically traversed in a time of 60 min between May and October, the flying season of the butterflies, in 1992.

The sampling of Curculionids in the natural and reafforested areas of each site was carried out by direct sweeping using a 50 cm diameter entomological net, with which all the vegetation within a 100 m square quadrat was swept. Samples were collected in 1992, twice a month at each sampling point during spring and summer, between May and July. The plants of the shrub and tree substrates and the herbaceous vegetation were swept for 60 min.

Pitfall traps were used to collect Collembola, and soil samples were taken at each one of the reafforested and natural areas. Six samples of 250 cm$^3$ of soil and six samples of litter were taken, following a design drawn up for the development of this project (DEHARVENG, 1996; SOUSA, 1996). Collembola were extracted through funnels following the Berlese-Tullgren method. Collembola were collected in 1991. This year was particularly dry in the central region of Spain, and this condition may have affected the numbers of species and individuals caught.

The individual butterflies, Curculionids and Collembola collected have been deposited in the collections of the Departamento de Biología in the Universidad Autónoma de Madrid.

**Data analysis.** - For the analysis of diversity, the Shannon-Weaver (H') index (MAGURRAN, 1988; MARGALEF 1991) was calculated as $H' = -\sum (p_i \cdot \log_2 p_i)$, where $p_i$ is the probability of occurrence of species i, and $\sum p_i = 1$. The Margalef (R') index (MAGURRAN, 1988; MARGALEF, 1991) was calculated as $R' = (S-1)/\mathrm{Ln}(N)$, where S is the number of species and N the number of individuals.

## Results

**Number of species and individuals.** - A total of 7227 individuals (3033 butterflies, 1948 Curculionids and 2246 Collembola) from 189 species (53 butterflies, 97 Curculionids and 39 Collembola) were collected. They were distributed among natural and reafforested areas as indicated in Tables 1, 2, 3 and 4.

In the case of the butterflies, the greatest numbers of species and individuals were found at site 2 (Soto del Real) in the natural and reafforested zones. At site 3 (Valsaín) there was a considerable difference between the numbers of individuals and species in the natural and reafforested zones. While the zone of natural woodland featured large numbers of individuals and species, the reafforested zone had the lowest values found in this study. At site 1 (Valdelatas) the number of species was greater in the natural than in the reafforested zone, but the greatest number of individuals was encountered in the reafforested zone. This was almost exclusively due to the abundance of the species *Melanargia lachesis*, which by itself represented more than 30% of all the observations made in this zone. On the other hand, site 1 (Valdelatas) had the lowest abundances of species and individuals overall. Site 3 (Valsaín) had intermediate values, but with some notable differences between the zone conserving the original woodland and the reafforested zone. Thus, while the zone of oaks at Valsaín had numbers of species and individuals similar to the of the richer zone, the reafforested zone had the lowest numbers of species and individuals of those sampled sites. These differences were apparent in all the samples, as illustrated in Figs 1 and 2a, in the graphs corresponding to Valsaín.

In the Curculionids, the greatest numbers of species and of individuals were collected from site 2 (Soto del Real) in the area occupied by the original *Q. pyrenaica*. At this site it was notable that 74% of the individuals present were of a single species, *Apion haematodes*. The larvae of this species live on *Rumex acetosella*, which is an invasive species very abundant in the clearings of the natural zone of site 2 (Soto del Real). In the reafforestation, the abundance of this species diminished drastically as the clearings in the wood disappeared. The lowest numbers of species and of individuals were found at site 1 (Valdelatas), particularly in the reafforested zone. Site 3 (Valsaín) yielded interme-

Table 1. Butterfly species recorded and abundance of each H.O.=Holm oak; O.W.=Oak woodland; P.P.= Pine plantation.

| | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|
| | H.O. | P.P. | O.W. | P.P. | O.W. | P.P. |
| Sampling days | 11 | 11 | 13 | 13 | 10 | 10 |
| PAPILIONIDAE | | | | | | |
| *Iphiclides feisthamelii* (Duponchel, 1832) | 2 | | 1 | 4 | 3 | |
| *Papilio machaon* Linnaeus, 1758 | | | 1 | | | |
| *Zerynthia rumina* (Linnaeus, 1758) | 3 | | 29 | 13 | 4 | |
| PIERIDAE | | | | | | |
| *Anthocharis belia* (Linnaeus, 1767) | | | 1 | 7 | | |
| *Anthocharis cardamines* (Linnaeus, 1758) | 1 | | 6 | 20 | | 2 |
| *Aporia crataegi* (Linnaeus, 1758) | 6 | 8 | 2 | 7 | 17 | 1 |
| *Colias croceus* (Fourcroy, 1785) | 4 | 7 | 80 | 40 | 25 | |
| *Gonepteryx cleopatra* (Linnaeus, 1767) | | | | 1 | | |
| *Gonepteryx rhamni* (Linnaeus, 1758) | | | 14 | 25 | 14 | |
| *Pieris napi* (Linnaeus, 1758) | | | | 1 | 3 | |
| *Pieris rapae* (Linnaeus, 1758) | 14 | 28 | 15 | 18 | 17 | 3 |
| *Pontia daplidice* (Linnaeus, 1758) | 11 | 1 | 5 | 11 | | |
| LYCENIDAE | | | | | | |
| *Aricia cramera* (Eschscholtz, 1821) | 4 | 4 | 11 | 1 | | |
| *Callophrys rubi* (Linnaeus, 1758) | | | | | 3 | |
| *Celastrina argiolus* (Linnaeus, 1758) | | | 1 | 1 | | |
| *Lampides boeticus* (Linnaeus, 1767) | | | | | 1 | |
| *Lycaena alciphron* (Rottemburg, 1775) | | | 1 | 2 | 2 | |
| *Lycaena phlaeas* (Linnaeus, 1761) | 8 | 11 | 40 | 66 | 5 | 1 |
| *Lycaena tityrus* (Poda, 1761) | | 2 | 2 | 1 | | |
| *Lycaena virgaureae* (Linnaeus, 1758) | | | | 1 | | |
| *Polyommatus icarus* (Rottemburg, 1775) | | | 6 | 6 | 2 | |
| NYMPHALIDAE | | | | | | |
| *Aglais urticae* (Linnaeus, 1758) | | | 2 | | | |
| *Argynnis adippe* (Denis & Schiffermüller, 1775) | | | 1 | 7 | | 3 |
| *Argynnis niobe* (Linnaeus, 1758) | 18 | 25 | 4 | 6 | 1 | |
| *Argynnis paphia* (Linnaeus, 1758) | | | 1 | 3 | 1 | |
| *Brenthis ino* (Rottemburg, 1775) | | | | | 1 | |
| *Brintesia circe* (Fabricius, 1775) | 8 | 1 | 75 | 57 | 16 | 6 |
| *Coenonympha pamphilus* (Linnaeus, 1758) | 1 | 1 | 51 | 7 | 29 | 14 |
| *Euphydryas aurinia* (Rottemburg, 1775) | | | 35 | 41 | | 2 |
| *Hipparchia statilinus* (Hufnagel, 1766) | 8 | 2 | 49 | 7 | 13 | 4 |
| *Hipparchis semele* (Linnaeus, 1758) | | | 2 | | 5 | 34 |
| *Hyponephele lycaon* (Rottemburg, 1775) | | | 1 | | | |
| *Issoria lathonia* (Linnaeus, 1758) | | 2 | 37 | 55 | 38 | 2 |
| *Lasiommata maera* (Linnaeus, 1758) | 1 | | | | 1 | |
| *Lasiommata megera* (Linnaeus, 1767) | 6 | 1 | 2 | 5 | 7 | 2 |
| *Limenitis reducta* Staudinger, 1901 | | | 2 | 1 | | |
| *Maniola jurtina* (Linnaeus, 1758) | 14 | 36 | 43 | 34 | 17 | 13 |
| *Melanargia ines* (Hoffmannsegg, 1804) | 13 | | | | | |
| *Melanargia lachesis* (Hübner, 1790) | 11 | 113 | 208 | 243 | 284 | 13 |
| *Melitaea athalia* (Rottemburg, 1775) | | | | 6 | | |
| *Melitaea cinxia* (Linnaeus, 1758) | | | 3 | 3 | | |
| *Melitaea didyma* (Esper, 1778) | | | 1 | 2 | 1 | |
| *Mesoacidalia aglaja* (Linnaeus, 1758) | | | 7 | 7 | 6 | 1 |
| *Nymphalis antiopa* (Linnaeus, 1758) | | | 2 | 2 | | |
| *Nymphalis polychloros* (Linnaeus, 1758) | | 1 | 2 | 1 | | |
| *Pandoriana pandora* (Denis & Schiffermüller, 1775) | 3 | 8 | 16 | 41 | 37 | 23 |
| *Pararge aegeria* (Linnaeus, 1758) | 2 | 6 | 6 | 1 | 4 | 1 |
| *Polygonia c-album* (Linnaeus, 1758) | | 1 | 1 | | | |
| *Pyronia bathseba* (Fabricius, 1793) | 6 | | | 1 | | |
| *Pyronia cecilia* (Vallantin, 1894) | 68 | 61 | 105 | 27 | 128 | 17 |
| *Vanessa atalanta* (Linnaeus, 1758) | | | 1 | | 5 | |
| *Vanessa cardui* (Linnaeus, 1758) | | | 1 | | 6 | |
| *Vanessa io* (Linnaeus, 1758) | | | 2 | 5 | 2 | |

diate results and the dominance was less pronounced than at the other sites. On the basis of the distribution of the species and individuals shown in Table 2 and Figure 2b, the zones with the original vegetation had higher values than those of the corresponding reafforested areas at all sites.

The majority of the Curculionid species are widely distributed, seven endemic species having been registered in the study sites, listed in Table 2. The greater or lesser abundance of these endemic species appears to be associated with the presence of their respective food plants, and therefore with the management of the woodland, and more specifically with the understorey. This is the case in *Exapion putoni*, which lives on *Genista cinerascens* and *G. florida*, which are common plants in the understorey of the reafforestation at site 2 (Soto del Real). Its presence appears to be due to the particular management of this reafforestation.

Another endemic species, *Pachyrrhinus glabratus*, lives on pines (*Pinus* spp.) and logically is found in reafforestations, in this case, in that of site 2 (Soto del Real).

The other species, *Attactagenus dispar*, *Lixus flaveolus*, *Phyllobius tubercullifer*, *Polydrusus interstitialis* and *Pleurodirus carinula* became more scarce or even disappeared with the reafforestations as they are mainly found on the new shoots of the oak, *Q. pyrenaica*.

As can be seen in Table 2, the majority of the endemic species were found in natural areas. However, it is worthwhile pointing out that in the reafforested areas the characteristic species of the understorey remained if their food plants were available, as was the case for *E. putoni*. At the same time in these areas, species established themselves that are trophically related to species involved in the reafforestation, as was the case for *P. glabratus*.

The greatest number of Collembola were collected at site 3 (Valsaín), followed by site 2 (Soto del Real). The lowest number were found at site 1 (Valdelatas) (Table 3 and Figure 2c). With respect to the differences between the reafforested zones and those that maintained their original vegetation, the greatest number of individuals from sites 1 and 3 were found in the reafforested zone, while nearly equal numbers were found in the reafforested zone as in that with the original vegetation at site 2.

Species richness was the same in the natural and reafforested zone of site 3 (Valsaín). At site 2 (Soto del Real) the number of species was similar in both zones (14-18), while at site 1 (Valdelatas) the natural zone conserved a greater number of species.

The vertical distribution of the species was similar at the three locations, whereby most individuals were found in the soil and not in the leaf litter (Table 3).

**Diversity.** - The highest values of H' and R' for the butterflies were found in the zones that maintained their original vegetation (Table 4), with the exception of site 3 (Valsaín), where the value of H' for the reafforested zone

Table 2. As table 1, for Curculionids.

| | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|
| | O.H. | P.P. | W.O. | P.P. | W.O | P.P. |
| APIONINAE | | | | | | |
| *Apion (s.st.) cruentatum* Walton, 1844 | | | 7 | | | |
| *Apion (s.st.) haematodes* Kirby 1808 | | | 529 | 18 | 1 | 4 |
| *Apion (s.st.) rubiginosum* Gryll, 1843 | | | 1 | | | |
| *Aspidapion aenum* (F., 1775) | | | | 1 | 1 | 1 |
| *Catapion pubescens* (Kirby, 1811) | | | 3 | | 1 | |
| *Catapion seriatosetosulum* (Wencker, 1864) | | | 3 | 2 | 2 | |
| *Ceratapion carduorum* (Kirby, 1808) | 1 | | 1 | | | |
| *Ceratapion gibbirostre* (Gyllenhal, 1813) | | | 2 | 4 | | |
| *Cyanapion alcyoneum* (Germar, 1817) | | | 1 | 3 | | |
| *Cyanapion spencei* (Kirby, 1808) | | | | 1 | | |
| *Dieckmanniellus nitidulus* (Gyllenhal, 1838) | | | 1 | | | |
| *Diplapion confluens* (Kirby, 1808) | | | 1 | | | |
| *Exapion compactum* (Desbrochers, 1888) | | | | 83 | | 1 |
| *Exapion fulvum* (Desbrochers, 1894) | | | | 2 | | |
| *Exapion fuscirostre* (F., 1775) | | | 1 | | | |
| * *Exapion putoni* (Ch.Brisout, 1866) | | | | 51 | | |
| *Eutrichapion reflexum* (Gyllenhal, 1833) | | | 1 | | | |
| *Ischnopterapion loti* (Kirby, 1808) | 1 | | 2 | 8 | | 2 |
| *Ischnopterapion modestum* (Herbst, 1808) | | | 1 | 3 | | |
| *Lepidapion argentatum* (Gerstaecker, 1854) | | | | 3 | | |
| *Lepidapion squamigerum* (J.du Val, 1885) | | | | 6 | | |
| *Oxystoma craccae* (Linnaeus, 1797) | | | | 6 | | 1 |
| *Oxystoma pomoneae* (F., 1798) | 1 | | 2 | | 2 | 1 |
| *Perapion ilvense* (Wagner, 1905) | | | 16 | | | |
| *Perapion marchicum* (Herbst, 1797) | | | 56 | | 1 | 2 |
| *Perapion violaceum* (Kirby, 1808) | | | 2 | | | |
| *Pirapion inmune* (Kirby, 1808) | | | | 3 | | 6 |
| *Pirapion striatum* (Kirby, 1808) | | | | 7 | | |
| *Protapion apricans* (Herbst, 1797) | 1 | | 2 | | 1 | |
| *Protapion interjectum* (Desbrochers, 1895) | | | 2 | | | |
| *Protapion laevicolle* (Kirby, 1811) | | | 2 | | 3 | 3 |
| *Protapion nigritarse* (Kirby, 1808) | | | 1 | | 2 | 2 |
| *Protapion trifolii* (Linnaeus, 1768) | 1 | | 5 | | 4 | |
| *Stenopterapion tenue* (Kirby, 1808) | | | | 5 | | |
| CEUTHORRHYNCHINAE | | | | | | |
| *Ceuthorrhynchus atomus* Boheman, 1845 | | | | 1 | | 1 |
| *Ceuthorrhynchus cochleariae* Gyllenhal, 1813 | 3 | 2 | 3 | | | 1 |
| *Ceuthorrhynchus contractus* (Marsham, 1802) | | | 2 | 1 | 2 | |
| *Ceuthorrhynchus erysimi* (F., 1787) | | 1 | 2 | 1 | 1 | 2 |
| *Ceuthorrhynchus leucorhamna* Rosenhauer, 1856 | 3 | | | | | |
| *Ceuthorrhynchus* sp. | | | 1 | | | |
| *Ceuthorrhynchus parvulus* Ch. Brisout, 1869 | | | | | | 1 |
| CIONINAE | | | | | | |
| *Cionus hortulanus* (Geoffroy, 1783) | | | | | | 1 |
| CLEONINAE | | | | | | |
| *Larinus brevis* Herbst, 1795 | | | | | | 1 |
| *Lixus cardui* Olivier, 1807 | 1 | | 1 | | | |

Table 2. Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| * *Lixus flaveolus* Motschoulsky, 1849 | 1 | | | | | |
| CURCULIONINAE | | | | | | |
| *Balanobius pyrrhoceras* Marsham, 1802 | | | 5 | | 2 | |
| *Curculio elephas* (Gyllenhal, 1836) | | | | | 1 | 1 |
| *Curculio glandium* Marsham, 1802 | | | | | 1 | |
| *Gymnetron antirrhini* (Paykull, 1800) | 1 | | 1 | 1 | | 3 |
| *Gymnetron pascuorum* (Gyllenhal, 1813) | | | 7 | | | |
| *Gymnetron rostellum* (Herbst, 1795) | 1 | | 72 | 1 | | 1 |
| *Sibinia attalica* (Gyllhenhal, 1836) | 1 | 2 | 1 | | | |
| *Sibina potentillae* Germar, 1824 | | | 1 | | | |
| *Sibinia sodalis* Germar, 1824 | | | 79 | | | |
| *Tychius capucinus* Boheman, 1824 | | | 1 | | | |
| *Tychius cuprifer* (Panzer, 1799) | | | | | 1 | |
| *Tychius grenieri* Ch. Brisout, 1861 | | | 1 | | | |
| *Tychius tibialis* Boheman, 1843 | 2 | | 19 | 1 | 9 | 2 |
| *Tychius venustus* F., 1791 | | | | 2 | | |
| ENTIMINAE | | | | | | |
| * *Attactagenus dispar* (Graells, 1858) | | | 15 | 5 | 2 | |
| *Brachyderes incanus* (Linnaeus, 1758) | 1 | | 1 | | | 2 |
| *Brachyderes lusitanicus* (F., 1781) | | | 2 | | | 1 |
| *Brachyderes pubescens* Boheman, 1833 | 1 | | | | | |
| * *Pachyrrhinus glabratus* (Chevrolat, 1866) | | | | 18 | | |
| * *Phyllobius tubercullifer* Chevrolat, 1865 | | | 26 | | 20 | 2 |
| *Pleurodirus carinula* (Olivier, 1808) | | | 175 | 163 | 29 | |
| * *Polydrusus impressifrons* Gyllenhal, 1834 | | | 3 | | 2 | |
| * *Polydrusus interstitialis* Perris, 1864 | | | | | 3 | |
| *Polydrusus setifrons* J. du Val, 1852 | 1 | | 187 | 1 | | |
| *Polydrusus* sp. | | | | | 1 | |
| *Sitona cambricus* Stephens, 1831 | | | | 1 | | |
| *Sitona cinnamomeus* Allard, 1863 | | | 3 | | | |
| *Sitona discoideus* Gyllenhal, 1834 | 1 | 1 | | | | |
| *Sitona flavescens* (Marsham, 1802) | | | 4 | | 1 | |
| *Sitona gemellatus* Gyllenhal, 1834 | | | 2 | | | 2 |
| *Sitona intermedius* Kuster, 1842 | | | 3 | 4 | | |
| *Sitona lividipes* Fahrs, 1840 | 1 | 3 | | | | |
| *Sitona macularius* (Marsham, 1802) | | | | 1 | | |
| *Sitona puncticollis* Stephens, 1841 | 1 | 5 | 6 | | | |
| Sitona regensteinensis (Herbst, 1794) | | | | 17 | | |
| *Sitona sulcifrons* (Thundberg, 1798) | | | | 1 | | |
| *Strophosoma erinaceus* Chevrolat, 1865 | | | 7 | | 2 | 3 |
| ERIRHININAE | | | | | | |
| *Pachytychius asperatus* (Dufour, 1843) | | | 5 | 7 | 1 | 2 |
| *Pachytychius haematocephalus* (Gyllhenal, 1835) | | | | 1 | | |
| *Pachytychius sparsutus* (Olivier, 1807) | | | 4 | 18 | | |
| HYPERINAE | | | | | | |
| *Hypera arator* (Linnaeus, 1758) | | | 1 | | | |
| *Hypera maculipennis* Fairmaire, 1859 | 3 | 1 | | | | |
| *Hypera meles* (F., 1792) | 4 | | | | | |
| *Hypera nigrirostris* (F., 1775) | | | | 1 | | |
| *Hypera rumicis* (Linnaeus, 1758) | | | 1 | | | |

Table 2. Continued.

| | | | | | | |
|---|---|---|---|---|---|---|
| *Hypera postica* (Gyllenhal, 1813) | | | | | 1 | |
| MAGDALINAE | | | | | | |
| *Magdalis duplicata* Germar, 1819 | | | | 1 | | |
| *Magdalis linearis* (Gyllenhal, 1827) | | | | 3 | | 1 |
| *Magdalis memnonia* Gyllenhal, 1837 | | | | 2 | | |
| *Magdalis rufa* Germar, 1824 | | | | 2 | 1 | |
| RHYNCHITINAE | | | | | | |
| *Attelabus nittens* (Scopoli, 1763) | | | 6 | | | |
| *Rhynchites sericeus* Herbst, 1797 | | | 5 | | | |

Table 3. As table 1, for Collembola.

| Endemics | | Valdelatas | | | | | | Soto del Real | | | | | | Valsaín | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | H.O. | | | P.P. | | | O.W. | | | P.P. | | | O.W. | | | P.P. | | |
| | | Litter | Soil | Total | Litter | Soil | Total | Litter | Soil | Total | Litter | Soil | Total | Litter | Soil | Total | Litter | Soil | Total |
| | HYPOGASTURIDAE | | | | | | | | | | | | | | | | | | |
| | *Ceratophysella engadinensis* Gisin, 1949 | | | | | | | | | | | 2 | 2 | | 3 | 3 | | | |
| • | *Hypogastrura meridionalis* Steiner, 1955 | | 2 | 2 | | | | | | | | | | | | | | | |
| | *Willemia anophthalma* Börner, 1901 | | 1 | 1 | | | | | | | | 1 | 1 | | | | | | |
| | *Xenylla schillei* Börner, 1903 | | | | | | | | | | 10 | | 10 | 7 | 35 | 42 | 826 | 16 | 842 |
| | *Xenyllogastrura octoculata* (Steiner, 1955) | | 1 | 1 | | | | | | | | | | | | | | | |
| | NEANURIDAE | | | | | | | | | | | | | | | | | | |
| | *Micranurida meridonalis* Cassagnau, 1952 | | 3 | 3 | | | | | | | | | | | | | | | |
| | *Pseudachorutes palmiensis* Börner, 1903 | | | | | | | | | | | 1 | 1 | | | | | | |
| | *Pseudachorutes parvulus* Börner, 1901 | | 1 | 1 | | | | | | | | | | | | | | | |
| | ONYCHIURIDAE | | | | | | | | | | | | | | | | | | |
| • | *Fissuraphorura gisini* (Selga, 1963) | | | | | | | | 5 | 5 | | 1 | 1 | | | | | | |
| | *Mesaphorura betschi* Rusek, 1979 | | | | | | | | | | | | | | 2 | 2 | | 1 | 1 |
| | *Mesaphorura critica* Ellis, 1976 | | 3 | 3 | | | | | | | | | | | | | | | |
| | *Mesaphorura hygrophila* (Rusek, 1971) | | | | | | | | 5 | 5 | | 1 | 1 | | | | | 11 | 11 |
| | *Mesaphorura hylophila* Rusek, 1982 | | | | | 3 | 3 | | 5 | 5 | | | | | 9 | 9 | | | |
| | *Mesaphorura macrochaeta* Rusek, 1976 | | 7 | 7 | | 32 | 32 | | 106 | 106 | 1 | 112 | 113 | 1 | 124 | 125 | | 227 | 227 |
| | *Mesaphorura yosii* (Rusek, 1967) | | | | | 1 | 1 | | | | | | | | | | | | |
| | *Paratullbergia callipygos* (Börner, 1902) | | | | | | | | 7 | 7 | | 5 | 5 | | | | | | |
| • | *Protaphotura subaparallata* (Selga, 1962) | | 2 | 2 | | | | | | | | 4 | 4 | | 5 | 5 | | | |
| | ISOTOMIDAE | | | | | | | | | | | | | | | | | | |
| | *Cryptopygus thermophilus* (Axelson, 1900) | | 2 | 2 | 1 | 19 | 20 | | 8 | 8 | | 55 | 55 | | 1 | 1 | | 1 | 1 |
| | *Folsomides navacerradensis* Selga, 1962 | | | | | | | | | | | | | | 1 | 1 | | 2 | 2 |
| | *Isotoma (Parisotoma) notabilis* Schäffer, 1896 | | 19 | 19 | | 6 | 6 | | 117 | 117 | | 51 | 51 | | 54 | 54 | 2 | 7 | 9 |
| | *Isotomiella minor* (Schäffer, 1896) | | | | | | | | 16 | 16 | 1 | 21 | 22 | | 8 | 8 | 1 | | 1 |
| | *Isotomodes bisetosus* Cassagnau, 1959 | | | | | 8 | 8 | | 1 | 1 | | | | | 37 | 37 | | | |
| | *Isotomodes trisetosus* Denis, 1923 | | | | | 2 | 2 | | | | | | | | | | | | |
| | *Isotomurus palustris* (Müller, 1776) | | | | | | | | | | | | | | | | | 1 | 1 |
| | ENTOMOBRYIDAE | | | | | | | | | | | | | | | | | | |
| | *Cyphoderus albinus* Nicolet, 1841 | | 1 | 1 | | | | | | | | | | | | | | | |
| • | *Entomobrya* n. sp. | 2 | 19 | 21 | | | | 11 | 39 | 50 | 23 | 21 | 33 | 10 | 1 | 11 | 23 | | 23 |
| | *Heteromurus (H.) major* (Moniez, 1889) | | 2 | 2 | | | | | 1 | 1 | 2 | 1 | 3 | | | | 1 | | 1 |
| • | *Lepidocyrtus lusitanicus* Gama, 1964 | | 2 | 2 | | 9 | 9 | | | | | | | | | | | | |
| • | *Pseudosinella* n. sp. | | 3 | 3 | | | | | | | | 6 | 6 | | | | 1 | | 1 |
| • | *Pseudosinella serrana* Luciañez y Simón, 1994 | | | | | | | | 2 | 2 | | | | | | | | | |
| • | *Pseudosinella templadoi* Simón y Selga, 1977 | | | | | | | | | | | 12 | 12 | | | | | | |
| | *Seira domestica* (Nicolet, 1842) | | | | | | | | | | | | | | | | 1 | | 1 |
| | NEELIDAE | | | | | | | | | | | | | | | | | | |
| | *Megalothorax minimus* (Stach, 1951) | | 1 | 1 | | | | | 1 | 1 | | 1 | 1 | | | | | | |
| | ARRHOPALITIDAE | | | | | | | | | | | | | | | | | | |
| | *Arrhopalites acanthophthalmus* Gisin, 1958 | | | | | | | | | | | | | | | | | 1 | 1 |
| | BOURLETIELLIDAE | | | | | | | | | | | | | | | | | | |
| | *Bourletiella viridescens* (Stach, 1920) | | | | | | | | 1 | 1 | | | | | | | | | |
| | DICYRTOMIDAE | | | | | | | | | | | | | | | | | | |
| | *Dicyrtomina minuta* (Lubbock, 1862) | | | | | | | | | | | | | 3 | | 3 | | | |
| | KATIANNIDAE | | | | | | | | | | | | | | | | | | |
| | *Sminthurinus aureus* (Lubbock, 1862) | | | | | | | | | | | | | 17 | 2 | 19 | | | |
| | SMINTHURIDIDAE | | | | | | | | | | | | | | | | | | |
| | *Sphaeridia pumilis* (Krausbaur, 1898) | | | | | | | | | | 2 | | 2 | | | | | | |

was somewhat higher than that of the area of original woodland. The graphs in Figure 3 illustrate the variation of butterfly diversity indices over the sampling period, whereby values tended to fall during the summer. Diversity increased in the reafforested zone of site 3 (Valsaín) during the summer.

The values of annual H' for the Curculionids were greater in the reafforested areas than in the original woodlands except at site 1 (Valdelatas). However, the values of annual R' were higher in natural than in reafforested areas, except at site 3 (Valsaín). The values of monthly H' and R' for July were greater in the original woodland at all the sites.

The highest values of Collembola H' and R' were found in the natural zones, except at site 2, where the indices were higher in the reafforested area.

## Discussion

The relation of the species of butterfly, Table 1, includes principally broadly distributed species. However, some are interesting from the conservation point of view, such as *Euphydryas aurinia*, which is protected under the Habitat Directive and the Bern Convention (HELSDINGEN *et al.* 1996). No endemic species were noted. In the case of butterflies, endemism is associated with higher altitudes (MARTÍN *et al.*, 2000).

The most striking results from the butterflies were noted at site 3 (Valsaín), where there was a decrease in the number of individuals and therefore in the density (79.6%) and a loss of 43.7% of species as a consequence of the reafforestation. This fall in the number of individuals and species is illustrated in Figure 1, where different samples always had lower values. These results are similar to those obtained by ROBERTSON *et al.* (1988) in Great Britain, where butterfly density was 5 individuals/km transect in mature conifer reafforestations. The H' and R' diversity indices were highest in spring and tended to decrease over summer and autumn, as normally occurs in a Mediterranean climate with a severe summer drought. Conversely, the values in the reafforested zones remained low, with a slight tendency to rise in the summer. These reached a maximum in autumn with values similar to those of the natural zones. This trend is partly due to some of the Nymphalidae Satyrini, which seek refuge in the shady zones of the woods during the summer, before laying their eggs (GARCÍA-BARROS 1987). The overall seasonal value of R' reflects this situation, although paradoxically the value of H' was slightly higher in the reafforested zone (Table 4). This unusual behaviour of the Shannon-Weaver index was due to its sensitivity to the presence of dominant species, *Pyronia cecilia* and *M. lachesis* in this case, which indicate that the natural woodland is fragmented, with herbaceous zones between the patches of trees, and to the absence of any abundant species in the reafforested zone.

The similar numbers of butterfly species and individuals and values of diversity indices in the reafforested area and the natural zone of site 2 (Soto del Real) were probably due to their management conditions. The oakwood is cleared and has a scarce understorey due to grazing and charcoal production.

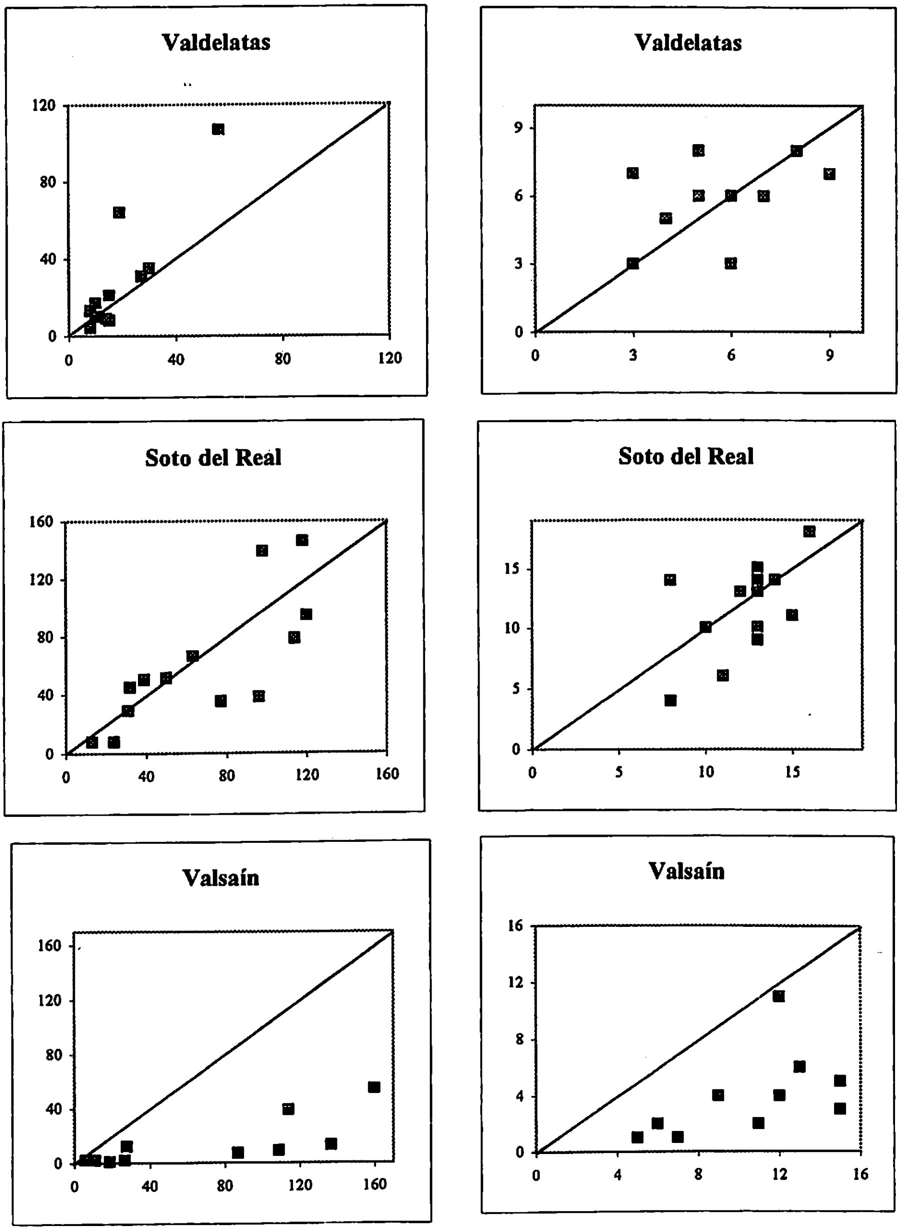


Fig. 1. Comparison in butterflies of the numbers of individuals (left) and species (right) between the zones with original vegetation (abscissa) and reafforested (ordinate) at each site. Each point represents one sampling day.

Conversely, the understorey is well developed and there is less grazing in the reafforested area, with the result that the diversity was similar to that of the natural zone. These observations support the claim of ROBERTSON *et al.* (1995) that the type of management of the understorey has an important influence on the butterfly community.

At site 1 there were fewer butterfly species and lower butterfly diversity indices in the reafforested than the natural zone. On the other hand, due to the abundance of *M. lachesis*, there were fewer individuals in the natural zone. The behaviour of this species may be explained by the large distance between patches of trees, with abundant herbaceous ground vegetation, and the cleanliness of the understorey in the reafforested zone. Overall, there were fewer species and individuals in this zone than in the oakwood, as occurs with the Curculionids. This may therefore be attributed in these phytophagous groups to the fewer plant species in the holm oakwoods compared with the oakwoods (RIVAS-MARTÍNEZ *et al.*, 1990). The reduction in values of H' and R' over summer and autumn is due to the dryness of the Mediterranean climate in summer, which is particularly pronounced in the bioclimatic stage where the holm oakwood occurs.

The density of Curculionids was greater in terms of species and individuals in the oakwoods than in the holm oakwoods. The numbers of species and individuals were greater in the natural than in the reafforested areas (Table 2 and Fig. 2b). The differences between the areas are correlated with the lower floristic richness of the *Q. ilex* woodlands compared with those of *Q. pyrenaica* in the Sierra de Guadarrama (RIVAS-MARTÍNEZ *et al.*, 1990). These observations are consistent with those of BUSE (1988), who found a positive correlation between the number of Coleoptera species and the number of plant species. MURDOCH *et al.* (1972) discovered a similar relationship in Homoptera.

The abundance of Curculionids was lower in the zones reafforested with *Pinus* than in the natural *Quercus* woodlands (Table 2), irrespective of the species of *Pinus* used in the reafforestation and the floristic characteristics of the adjacent natural zones. This decrease in the density and frequency of the species in the reafforested areas in comparison with those with natural vegetation has also been observed in other animal groups (BONNET *et al.*, 1979; DEHARVENG, 1996).

Curculionid diversity in the reafforested places of Valdelatas was the poorest and least diverse for two possible reasons. First, the site is located in the mesomediterranean stage, which generally has a lower floristic and faunistic diversity than the supramediterranean stage where the two other sites are located (RIVAS-MARTÍNEZ *et al.*, 1990; MARTÍN *et al.*, 1995), as has already been shown for butterflies.

Second, the reafforestation, has involved the elimination or alteration of the habitat and resources, causing a reduction in the number of individuals and species with respect to the original zone. The variations in H' and R' were more pronounced in those zones in which there were relatively very abundant

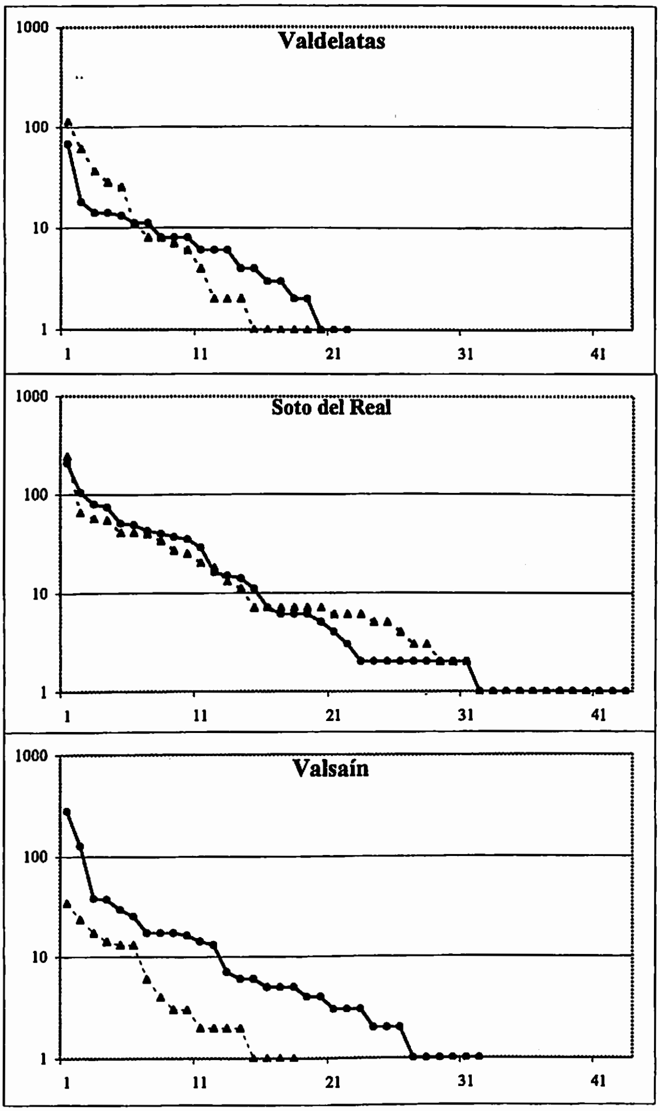


Fig. 2a. Distribution of abundances of butterflies in natural and reafforested areas. Abscissa= number of species; Ordinate=log frequency. Continuous line and circles: natural vegetation; broken line and triangles: reafforested vegetation.

species (such as *A. haematodes*, which uses invasive plants), or those that have stricter trophic requirements, such as *Eutrichapion putoni*, which is a species linked to the shrub of the Genisteae (GURREA *et al.*, 1991).

Thus, the reafforestations carried out at sites 2 and 3 (Soto del Real and Valsaín) led to a two-thirds reduction in the number of Curculionid species com pared with the adjacent areas of natural oakwood (Tables 2 and 4). The highest values of H' (Shannon-Weaver diversity index) were noted in the areas reafforested with *Pinus* in Valsaín. As a consequence of reafforestation, the number of individuals of the dominant species decreased (as *Phyllobius tubeculifer* and *Pleurodirus carinula* are species linked to oak trees) while remaining approximately constant in the other species.

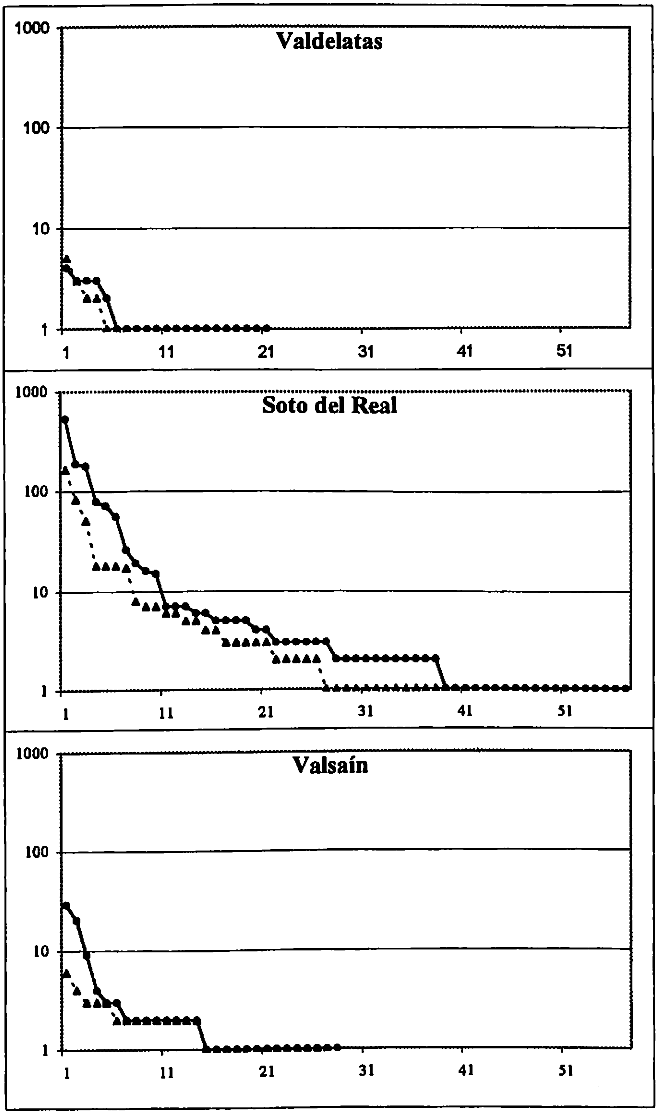


Fig. 2b. Distribution of abundances of Curculionids in natural and reafforested areas. Abscissa= number of species; Ordinate=log frequency. Continuous line and circles: natural vegetation; broken line and triangles: reafforested vegetation.

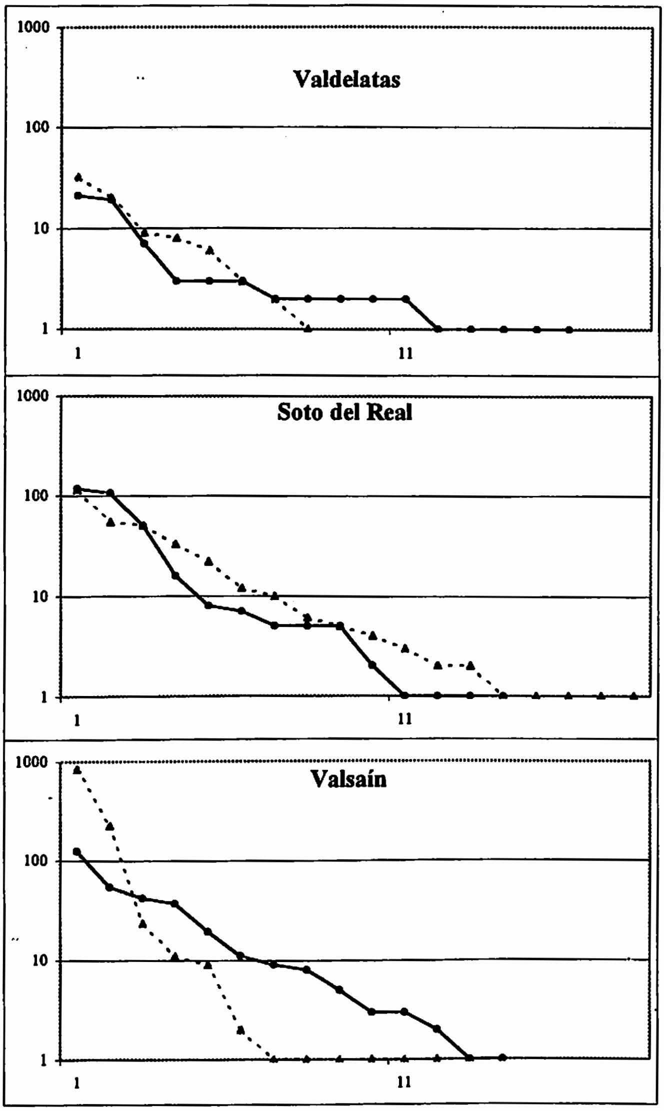


Fig. 2c. Distribution of abundances of Collembola in natural and reafforested areas. Abscissa= number of species; Ordinate=log frequency. Continuous line and circles: natural vegetation; broken line and triangles: reafforested vegetation.

In the Collembola the observed trend was only partially similar to those reported in the previous groups. At site 1 (Valdelatas) the number of individuals was relatively small in comparison with those in the other sites, but not the number of species. For this reason the Margalef (R') and Shannon-Weaver (H') indices were the highest of the three sites. Site 3 provides a very clear example of how reafforestations favour the establishment of opportunistic spe-

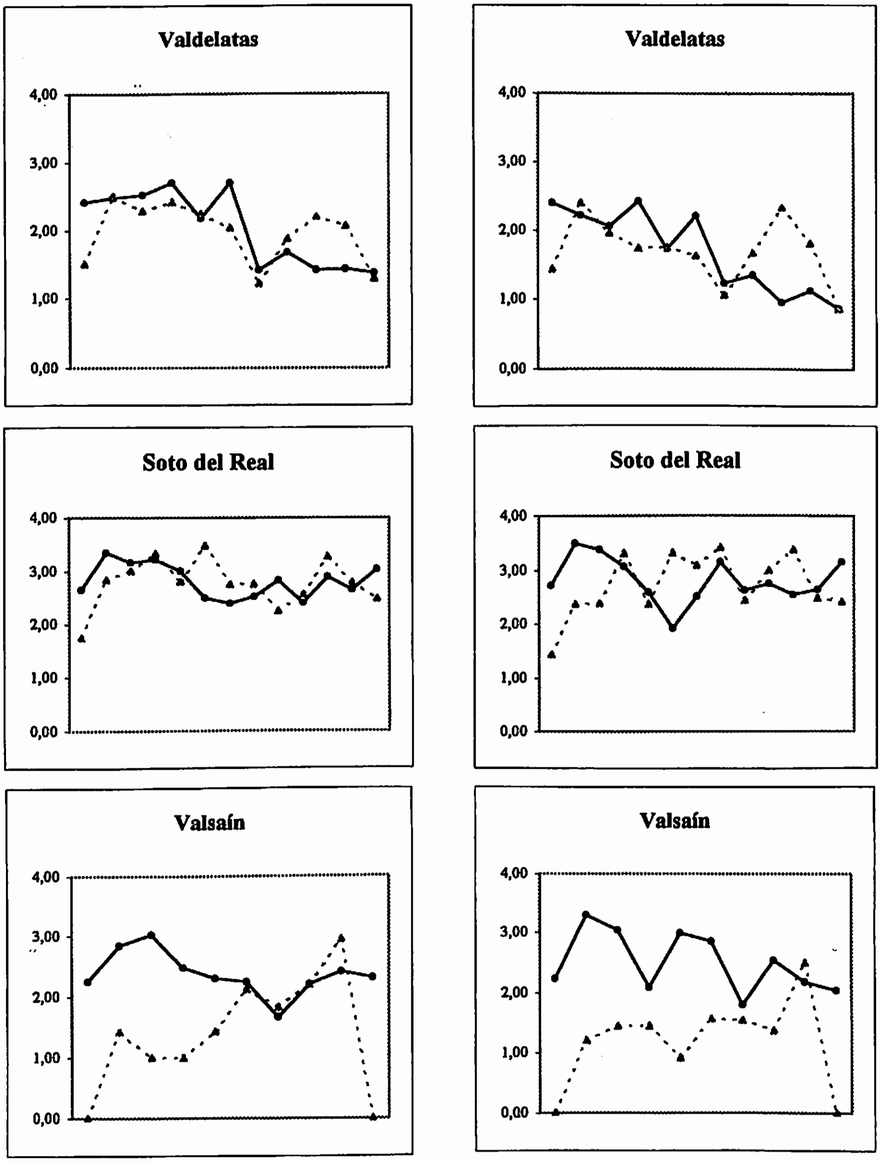


Fig. 3. Variation in values of H' (left) and R' (right) over the butterfly flying period (May-October). Continuous line and circles: natural vegetation; broken line and triangles: reafforested vegetation.

cies. The greatest number of individuals was found here with a similar number of species, as in the other two sampling sites. However, the difference was due to the great abundance of individuals of the opportunistic or generalist species, *Xenylla schillei* and *Mesaphorura macrochaeta*, which reduced the diversity of the reafforested habitat with respect to the natural habitat, despite them having the same number of species.

Of all the species recorded from Valdelatas, Soto del Real and Valsaín, 25%, 27% and 14%, respectively, are Iberian endemics.

At site 1 (Valdelatas) the number of endemic species and rare species (i.e., those that are always represented by a small number of individuals; GAMA *et al.*, 1997) were greater in the natural than the reafforested environment. The number of endemic species was the same in both habitats at sampling point 3 (Valsaín), although there were fewer rare species in the reafforestation. In Soto del Real the numbers of endemic and rare species were greater in the reafforestation. Overall, reafforestations cause a loss of the most sensitive (i.e., rare and endemic) species, although it should be pointed out that in Soto del Real the reafforested environment is better conserved.

The species *Mesaphorura hylophila, M. macrochaeta, Protaphorura subparallata, Cryptopygus thermophilus, Isotoma (P.) notabilis, Isotomodes bisetosus, Entomobrya* n. sp., *Heteromurus major*, and *Pseudosinella* n. sp. were common to all three sites. Of these, *M. macrochaeta* and *I.(P.) notabilis* were the most abundant and frequent and can be considered to be the fundamental species of the community, while the rest are characteristic species, some of them endemic, as is the case of *Protaphorura subparallata, Entomobrya* n. sp. and *Pseudosinella* n. sp.

In Valdelatas, 45% of the species were exclusive to the site. Those found in the holm oakwood were: *Hypogastrura meridionalis, Xenyllogastrura octoculata, Micranurida meridionalis, Pseudachorutes parvulus, Mesaphorura critica, Cyphoderus albinus,* and *Megalothorax minimus,* indicating a xerophilic forest habitat (GAMA *et al.* 1994, GAMA *et al.* 1997, LUCIAÑEZ & SIMÓN, 1991), with colonizing species such as *P. parvulus* (HUTSON, 1980) . This tendency is also indicated by *Lepidocyrtus lusitanicus*, which is found in the natural and reafforested vegetation. The numbers of individuals are low but they represent edaphic or hemiedaphic taxa well adapted to xeric environments (MATEO & SELGA, 1991). The most abundant species in the holm oakwood were *Entomobrya* n. sp. (29.6%), *I.(P.) notabilis* (26.8%), and *M. macrochaeta* (9.9%). In the pinewood the xerophilic and thermophilic species *C. thermophilus* and *M. macrochaeta* became dominant (BONNET *et al.*, 1977).

In Soto del Real 31.8% of the species were exclusive to the site: *Pseudachoutes palmiensis, Fissuraphorura gisini, Paratullbergia callipygos, Pseudosinella serrana, Pseudosinella templadoi, Bourletiella viridescens* and *Sphaeridia pumilis*, typical of open, mountainous places. The presence of two local endemics, *P. serrana* and *P. templadoi*, is particularly striking. The most abundant species in the oakwood and the pinewood were the same as in Valdelatas in spite of native differences (*Q. ilex / pyrenaica*).

In Valsaín 35.0% of the species were unique to the site: *M. betschi, Folsomides navacerradensis, Isotomurus palustris, Seira domestica, Arrhopalites* *acanthophthalmus, Dicyrtomina minuta* and *Sminthurinus aureus.* These are typical of an acidophilic habitat (PONGE & PRAT, 1982; HAGVAR, 1984) and in natural areas with open spaces between the zones with trees (PONGE, 1980; POZO *et al.*, 1986). The most abundant species were the same as those in the two other habitats and also *X. schillei.* The latter is a xerophilic colonizing species found in relatively degraded places and makes up 60.0% of the individuals in the reafforestation (RUIZ & SIMON, 1995).

An overall analysis reveals the differences between the three groups of arthropods in the areas studied. With respect to the number of individuals (Table 4) site 1 (Valdelatas) was the poorest. However, the richest is not so well defined: for butterflies and Curculionids it was site 2 (Soto del Real), while for the Collembola it was site 3 (Valsaín).

With respect to the number of species (Table 4), site 2 (Soto del Real) had the most in all three groups. On this occasion it is the site with fewest species that is poorly defined. For butterflies and Curculionids site 1 (Valdelatas) had the fewest, while for Collembola, site 3 (Valsaín) had the fewest species. It is interesting that herbivorous groups respond differently to detritivorous ones.

Table 4. Parameter values used in the study. Abundance, number of species, Shannon-Weaver diversity index (H'), Margalef richness index (R') for each of the groups studied.

| | Valdelatas | | Soto del Real | | Valsaín | |
|---|---|---|---|---|---|---|
| | H.O. | P.P. | O.W. | P.P. | O.W. | P.P. |
| | **Butterflies** | | | | | |
| Abundancy | 212 | 319 | 875 | 787 | 698 | 142 |
| Species | 22 | 20 | 43 | 41 | 32 | 18 |
| Shannon- Weaver Index (H') | 3,63 | 2,97 | 3,91 | 3,90 | 3,21 | 3,37 |
| Margalef Index (R') | 3,92 | 3,30 | 6,20 | 6,00 | 4,73 | 3,43 |
| | **Curculionidae** | | | | | |
| Abundancy | 31 | 15 | 1294 | 460 | 98 | 50 |
| Species | 21 | 7 | 57 | 41 | 28 | 27 |
| Shannon- Weaver Index (H') | 4,17 | 2,55 | 3,15 | 3,46 | 3,66 | 4,53 |
| Margalef Index (R') | 5,82 | 2,22 | 7,82 | 6,52 | 5,89 | 6,65 |
| | **Collembola** | | | | | |
| Abundancy | 71 | 81 | 325 | 323 | 320 | 1122 |
| Species | 16 | 8 | 14 | 18 | 14 | 14 |
| Shannon- Weaver Index (H') | 3,10 | 2,37 | 2,36 | 2,88 | 2,71 | 1,10 |
| Margalef Index (R') | 3,52 | 1,59 | 2,25 | 2,94 | 2,25 | 1,85 |

Also, overall, with reference to the changes in individual abundance that are supposedly induced by the reafforestations, of the 9 combinations considered (3 taxa at each of 3 sites), 6 showed a decrease in the number of individuals, while an increase was observed in the other 3. With regard to the number of species, reafforestation resulted in a decrease in the number of species in 8 cases, and an increase in one.

The analysis of the diversity and richness indices is rather more complex. The Margalef index indicates losses of richness due to reafforestation in 7 cases, compared with 2 in which the opposite trend was noted. The Shannon-Weaver index reveals more similar results, whereby the diversity index decreased in 5 cases, compared with 4 in which it increased. If we take into account the results discussed above concerning the number of species and individual abundance, it appears that the Shannon-Weaver index does not accurately reflect the situation, being highly influenced by the presence of dominant species, as many authors, such as WOLDA (1983) and MAGURRAN (1985), have pointed out. The Margalef index appears to be more appropriate for quantifying the changes observed here.

Therefore, the woodland reafforestations generally caused the reduction in the number of species, individuals and the values of richness and diversity indices in the communities of butterflies, Curculionids and Collembola. The changes did not affect the three taxonomic groups studied equally, given the influence of many factors ranging from the biological and ecological characteristics of the animal species involved to the type of management carried out in the reafforestation or in the natural woodland with which the former is compared, the management of the understorey being of special importance.

## Conclusion

Overall the number of individuals, species and the value of the diversity indices was lower in the reafforested zones than in the corresponding natural zones, but each group differed in the behaviour of its community, distinguishing the various types of reafforestation.

The reafforestations bring about a decrease or disappearance of the least abundant species, while the most abundant species persist. They also cause the loss of endemic species.

Therefore, reafforestations implied a loss of diversity in the three groups studied here, as was observed in birds (BATTEN, 1976; BONGIORNO, 1982; POTTI, 1986; AVERY & LESLIE, 1990), butterflies (ROBERTSON *et al.* 1995), moths (MAGURRAN 1985, 1988), staphylinids (BUSE & GOOD 1993), and collembola (ARBEA & JORDANA, 1985; ARBEA, 1987; GAMA *et al.*, 1997; DEHARVENG, 1996). This decrease is determined by several factors, among which the management of the plantation is of particular importance. In the most typical reafforestations, with closed tree formations and periodic cleaning of the understorey, the loss of butterflies may exceed 75% of individuals and 40% of species.

The numbers of individuals and species were greater in natural *Quercus* woodland areas than in the *Pinus* reafforestations, although the value of the Shannon-Weaver diversity index was lower on some occasions. This was due to a considerable decrease in the number of individuals of dominant species. Thus, the Margalef diversity index better reflects the entomological status of these areas.

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