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DECLINE OF *PARNASSIUS APOLLO* IN THE SIERRA DE GUADARRAMA, CENTRAL SPAIN (LEPIDOPTERA: PAPILIONIDAE)

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ABSTRACT.– This work describes the distribution, density, phenology and habitat (altitude range and type of vegetation) of *Parnassius apollo* (Linnaeus) in the Sierra de Guadarrama of Central Spain. Its present state of conservation in the area is analyzed and compared to that of twenty years ago.

KEY WORDS: Asia, Campanulaceae, conservation, Compositae, Crassulaceae, decline, density, distribution, endangered species, Europe, Fabaceae, Fagaceae, France, habitats, hostplants, Iberian Peninsula, Leguminosae, phenology, Pinaceae, Plumbaginaceae, Poland, population biology, relict species, Sweden.

Parnassius apollo (Linnaeus) is an emblematic species of international entomology. It is included in a great many 'red lists' of butterflies (Cites, Berna, UICN-R, etc.) and is still a threatened species (Collins and Morris, 1985).

The species is a postglacial relict that inhabits the majority of the mountainous regions of Europe and Asia. Its large number of subspecies and local races have made it extraordinarily attractive to both scientist and collector. However, in the last twenty years its European populations have declined generally, causing alarm amongst researchers who have documented this in many countries, e.g., Poland, Sweden and France (Dabrowski, 1980; Bengtsson *et al.*, 1989; Braconnot *et al.*, 1993).

The main factors that have provoked this regression are man-made, e.g., massive reforestation programs, tourism, public works, atmospheric pollution — in essence, the transformation of its habitat by man (Kudrna, 1986) — and commercial over-collecting.

The main colonies of the Iberian Peninsula show very different states of conservation. The populations of the Pyrenees and Ayllón (Rosas *et al.*, 1992) do not appear to be too adversely affected by transformations of their habitat and have managed to maintain their numbers. However, other populations such as those of the Sierra Nevada (Gomariz-Cerezo, 1993) and the Sierra de Javalambre are very seriously threatened by excess tourism and the destruction of their habitat. Others still can be almost certainly considered extinct, such as that of the Sierra de Gador (see Gomariz-Cerezo, 1993).

The aim of this investigation was to record the present distribution, habitat (range of altitude and vegetation type) and phenology of the largest populations still surviving in the Sierra de Guadarrama, in central Spain near Madrid.

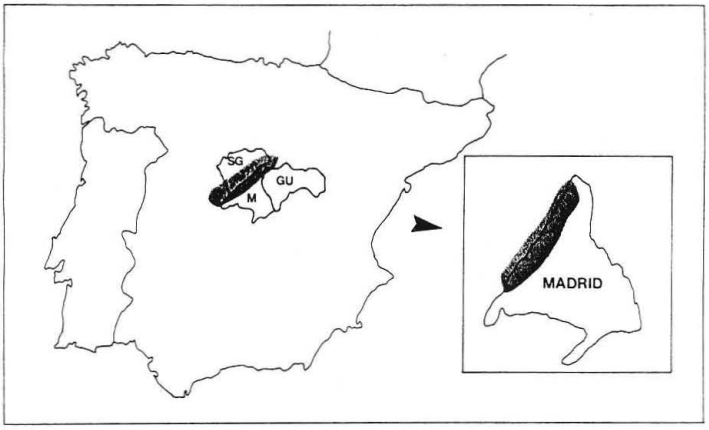


Fig. 1.- Location of study area.

STUDY AREA

The study area included nearly the entirety of the Sierra de Guadarrama, with the NE limit at Puerto de Somosierra and SW limit at Pico de San Benito. This mountain range forms part of the Sistema Central which divides the Meseta of central Spain into two Submesetas (Fig. 1), and is a mountainous chain lying NE-SW. It is some 30km wide and approximately 100km long and occupies part of the Provinces of Madrid, Avila and Segovia. The highest altitudes are found in the central area, with several peaks surpassing 2000m. Towards either end of the range, altitudes are not quite so high.

Bioclimatically, the Sierra de Guadarrama can be divided into Mesomediterranean, Supramediterranean, Oromediterranean and Criomediterranean levels. The most characteristic vegetation ranges from high mountain grassy meadows to *Cytisus purgans* (Fabaceae) shrublands, pinewoods and oakwoods, and to holm

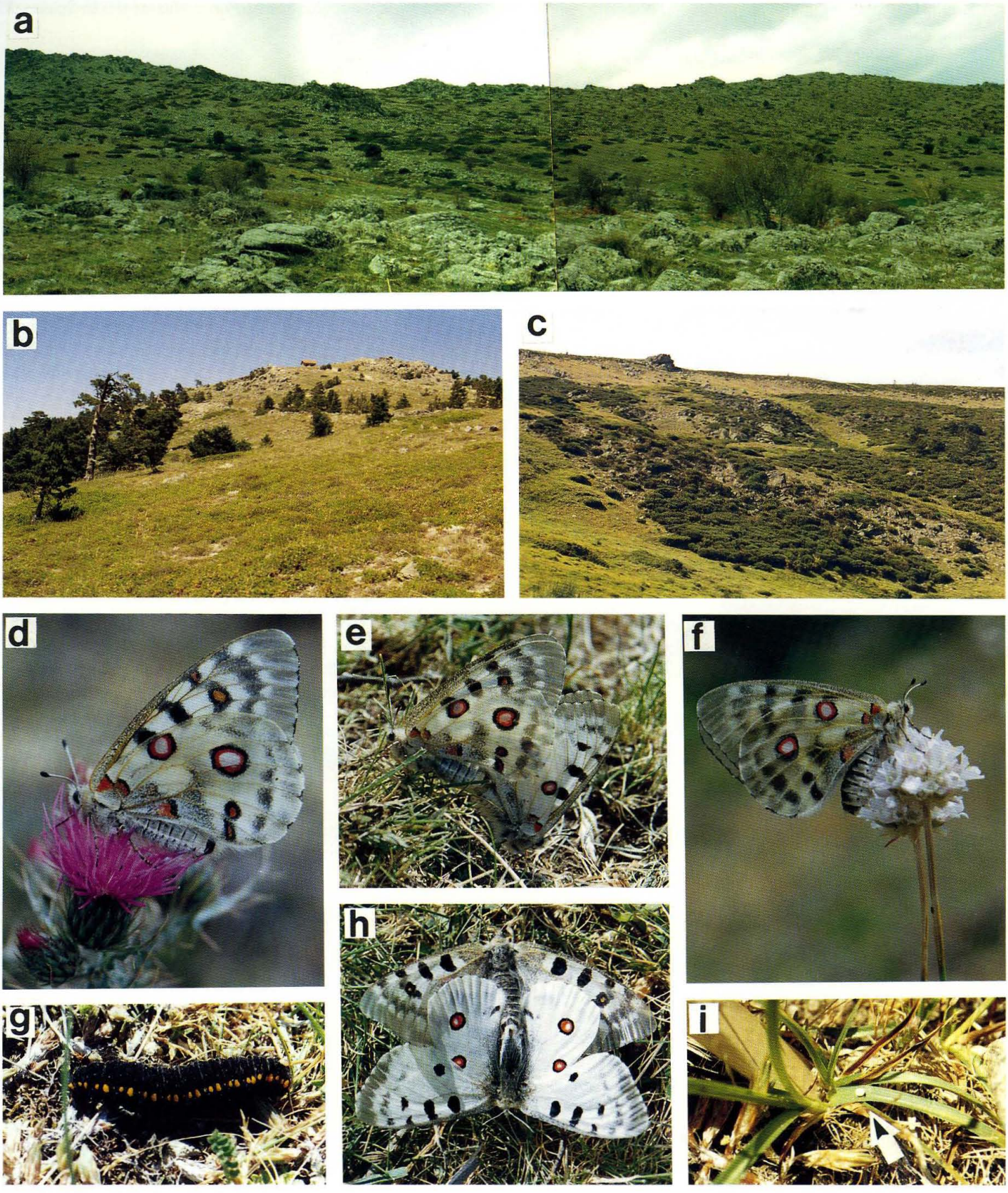


PLATE 1.– a-c: Examples of the biotopes who *Parnassius apollo* has been found in the Sierra de Guadarrama, a: San Benito site, showing the vegetation typical of serial stages of oakwoods. b: Collado de la Mina site, scot pine forest predominate in this area. c: Las Berrocosas site, with its tipical *Cytisus purgans* shrubland. d-i: Some aspects of the biology of *Parnassius apollo* in the Sierra de Guadarrama. d: Female on a inflorescence of *Carduus carpetanus*. e: A pair in copula. f: Female feeding on a inflorescence of *Armeria arenaria*, the main nectar source for adults in this area. g: Last instar larvae feeding on its foodplant (*Sedum tenuifolium*). h: A pair in copula, showing its defensive display. i: Isolated egg.

TABLE 1. Census results at each locality sampled for *Parnassius apollo*.

LOCALITIES	ELVT.	VEGET.	T.T.	P.T.	Nº I.	DENS.
1 San Benito	1400	OAKWOOD	67	52	60	1.15
2 Hoyo de la Güija	1400	OAKWOOD	77	65	8	0.12
3 Pinar de Peguerinos	1450	PINEWOOD	71	---	---	-----
4 Puerto de Malagón	1600	SHRUBLAND	88	---	---	-----
5 Collado de la Mina	1750	PINEWOOD	127	30	9	0.30
6 Puerto de los Leones	1500	PINEWOOD	27	---	---	-----
7 Mirador Luis Rosales	1650	PINEWOOD	65	---	---	-----
8 Puerto de la Fuenfría	1750	PINEWOOD	131	---	---	-----
9 La Peñota (Cercedilla)	1600	PINEWOOD	10	---	---	-----
10 Pista de Losillas	1650	OAKWOOD	64	15	1	0.06
11 Cabeza de Hierro	1950	SHRUBLAND	101	---	---	-----
12 Laguna de Peñalara	2000	SHRUBLAND	110	---	---	-----
13 Cinco Lagunas	2000	SHRUBLAND	20	---	---	-----
14 Miraflores	1300	OAKWOOD	38	38	2	0.05
15 Puerto de la Morcuera	1800	SHRUBLAND	81	---	---	-----
16 Peñas Viborizas	1750	SHRUBLAND	135	---	---	-----
17 Cerro Pelado	1650	SHRUBLAND	10	---	---	-----
18 Alto del Robledillo	1450	OAKWOOD	90	80	42	0.52
19 El Palancar	1350	OAKWOOD	15	15	2	0.13
20 La Maleza	1450	OAKWOOD	44	---	---	-----
21 Puerto de Navafría	1900	PINEWOOD	65	---	---	-----
22 La Nevera	1800	PINEWOOD	104	47	4	0.08
23 La Peñota	1900	PINEWOOD	72	72	13	0.18
24 Las Berrocosas	1850	SHRUBLAND	92	20	2	0.10
25 Puerto de Peñaquemada	1800	SHRUBLAND	92	---	---	-----
26 Puerto de la Acebeda	1600	SHRUBLAND	22	---	---	-----

oakwoods which are found at lower altitudes. A much more detailed botanical and morphostructural account can be found in Rivas-Martínez *et al.* (1987).

MATERIALS AND METHODS

Prior to the commencement of field studies, a complete search was made of the literature citing the presence of *P. apollo* in the study area. Twenty-six localities were chosen, including 12 places where the species had been recorded in the last twenty years, and a further 14 sites exhibiting the minimum environmental conditions thought required by the species (e.g., acceptable density of food plants, altitude of over 1200m, areas without excessive tree cover, etc). These places were inspected weekly (a total of eight times) between the end of June and the end of August 1993, the time of year when the imagos take to the air.

To detect and count the different populations, transects were made according to a previously established route and individuals were counted over a period of time. Specimens seen within a range of 20m to the front and sides of the observer were counted (see, by instance Pollard, 1977). This distance, though less than that used by other authors in similar investigations (Gomariz-Cerezo, 1993), was considered the maximum at which *P. apollo* could be safely identified.

The biotopes sampled showed different altitude, orientation, slope and alteration by Man, and presented different types of vegetation and plant cover. Each of the sampled areas belonged to one of three vegetation strata: Spanish broom brush (*Cytisus purgans)*, pinewoods of *Pinus sylvestris* (Pinaceae) and oakwoods of *Quercus pyrenaica* (Fagaceae) (with its different successional stages of degradation).

RESULTS

Table 1 shows the results of the census at each locality. The types of dominant vegetation and elevation of each are also given. The species was distributed between altitudes of 1300 and 1900m. It appeared most frequently between 1300 and 1500m, which is basically the altitude range of oakwoods. At immediately higher altitudes (1500-1700m), the species was less abundant but became more common again at altitudes of 1700-1900m. The presence of the species at higher altitudes was not confirmed.

This distribution of the species along the altitude gradient resulted in phenological differences (Fig. 2) between populations. This led to a difference in the time when the imagos took to the air. Specimens were seen earlier at the lower inhabited altitudes

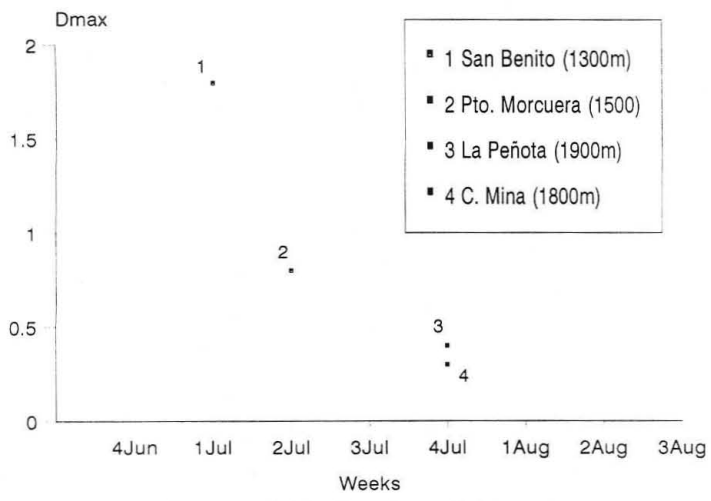


Fig. 2.- Maximun density reached by the main populations at different elevations.

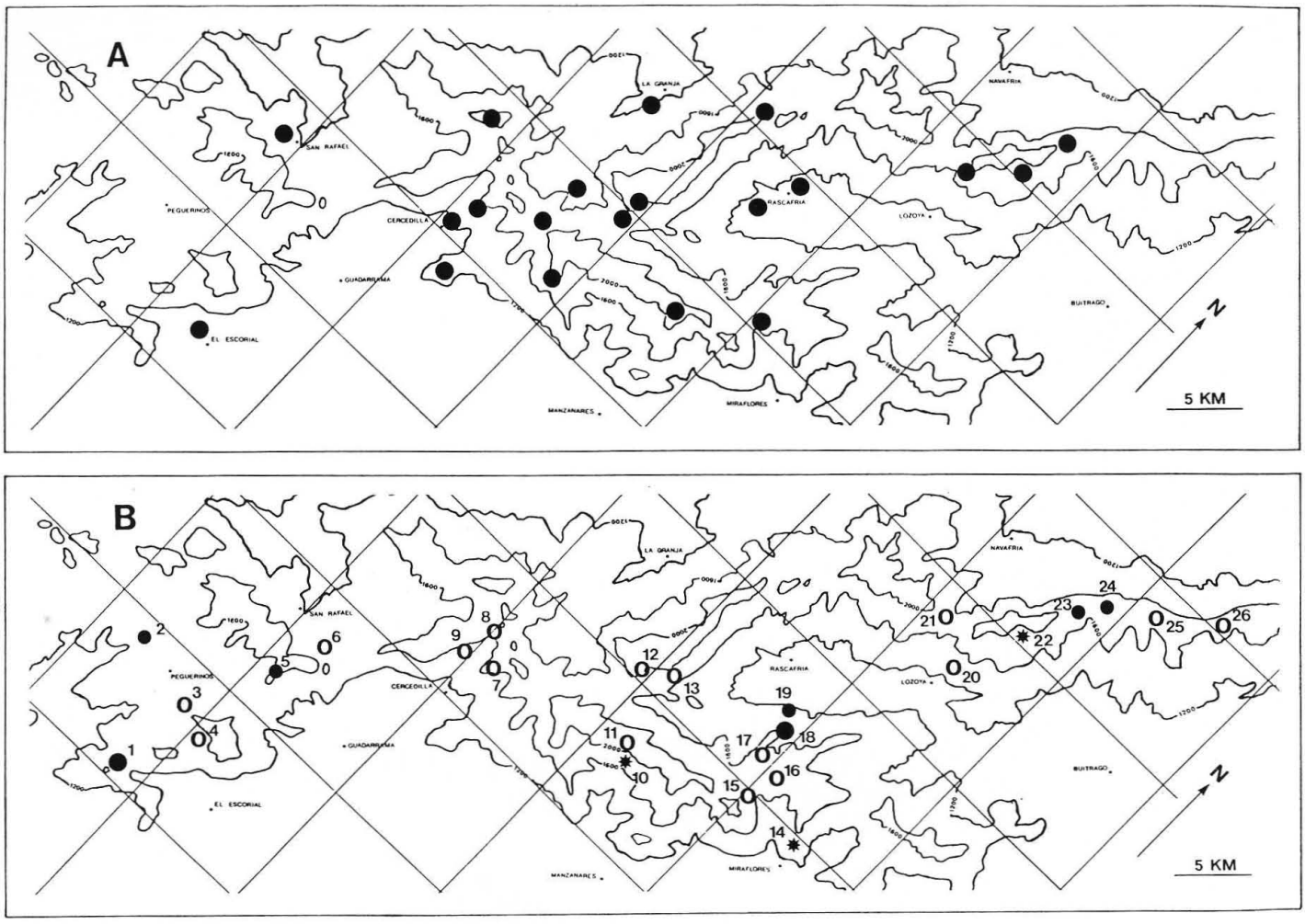


Fig. 3.- Changes in the distribution of populations of *Parnassius apollo* in the Sierra de Guadarrama during the last tewnty years. A) Data from Monserrat (1976). B) Actual distribution after our censuses in 1993.

Big black dots: density population > 0.5 individuals/minute
Little black dots: density population between 0.5 and 0.1
Asterisk (*): occasional observations
White circles: localities were *Parnassius apollo* are absent

(end of June) and later towards higher altitudes (end of July). The imagos of populations occupying the biotopes of highest altitude were not seen until the beginning of August.

Independent of the vegetation level occupied, the species was always seen flying in clearings and herbaceous meadows where a good density of food plants existed (*Sedum tenuifolium* (Crassulaceae), personal observations) and where nectar could be found (*Armeria arenaria* (Plumbaginaceae), *Jasione montana* (Campanulaceae), *Carduus carpetanus* (Compositae), personal observations). It was precisely in these areas where the males were seen to patrol in search of females, clearly avoiding closed, wooded places and areas of dense *C. purgans*.

The frequency with which the species appeared in the three biotopes described was different. It was detected in only one of the 10 areas of *C. purgans* investigated, in 3 of 9 pinewoods and 6 out of 7 oakwoods. It is in these latter woods where the species shows its highest density, with a maximum value of 1.15 and a mean of 0.33 individuals recorded per minute. The pinewoods showed values of 0.30 and 0.18 respectively and the only *C. purgans* shrubland in which the species was detected showed 0.10 individuals per minute (Table 2).

DISCUSSION

Table 1 shows *P. apollo* was found in only 10 of the 26 selected areas. Fig. 3b shows the present distribution of the species in the Sierra de Guadarrama. The species has suffered an alarming, rapid decline over the last twenty years. Monserrat (1976) showed it to be fairly common in the '70s and recorded a distribution that included practically the whole of the Sierra (Fig. 3a). The regression of the species became appreciable in the '80s (Gómez de Aizpurua, 1987). Unfortunately, this work is largely a bibliographical study and therefore an in-depth analysis of the species' distribution at that time is not possible.

Fig. 3 graphically reveals how the species has disappeared from most of the enclaves where it was once common. This drastic reduction in the number of populations has provoked a breakdown in the once homogeneous distribution of the species throughout the Sierra. There now exist only small, remote, isolated populations. Any movement of individuals between populations has probably been lost and isolation has become a new factor to further threaten the survival of the species. Such theoretical isolation has been placed in doubt by Gómez-Bustillo and Fer-

TABLE 2. Maximum, minimum and average density on each main biotope studied (* the data for shrubland reflects the only positive census in this biotope site).

DENSITY:	MAXIMUM	AVERAGE	MINIMUM
OAKWOOD	1.15	0.33	0.05
PINEWOOD	0.30	0.18	0.08
SHRUBLAND*	0.10	0.10	0.10

nández-Rubio (1973) who captured specimens far away from the closest colonies, probably as a result of being blown by the wind. However, in the present study no such displacements of individuals were seen and it seems improbable that other populations could be reached given the very large distances that separate even the closest colonies. Rather, the observations made coincide with those of Gomariz-Cerezo (1993), working with *P. apollo*, and Guppy (1986), working with *Parnassius phoebus* (Fabricius), who reported the sedentary nature of the populations they studied. The males of these populations moved within well defined areas with high densities of both food-plants and virgin females with whom they could mate.

The reduction in the number of populations was not uniform across the three biotopes. Rather—and as can be seen by comparing the present results with those of Montserrat (1976)—the species has disappeared mainly from pinewoods and areas with *C. purgans*. Montserrat (1976) reports a homogeneous distribution of *P. apollo* across the three vegetation groups (χ^2=0,83 p=0.65). However, the results of the present study show the species to be more common in oakwoods (χ^2=10,12 p=0.006) (see Fig. 4). The disappearance of *P. apollo* over the last twenty years has, therefore, taken place mainly from pinewoods and areas of *C. purgans*. In these biotopes, colonies are less dense and therefore more vulnerable. Furthermore, the flying period of the imagos in these areas coincides with a time of year when the Sierra receives the most tourists (Gómez-Limón *et al.*, 1994). It might be speculated that the massive human occupation of the Sierra during summer is the main cause of the disappearance of a great number of populations in the high areas of the center of the Sierra. By means of example, in two areas which now experience excessive tourist pressure (the protected enclaves of Macizo de Peñalara and the Cuenca Alta del Manzanares), no specimens were found at all, despite the intensive search undertaken. Yet, these are areas where the species has traditionally been reported. Similarly, Gómez-Limón and De Lucio (1994) have reported that the massive influx of visitors to the Biosphere Reserve of the Cuenca Alta del Manzanares has provoked changes in the soil and in the range of vascular plants that inhabit the area, factors which have led to a reduction in biological diversity.

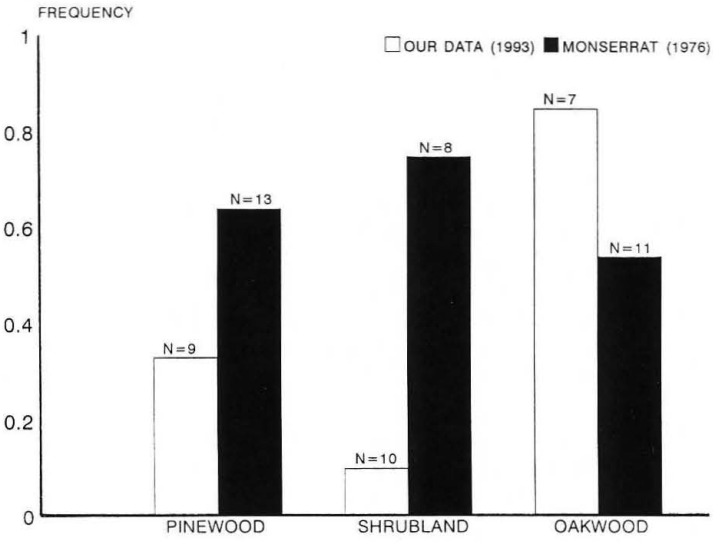
Other agents, such as acid rain (Bengtsson *et al.*, 1989), reforestation programs (Dabrowsky, 1980), overgrazing and excessive collecting (Kudrna, 1986), have been reported directly responsible for the decline of the species in the main mountainous regions of Europe (see Bourgogne, 1971; Pretscher and Schult, 1978).

Investigations designed to understand the impact of these agents on the surviving populations of the Sierra de Guadarrama would be of use. Though there has been no massive reforestation in the region in the last twenty years, other agents such as over-collecting could certainly have had a negative influence on the species (Bourgogne, 1971; Ibero, 1990). The species is very easy to catch and large populations occur within defined areas. Indeed, some studies (Varea de Luque, 1945, Gómez-Bustillo and Fernández-Rubio, 1974) reveal the long-known existence of *P. apollo* 'haunts' in the Sierra de Guadarrama.

Since stock-raising is the main economic activity in the sampled areas, it might also be opportune to determine its effect on the species. However, Losa *et al.*, (1986), and Viejo and López-Munguira (1991), report that this activity might be beneficial, since it produces clearings and inhibits the growth of bushes whilst favoring that of herbaceous species, the main source of nectar for the imagos.

It can be concluded that *P. apollo* is seriously threatened with extirpation in the Sierra de Guadarrama. Unfortunately, the probable causes of its demise, far from ameliorating, are worsening. There are still a few apparently healthy populations that guarantee, at least for the moment, the survival in Spain of this emblematic butterfly, and which might provide the necessary material for reintroduction programs in areas traditionally inhabited by the species. However, urgent and new measures of protection are required since those that have been adopted so far have proved insufficient.

In closing, the authors implore, given the critical situation of the species, that those who should read this article make no use of it that could further endanger its survival.



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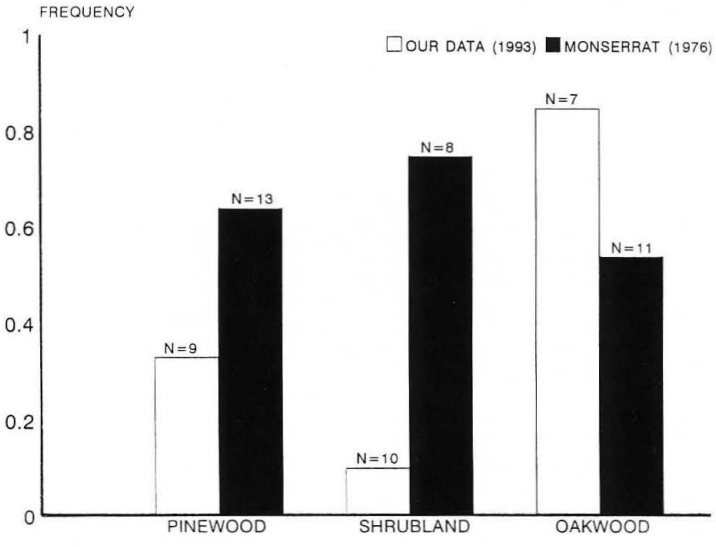

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