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CERAMBYCIDAE (*COLEOPTERA*) DIVERSITY AND COMMUNITY STRUCTURE IN THE MEDITERRANEAN FOREST OF THE NATURAL PARK OF SIERRA CALDERONA (SPAIN)

I *CERAMBYCIDAE* (*COLEOPTERA*) DEL PARCO NATURALE DELLA SIERRA CALDERONA (SPAGNA): DIVERSITÀ E STRUTTURA DELLA POPOLAZIONE IN UNA FORESTA MEDITERRANEA

ABSTRACT

The present work offers new information about the faunistic diversity of *Cerambycidae* (*Coleoptera*) in the Natural Park of Sierra Calderona, together with data on the family's ecology. A total of 27 species were identified during the sampling period (2008–2011), the adult activity of which spans from early March to late October. Community analyses showed that this community was observed to be unstable, and are composed of only a few abundant species and a large number of rare species.

INTRODUCTION

The *Cerambycidae* is one of the richest families of saproxylic beetles, with around 35,000 catalogued species (GRIMALDI *et al.*, 2005). Some of these species are often significant in supporting the declaration of internationally important forests (SPEIGHT, 1989). Saproxylic insects are associated with dead wood tissue, or with the fungi and microorganisms responsible for decomposition (SPEIGHT, 1989; MENDEZ IGLESIAS, 2009). Saproxylic insect assemblages are functionally highly dominant (ELTON, 1966) and speciose (SIITONEN, 1994), they frequently include naturally rare species (STORK & HAMMOND, 1997). The death and decay of woodlands offers a broad range of potential microhabitats for the spatial segregation of different saproxylic insects, according to the tree species, tissue type and position within the tree.

Mediterranean forests are rich in evergreen species, frequently intersected by areas of brushwood, pasture, farming and ranching. In close proximity to these areas, however, it is often possible to identify zones that have regained their highly diverse natural communities after the cessation of human intervention. This favours the proliferation of hotspots in Mediterranean ecosystems (MYERS *et al.,* 2000). Despite the huge resistance posed by Mediterranean biotopes to

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human pressure, isolation and fragmentation are unavoidable (Pungetti, 2003), resulting in the emergence of isolated patches within the landscape.

Moreover, Mediterranean Spanish forests are very rich in *Cerambycidae* fauna and offer an important contribution to knowledge of the group at the European level. However, diversity studies, habitat-comparative analysis and the preferences of *Cerambycidae* in protected natural landscapes, have received less attention, though in recent years some studies have been carried out in the Natural Park of Carrascal de la Font Roja (Alicante, Spain) (Peris-Felipo *et al.,* 2011). In this context, the aim of this study was to analyse the *Cerambycidae* fauna present in the Natural Park of Sierra Calderona (Valencia-Castellón, eastern Spain), which, due to bioclimatic conditions, is extremely diverse. Abundance, phenological, specific richness analyses and communities analyses were also carried out.

MATERIALS AND METHODS

Samples were taken in the Natural Park of Sierra Calderona. This area, located between Valencia and Castellón provinces (UTM 30SYK71), consists of a mountain range, orientated in a NW-SE direction, that separates the basins of the rivers Túria and Palancia and extends through the regions of Alto Palancia, Camp de Morvedre and Camp del Túria. This Natural Park covers 18,019 ha and is one of the most valuable landscapes of Comunidad Valenciana, because its physical-natural characteristics afford it great ecological and landscape interest. The rugged terrain and significant slopes, along with the presence of both carbonate and siliceous materials, promote the development of a diverse vegetation. However, human activity and forest fires have relegated the climax vegetation to the ravines and inaccessible areas. The vegetation of this area is typically Mediterranean, and the predominant species are *Pinus halepensis* Mill and *Quercus suber* L., interspersed with areas of crops and herbaceous plants. This Natural Park is characterized by the typical Mediterranean climate of moderate temperatures, with an average of 17ºC, and strong irregular rainfall with average values ranging from 350 to 600 mm. The normal pattern is drought in summer, torrential rainfall in autumn and occasional snow on the coldest days of winter.

Specimen capture was carried out both by direct collection from plants in the sampling areas, and by indirect collection using Malaise traps (Townes model) distributed across the park. Sampling took place weekly between 2008 and 2011, with a few exceptions due to unforeseeable circumstances, and captured specimens were preserved in ice (for direct collection) or ethanol 70% (for Malaise trap collection) until final preparation. Prepared specimens were identified according to Vives (2000) and Sama (2010) criteria, and were housed in the entomological collection of University of Valencia (UVEG). Taxa were listed in alphabetical order.

The data were organised according to the presence of species, an approach particularly suited to interspecific comparisons (TAVARES *et al.*, 2001). Data on the habitat type of each specimen were also collected. The park supports three different habitats: *Quercus* forest (mainly populated by *Quercus suber* L.), *Pinus* forest (populated by *Pinus halepensis* Miller) and crops (populated by *Prunus amygdalus* L. and *Prunus avium* L., among others, and surrounded by *Quercus* and *Pinus* forest). The data were used in species richness analyses, diversity indices and correspondence analyses to identify possible relationships between species distributions within each habitat; similarity/dissimilarity analyses to identify the relationship between species; phenological analyses and community analyses. All analyses were carried out using PAST (HAMMER *et al.*, 2001).

In order to complete the diversity analyses and investigate the community structure, *log-series, log-normal* and *broken-stick* models were also applied (Magurran, 1991). The *log-series* model represents an unstable community, composed of a few abundant species and a high number of rare species. The *broken-stick* model refers to maximum occupation of an environment, with equitable sharing of resources between species. Finally, the *log-normal* model reflects an intermediate situation between the other two models (SOARES *et al.*, 2010). Using the data obtained from this park, each of these models was applied to calculate the expected number of species - $\log_2$, grouping species according to abundance (MAGURRAN, 1991; TOKESHI, 1993; KREBS, 1999). To test the significance of the models, expected species values were compared with those from observed species using chi-square analysis (ZAR, 1999).

RESULTS

During our four-year research programme, a total of 370 beetles belonging to the *Cerambycidae* family, representing 27 different species, were captured. The figures shown in Table 1 reflect the species abundance, average abundance and abundance per habitat.

Analysis of captured specimens revealed the prevalence of certain species, such as *Agapanthia cardui* (L. 1767), with 82 specimens collected, amounting to 22.16% of the total, and *Stenurella melanura* (L. 1758), with 78 specimens (21.08%). Other species were much rarer, with only between one to three specimens captured during the four years of sampling. The latter included *Cerambyx cerdo* (Lucas 1842)*, Clytus arietis* (L. 1758), *Iberodorcadion (Baeticodorcadion) suturale* (Chevrolat, 1862), *Phymatodes testaceus* (L. 1758)*, Pogonochorus perroudi* Mulsant 1839 and *Trichoferus griseus* (Fabricius, 1792).

Phenological studies carried out during 2010, were based on the number of specimens in monthly catches and other data collected during their capture (Fig. 1). Figure 1 shows that adult *Cerambycidae* typically appeared in the Natural Park of Sierra Calderona in spring and summer, with no activity during autumn and winter except for *Vesperus xatarti* Dufour 1839, of which two specimens were collected in January 2010.

Tab. 1 - List of species captured and global and habitat abundance.

Species	Abundance	Average abundance	Habitat		
			Quercus forest	Crops	*Pinus* forest
Acanthocinus hispanicus	2	0.54	0	0	2
Agapanthia asphodeli	39	10.54	0	23	16
Agapanthia cardui	82	22.16	3	70	9
Albana m-griseum	6	1.62	0	0	6
Arhopalus ferus	14	3.78	0	0	14
Arhopalus rusticus	2	0.54	0	0	2
Calamobius filum	16	4.32	0	16	0
Cerambyx cerdo	1	0.27	1	0	0
Certallum ebulinum	10	2.70	2	7	1
Chlorophorus sartor	5	1.35	0	4	1
Chlorophorus trifasciatus	18	4.86	3	14	1
Clytus arietis	2	0.54	0	2	0
Ergates faber	2	0.54	0	0	2
Hylotrupes bajulus	9	2.43	0	0	9
Iberodorcadion suturale	1	0.27	0	1	0
Monochamus galloprovincialis	6	1.62	0	0	6
Opsilia caerulescens	12	3.24	1	11	0
Penichroa fasciata	6	1.62	0	0	6
Phymatodes testaceus	1	0.27	0	0	1
Pogonochorus perroudi	2	0.54	0	0	2
Spondylis buprestoides	1	0.27	0	0	1
Stenopterus ater	43	11.62	9	21	13
Stenurella melanura	78	21.08	10	43	25
Stromatium unicolor	2	0.54	0	0	2
Trichoferus fasciculatus	1	0.27	0	0	1
Trichoferus griseus	2	0.54	0	0	2
Vesperus xatarti	7	1.89	0	7	0

Each of the three differentiated habitats (crops, *Pinus* forest and *Quercus* forest) was also considered separately with regards to the abundance and phenology data. Table 1 shows data on the specific abundance for each habitat, which led to a separate diversity analysis (Table 2). *Pinus* forest presented the widest specific diversity, with 21 species, followed by crops (12) and *Quercus* forest (8). According to the Shannon Index, the most diverse habitat was again the *Pinus* forest, with a value of 2.548, followed by crops (2.024) and finally *Quercus* forest (1.616).

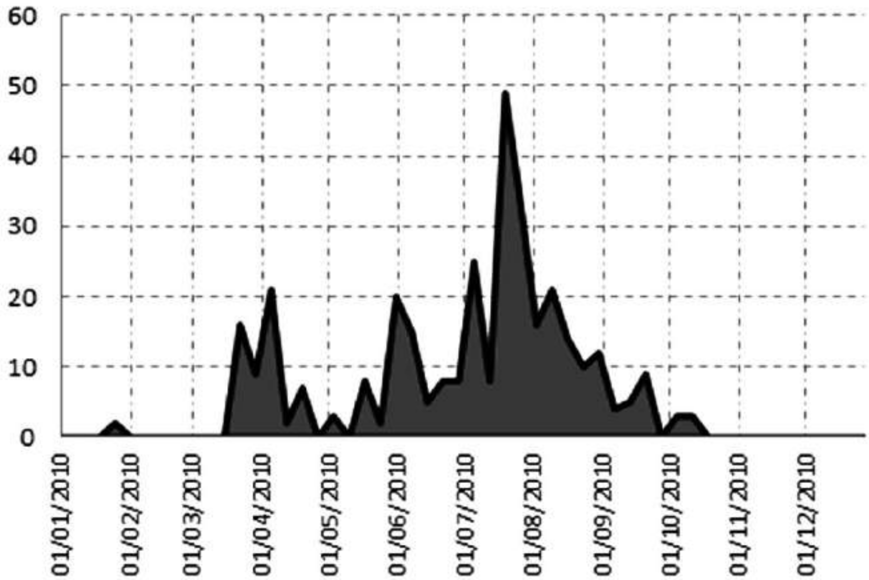

Fig. 1 - Phenology of *Cerambycidae* from Natural Park of Sierra Calderona in 2010.

Subsequent analyses were aimed at ascertaining the specific spatial distribution within habitats. This was done using correspondence analyses (Fig. 2) and led to the conclusion that a connexion existed between the three habitats because there were many species that appeared in two or more habitats. For example, it was possible to see that *Agapanthia asphodeli* (Latreille 1804) appeared in *Pinus* forest and crops; and *Certallum ebulinum* (L. 1767) and *Chlorophorus trifasciatus* (Fabricius 1781) appeared in crops and *Quercus* forest. There were also species such as *Stenopterus ater* (L. 1767) and *Stenurella melanura* (L. 1758) which were linked to all three habitats.

Finally, similarity/dissimilarity analysis aimed at showing distribution patterns did not reveal clustering according to habitat (Fig. 3), while neighbour-joining analysis (Fig. 4) did show such clustering. This kind of analysis allowed observation of the specific habitat distribution of all species.

Tab. 2 - Results of diversity analyses.

	Quercus forest	Crops	*Pinus* forest
Taxa S	7	12	21
Individuals	29	219	122
Dominance D	0.2438	0.1754	0.1039
Shannon H	1.616	2.024	2.548
Simpson 1-D	0.7562	0.8246	0.8961
Evenness e^H/S	0.7192	0.6305	0.6086
Menhinick	1.3	0.8109	1.901
Margalef	1.782	2.041	4.163
Equitability J	0.8306	0.8144	0.8369
Fisher alpha	2.931	2.729	7.309
Berger-Parker	0.3448	0.3196	0.2049

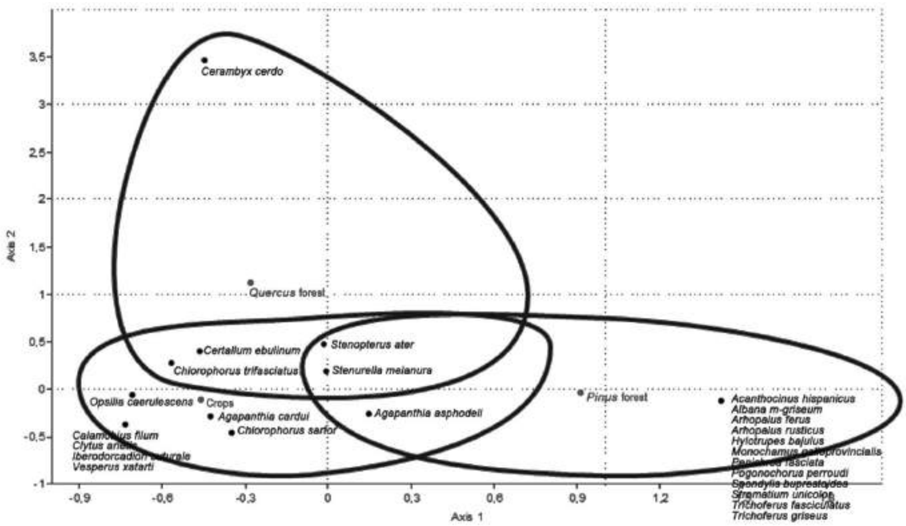

Fig. 2 - Distribution of *Cerambycidae* species per habitat.

Finally, analysis of the community structure of *Cerambycidae* in the Natural Park revealed agreement with *log-series* and *log-normal* models, with p-values greater than 0.05 (Tab. 3).

DISCUSSION AND CONCLUSIONS

Although saproxylic coleoptera have often been catalogued in the Iberian Peninsula, faunistic and ecological studies allowing a better understanding

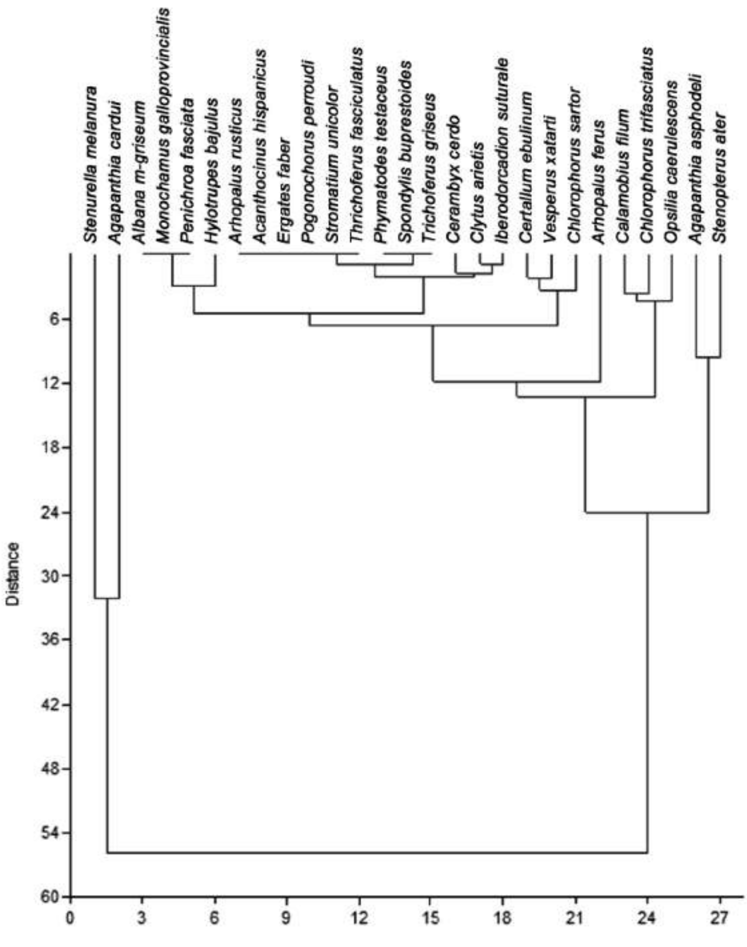

Fig. 3 - Cluster of similarity-dissimilarity of *Cerambycidae* species from Natural Park of Sierra Calderona.

of the biology and distribution of species of the *Cerambycidae* family are a recent development; these include studies in Mediterranean ecosystems, for example, in the Natural Parks of Tinença de Benifassà (PERIS-FELIPO *et al.*, 2008), Lagunas de la Mata-Torrevieja (Peris-Felipo *et al.*, 2009) and Carrascal de la Font Roja (Peris-Felipo *et al.,* 2011).

Sampling was carried out in the forest of Sierra Calderona, typical of the Mediterranean. During the sampling period, 370 specimens were collected, representing 27 different species. Of these, the most common were *Agapanthia*

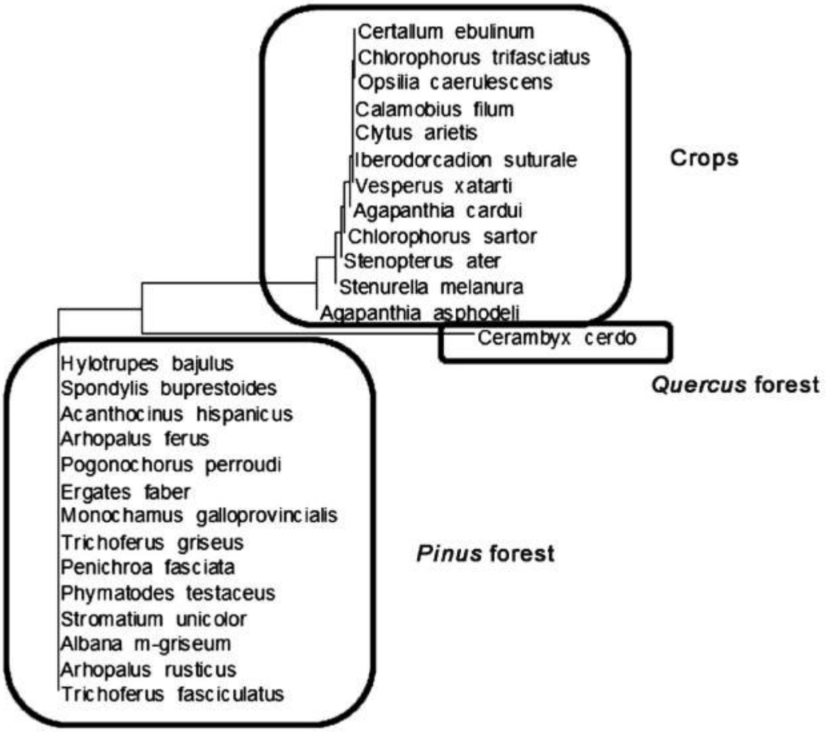

Fig. 4 - Distribution of *Cerambycidae* species with Neighbour-joining analyses.

cardui and *Stenurella melanura* with an abundance of 22.16% and 22.08% respectively. The sampling strategy also permitted the study of the family’s phenology, leading to the conclusion that adult activity in the park is restricted to the spring and summer months, specifically from early March to late October. This is different from other Natural Parks, as in the Natural Park of Tinença de Benifassà and Carrascal de la Font Roja, adults appear from May to late August, and in the Natural Park of Las Lagunas de la Mata-Torrevieja, adult activity spans from February to June, due to its higher average temperatures (Peris-Felipo *et al.*, 2011).

Diversity analyses carried out in the Natural Park of Sierra Calderona showed variations according to habitat. The most diverse was *Pinus* forest, with a Shannon Index score of 2.548, followed by crop habitat (2.024). *Quercus* forest (1.616) was the least diverse of all habitats considered. This could be due to the small number of *Cerambycidae* species, which require plant species of the genus *Quercus* to complete their life cycle. On the other hand, the correspondence analyses, aimed at exploring the distribution of *Cerambycidae* species according to vegetal species, showed that habitat specificity was occurring, hence favouring plant specificity. This was also reflected in specific association clusters, showing that species present in the *Pinus* forest, *Quercus* forest and crops habitats formed three separate groups.

Tab. 3 - Observed (Obs f) and expected frequencies of species (Exp f) according to abundance models (log-series, log-normal and broken-stick) for *Cerambycidae* in Natural Park of Sierra Calderona.

Class	Log-series		Log-normal		Broken-stick	
	Exp f	Obs f	Exp f	Obs f	Exp f	Obs f
0	-	-	2.47	-	-	-
1	9.80	12	7.16	12	3.43	12
2	3.67	0	3.35	0	2.99	0
3	3.79	5	3.68	5	4.88	5
4	3.57	5	3.10	5	6.50	5
5	2.98	1	2.19	1	5.77	1
6	2.01	2	1.29	2	2.28	2
7	0.92	2	0.61	2	0.18	2
8	0.20	0	0.24	0	0.00	0
9	0.01	0	0.11	0	0.00	0
	$X^2 = 7.916$		$X^2 = 12{,}729$		$X^2 = 47{,}132$	
	$p = 0.4416$		$p = 0.1215$		$p = 0.0000$	

In contrast, analysis of the structural models of these communities indicated that *Cerambycidae* communities in all of these Parks fit *log-series* and *log-normal* models, meaning that they include a few abundant species and a number of rare species.

To conclude, it is important to remember the prominent role that *Cerambycidae* play in decomposition processes and hence in the nutrient cycle in natural ecosystems, through interaction with other groups of living organisms such as mites, nematodes, bacteria and fungi, and that they are essential for the well being of ecosystems and their economic status (Nieto & Keith, 2010). In addition, some species of saprolyxic *Coleoptera* are highly significant in the declaration of wooded areas as internationally important forests (Speight, 1989). In this context, the position of *Cerambyx cerdo* must be emphasised, because its status as a protected species (Council Directive, 1992) may help in the declaration of the Natural Park of Sierra Calderona as an internationally important forest.

Finally, these kind of studies on biological diversity and community structure are vital for the development of a better understanding of ecosystems, and for the correct adoption of measures for the conservation and maintenance of biodiversity (Pearson & Cassola, 1992; Kremen *et al.*, 1993).

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SUMMARY

The present work offers new information about the faunistic diversity of *Cerambycidae* (*Coleoptera*) in the Natural Park of Sierra Calderona, together with data on the family's ecology. A total of 27 species were identified during the sampling period (2008-2011), the adult activity of which spans from early March to late October. *Agapanthia cardui* (L. 1767) and *Stenurella melanura* (L. 1758) were the most abundant species. The results of ecological studies carried out in three different habitats (*Quercus* forest, *Pinus* forest and crops), identified *Pinus* forest as the most diverse habitat (Shannon Index = 2.548), and *Quercus* forest as the least diverse (Shannon Index = 1.616). Correspondence and neighbour joining analyses showed that certain *Cerambycidae* species are associated with particular habitats, although some species may be present in more than one habitat, due to their lower plant specificity. Finally, community analyses showed that this community was observed to be unstable, and are composed of only a few abundant species and a large number of rare species.

RIASSUNTO

Il presente lavoro fornisce nuove informazioni sulla diversità faunistica e sull'ecologia dei *Cerambycidae* (*Coleoptera*) del Parco Naturale della Sierra Calderona (Spagna). Sono state identificate, durante il periodo 2008-2011, un totale di 27 specie ed accertato che l'attività degli adulti va dall'inizio di marzo a fine ottobre. *Agapanthia cardui* (L. 1767) e *Stenurella melanura* (L. 1758) sono risultate le specie più abbondanti. I risultati degli studi ecologici effettuati in tre diversi habitat (bosco di *Quercus*, foreste e pinete coltivate di *Pinus*) hanno indicato la foresta di *Pinus* come l'habitat più diversificato (Indice di Shannon = 2,548) e quella di *Quercus* come quello meno diversificato (Indice di Shannon = 1,616). I risultati delle analisi di corrispondenza e di prossimità hanno evidenziato che alcuni cerambicidi sono associati a habitat particolari, sebbene alcune specie possano essere presenti in più di un habitat, a causa della loro scarsa specificità. Infine, le analisi della comunità hanno dimostrato che quella presa in considerazione è instabile e composta da poche specie abbondanti e da un gran numero di specie rare.

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