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THE FAMILIES OF *HYMENOPTERA* (*INSECTA*) IN AN HETEROGENOUS ACIDOFILOUS FOREST IN ARTIKUTZA (NAVARRA, SPAIN)

LE FAMIGLIE DI *HYMENOPTERA* (*INSECTA*) IN UNA FORESTA ETEROGENEA ACIDOFILA IN ARTIKUTZA (NAVARRA, SPAGNA)

ABSTRACT

Hymenoptera were used as an indicator group to assess the diversity of the semi-natural acid forests in Artikutza (Navarra, Spain). In this paper we describe the data relative to taxonomic composition, relative abundance and spatial and temporal activity for *Hymenoptera* families recorded from six Malaise traps in two adjacent vegetation succesional series (beechwood and mixed forest) over a two year period.

INTRODUCTION

The European strategy for biodiversity conservation is designed to encourage the restoration and conservation of natural forests for sustainable resource management (DELBAERE, 1998). Forest fragmentation has been shown to be an important factor in species diversity and community structure conservation (SAUNDERS *et al.*, 1991; DIDHAM, 1997). In Guipúzcoa (Basque Country, Spain) impact of intensive *Pinus radiata* plantations on native deciduous forests is one the main causes of habitat loss and fragmentation that has shown to reduce species diversity (SCA, 1980).

Concern over this situation and the lack of information on the regional forest biodiversity, particularly with respect to invertebrates, prompted the investigation of a biological cenosis of high taxonomic and ecological diversity in a regenerating semi-natural system in the forest reserve of Artikutza (Goizueta, Navarra). Richness of higher taxa, as families, is considered as a potential tool for species richness estimates (GASTON & WILLIAMS, 1993; BALMFORD *et al.*, 1996).

The insect fauna of terrestrial ecosystems represent an essential component of biodiversity (OLEMBO, 1991; KIM, 1993) and a valuable tool for defining the conservation status of environments (ROSENBERG *et al.*, 1986; COLLINS & THOMAS, 1989; HOLLOWAY & STORK, 1991; KREMEN *et al.*, 1993; SAMWAYS, 1994; FINNAMORE, 1996). The *Hymenoptera* represents 20-25% of Europe's faunistic richness (NIEVES-ALDREY & FONTAL-CAZALLA, 1999; ULRICH, 1999a) and account, in European temperate forests, more than 700 species in at least ten ecological guilds (HILPERT, 1989; ULRICH, 1998).

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Among the plant-feeding species some have a recognized economic impact as forest pests or agricultural pollinators (GAULD *et al.*, 1990). Taxonomic richness and biological diversity of predators and parasitoids play an important role in maintaining the diversity of other organisms (DAY, 1991; LASALLE & GAULD, 1993) and their capacity for population regulation is recognized in biological control programs (KIDD & JERVIS, 1997). They are regarded as good indicators of biodiversity due to the fact that they are particularly sensitive to environmental perturbations (LASALLE & GAULD, 1992; 1993).

The Malaise trap (MALAISE, 1937; TOWNES, 1972) is the most common method used in *Hymenoptera* biodiversity studies at family level in both the tropics (NOYES, 1989; TAN, 1990; NIEVES-ALDREY & FONTAL-CAZALLA, 1997) and temperate regions (MATHEWS & MATHEWS, 1970; TERESHKIN & SHLYAKHTYONOK, 1989; NIEVES- ALDREY & REY DEL CASTILLO, 1991; FINNAMORE, 1994; SEGADE *et al.*, 1997). As a standarized method, they have been used to monitor the effects of fire (LOCKWOOD *et al.*, 1996) and silvicultural methods (LEWIS & WHITFIELD, 1999). Quantitative variability among traps location is useful in identifying activity patterns that can contribute to assessment of species conservation requirements (STEYSKAL, 1981; MUIRHEAD & THOMSON, 1991; PAPP, 1994; PAPP & JÓZAN, 1995; SHLYAKHTENOK, 1995).

The importance of the *Hymenoptera* in the diversity of the natural temperate forests, along with the significance of faunistic collections as a basic scientific resource in biodiversity assessment (WIGGINS *et al.*, 1991), emphasize the need for this group to be considered in the conservation of forests in the basque region. We present in this paper the data on families taxonomic composition, relative abundances and spatial and temporal activity distributions in a regenerating acidofilous beechwood heterogenous system.

MATERIALS AND METHODS

Study area

The study was conducted in the forest reserve of Artikutza (Goizueta, Navarra) (43°09'28"-43°14'52" North and 01°45'35"-01°49'30" West) located in the Cántabro-Euskaldun phytogeografic sector of the Eurosiberian region (Fig. 1) and described as a "humid temperate area, always humid with seasonal termic regime and scarce frost" which is characterized by the predominance of nutrient poor, acidic soils with a humus moder of granitic origin, that tends to support a vegetation dominated by *Quercus robur* L. (*Tamo Quercetum-robori*) and *Fagus sylvatica* L. (*Saxifrago hirsutae-Fagetum*) (CATALÁN *et al.*, 1989). Following extensive deforestation up to 1925, plantations were established comprising a variety of deciduous species (*F. sylvatica* L., *Quercus* spp., *Castanea sativa* Mill.) and conifers (*Pinus sylvestris* L., *Larix x eurolepis* A. Henry, *Chamaecyparis lawsoniana* ((A. Murray) Parl.). The present-day landscape now supports a heterogenous mosaic of remanent forest, plantations and derived secondary mixed forests.

The sampling was conducted in 5 Ha located in the northwest of the reserve (30TWN972868 U.T.M.) at an altitude of 575-652 m and includes two adjacent successional series delimited by a stream: mixed forest and beechwood. The mixed forest represents a secondary forest dominated by pine, oak and beech, and the beechwood is partially restocked with young plantings and surrounded by conifer plantations. Other plant species are *C. sativa* Mill., *Taxus baccata* L., *Salix atrocinerea* Brot., *Fraxinus excelsior* L., *Ilex aquifolium* L., *Crataegus monogyna* Jacq., *Corylus avellana*

L., *Blechnum spicant* (L.) Roth., *Deschampsia flexuosa* (L.) Trin., *Vaccinium myrtillus* L., *Euphorbia amygdaloides* L., *Daphne laureola* L., *Oxalis acetosella* L., *Pteridium aquilinum* (L.) Kuhn., *Erica vagans* L. or *Asphodelus albus* Miller (CATALÁN *et al.*, 1989).

Scarce coverage of the herb and shrub layers leave large understory areas covered only by a litter layer of variable depth depending on the slope. Under high humidity conditions, the mossy layer is well developed on soil, stumps and the north side of tree trunks. Site characteristics as pine advanced age, clearings and restockings, are responsible in a great extent for the important amount of dead wood, that accumulates particularly in the stream banks.

Fig. 1 - Geographical situation of the forest reserve of Artikutza (Navarra, Spain).

Temperature and rainfall data recorded at the meteorological station in the village of Artikutza during the study period (Fig. 2) shows an abundant annual rainfall, 1778 mm and 2190 mm respectively in each consecutive years. February (372 mm) and November (636 mm) are the wetest months while June (29 mm) and October (23 mm) and March (55 mm) are the dryest. Temperatures are moderate with a minimum mean of 5 °C in February and a maximum of 20 °C in July. The second season of this study was cooler and wetter than the first particularly in the summer and autumn months.

Sampling design

TOWNES (1972) modified Malaise traps supplied by Marris House Nets (United Kingdom) were used in this study. They are bidirectional (203 cm front height, 112

cm back height, and 122 cm wide by 183 cm long) black with the roof white and fine mesh (0.3 mm). Trap collection jars were filled with 70% ethanol along with three drops of glycerine to soften specimens.
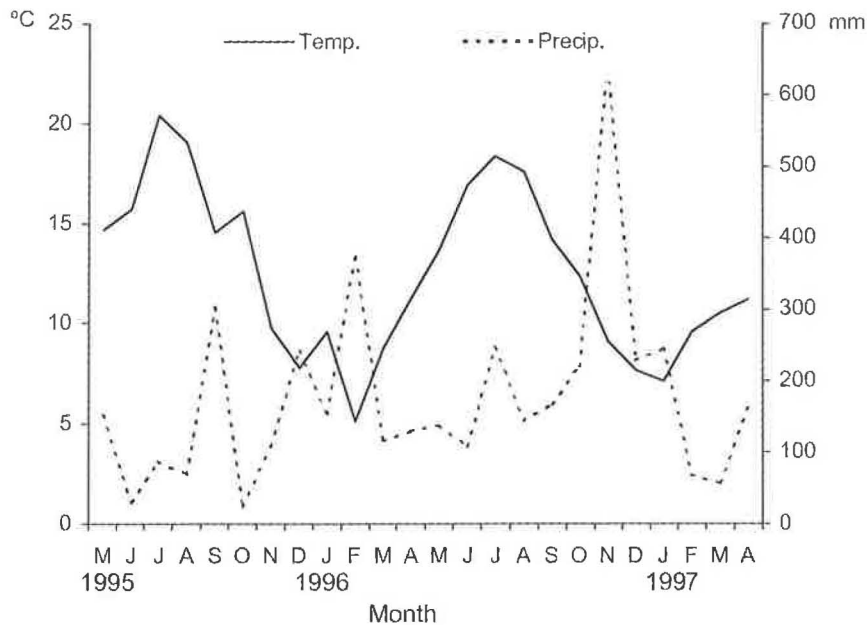

Fig. 2 - Climatic diagram following monthly mean values of temperature and monthly total values of rainfall from May (M) 1995 until April (A) 1997 in the forest reserve of Artikutza (Navarra, Spain).

A total of six malaise traps were placed, three in each vegetation series (Tab. 1). Traps were settled along the direction of the slope, NE-SO in the mixed forest and NO-SE in the beechwood, but all have similar orientation of the colector pole (SO) and captures (N-S). First trap in each vegetation series was placed at 50 m from the access and followed in the direction of the slope by a second one and from this one a third one at about 100 m of distance in between traps. Traps were coded following the name series, the letter M for mixed forest and H for beechwood, and number of trap in the series resulting that M-1, M-2 and M-3 are those located in the mixed forest and H-1, H-2 and H-3 those located in the beechwood.

Heterogenous tree coverage and differences in the slope in each of the series resulted in particular trap locations. In the mixed forest, the M-1 trap was located at the edge of a clearcut, the M-2 trap was in open forest and the M-3 trap was under a big beech in an area of major presence of pines. In the beechwood, the H-1 trap was under a big beech in a steep slope which affected in a lesser extent to the H-2 trap, settled near a clearcut and surrounded by a shrub beech stratum, and the H-3 trap standed under the shade of a big beech on a landing.

Data collection

Sampling was conducted continuously from May 1995 to April 1997, and produced a total of 46 samples per trap in 733 days. Samples were collected at fourteen day intervals, with the exception of seven samples made at 28 day intervals due to technical difficulties, with a total of 270 samples. Mesh goring by cows and damage to collection jars resulted in sample losses in two samples from M-3 (from 23-VI-96 up to 14-VII-96), one in M-1 (I-97), one in H-1 (III-96) and one in H-2 (XI-95). The original traps, except M-3, that was replaced by a new one, responded to time operatively well. *Hymenoptera* were identified to family level using descriptions and keys (GOULET & HUBER, 1993) and followed the classification in HANSON & GAULD (1995).

Tab. 1 - Trap location parameters in two successive vegetation series, mixed forest and beechwood in the forest reserve of Artikutza (Navarra, Spain).

Trap	Orientation of hill	Orientation colector pole	Orientation captures	Altitude	Slope	Distance traps
Mixed forest						
M-3	NE-SO	N216E	N-S	652 m	20°	82 m
M-2	NE-SO	N210E	N-S	631 m	15°	121 m
M-1	NE-SO	N230E	N-S	611 m	12°	206 m
Beechwood						
H-3	NO-SE	N242E	N-S	620 m	9°	92 m
H-2	NO-SE	N210E	N-S	595 m	18°	206 m
H-1	NO-SE	N235E	N-S	576 m	19°	75 m

Specimens were labelled and stored as vouchers in the collections of the Sociedad de Ciencias Aranzadi in San Sebastián (Guipúzcoa, Spain), the Cátedra de Entomología de la Facultad de Ciencias Biológicas de la Universidad Complutense de Madrid (Spain) and the Departmento de Biodiversidad del Museo Nacional de Ciencias Naturales (Madrid, Spain).

Analyses

Quantitative data recorded from Malaise traps refers to adult abundance, mobility or level of activity and species selection by phototropic response of species, sex or caste (SOUTHWOOD, 1978). Quantitative comparison among traps measured differences in the quotient between the number of individuals caught by day sampled (NIEVES-ALDREY & REY DEL CASTILLO, 1991). Similarity among traps and vegetation series in each of the three main *Hymenoptera* groups (*Symphyta*, *Aculeata* and *Parasitica*) were determined using the Bray-Curtis (Single link) clustering method according to similarity coefficients of relative abundances for families (LUDWIG & REYNOLDS, 1988) and represented graphically by dendrograms using BiodiversityPro (LAMBSHEAD *et al.*, 1997). Quantitative differences between the various families and their variability among traps are represented and compared using bar graphs. The relationship of *Hymenoptera* abundances with rainfall and temperature is described by the Spearman rank correlation (SOKAL & ROHLF, 1969).

Tab. 2 - *Hymenoptera* family composition and abundance recorded by each of the six Malaise traps (M-1, M-2, M-3, H-1, H-2 and H-3) in each of the two cycles studied (1995-96 and 1996-97).

Superfamily	Family	1995-96						1996-97						Total	Dates
		M-1	M-2	M-3	H-1	H-2	H-3	M-1	M-2	M-3	H-1	H-2	H-3		
Tenthredinoidea	*Tenthredinidae*	154	37	15	8	20	17	98	24	6	8	16	10	413	II-X
Xyeloidea	*Xyelidae*	0	1	1	0	0	0	2	8	12	0	0	1	25	IV-V
Megalodontoidea	*Pamphilidae*	0	0	0	0	0	0	1	0	0	0	0	0	1	V
Cephoidea	*Cephidae*	0	0	0	0	1	0	0	0	0	0	0	0	1	V
Apoidea	*Sphecidae*	5	10	6	8	5	6	16	15	12	16	18	9	126	V-XI
	Apidae	14	12	5	10	8	7	10	2	3	8	6	6	91	II-XI
Vespoidea	*Vespidae*	20	61	43	76	41	25	1	3	1	3	1	1	276	II-XII
	Formicidae	13	28	20	15	7	8	4	43	72	10	6	4	230	I-XII
	Pompilidae	3	2	1	24	7	1	3	6	3	22	15	1	88	V-XI
Chrysidoidea	*Dryinidae*	4	63	30	26	42	38	13	37	16	41	54	67	431	III-X
	Bethylidae	0	7	0	1	3	0	2	7	4	1	2	1	28	III-VIII
Ceraphronoidea		285	694	533	99	377	175	728	970	1.011	142	258	123	5.395	I-XII
Cynipoidea		198	203	127	52	122	117	235	182	219	42	92	51	1.640	I-.XII
Ichneumonoidea	*Ichneumonidae*	2.741	2.283	1.861	1.610	2.195	1.896	3.313	2.819	1.860	1.750	1.832	1.749	25.909	I-XII
	Braconidae	724	742	443	313	534	440	474	536	391	205	215	184	5.201	I-XII
Proctotrupoidea	*Diapriidae*	1.326	1.759	1.075	1.107	1.275	1.351	1.716	2.029	3.710	1.018	1.046	582	17.994	I-XII
	Platygastridae	425	260	138	162	425	470	672	275	280	197	323	356	3.983	I-XII
	Proctotrupidae	422	264	251	51	113	232	129	107	220	50	59	45	1.943	I-XII
	Scelionidae	34	41	34	38	12	21	208	224	223	92	262	115	1.304	I-XII
	Heloridae	6	21	4	8	6	8	0	0	0	0	0	0	53	III-X
Chalcidoidea	*Mymaridae*	239	248	141	173	360	208	592	395	456	276	402	386	3.876	I-XII
	Pteromalidae	114	360	249	288	421	183	164	427	294	268	344	192	3.304	I-XII
	Encyrtidae	192	417	313	132	419	500	260	222	248	71	193	179	3.146	I-XII
	Eulophidae	158	209	158	77	294	155	172	246	202	249	236	152	2.308	I-XII
	Trichogrammatidae	1	3	1	1	4	2	92	67	76	6	32	7	292	III-XII
	Torymidae	2	22	10	3	2	5	9	6	14	2	11	10	96	III-XII
	Eurytomidae	1	0	2	0	5	2	7	1	1	1	6	2	28	IV-X
	Eupelmidae	1	2	0	3	6	0	1	2	1	1	5	0	22	IV-XI
	Aphelinidae	1	3	0	5	0	1	3	1	3	1	1	1	20	IV-XI
	Ormyridae	1	1	0	0	0	0	0	0	0	0	0	0	2	X
	Perilampidae	0	0	0	1	0	0	1	0	0	0	0	0	2	III-IV
	Signiphoridae	0	0	0	0	0	0	1	0	0	0	0	0	1	V
	TOTAL	7.084	7.753	5.461	4.291	6.704	5.868	8.927	8.654	9.338	4.480	5.435	4.234	78.229	
	EFFICIENCY	19,5	21,4	15,0	12,8	19,2	16,2	26,0	23,3	27,7	12,0	14,6	11,4		
	N° DAYS	362	362	362	335	349	362	343	371	336	371	371	371		

RESULTS

Taxonomic composition and relative abundances

We collected 78,229 specimens representing 12 superfamilies and 35 families (Tab. 2) of which the *Symphyta* (*Tenthredinoidea*, *Xyeloidea*, *Megalodontoidea* and *Cephoidea*) accounted for a 0.56% of the total abundance. The remaining specimens comprised *Apocrita* with 1.62% in the *Aculeata* (*Apoidea*, *Vespoidea* and *Chrysidoidea*) and 97.81% in the *Parasitica* (*Ceraphronoidea*, *Cynipoidea*, *Ichneumonoidea*, *Proctotrupoidea*, *Chalcidoidea*).

Relative abundances among taxa indicate dominance of *Ichneumonoidea* and *Proctotrupoidea* followed by *Chalcidoidea*, *Ceraphronoidea* and *Cynipoidea*. The *Ichneumonoidea* includes two abundant families, *Ichneumonidae* and *Braconidae* with 33% and 6% respectively. The prominence of *Proctotrupoidea* is due to the *Diapriidae* with 23% of total abundance and 71% of taxa. Within the *Parasitica* 12 families belong to *Chalcidoidea* and, of these, four (*Mymaridae*, *Pteromalidae*, *Encyrtidae* and *Eulophidae*) account for 96% of the taxa and comprise 4-5% of total abundance.

The aculeates include seven families with the *Dryinidae* being most abundant (34%) due to the absence of *Vespidae* in the second year (Tab. 2). *Formicidae* and *Sphecidae* are the next most abundant familes in both years and account respectively for 18% and 10% of total aculeate abundance. In symphytans, *Tenthredinidae* represents 93.86% of the abundance followed by *Xyelidae* with 5.68%.

In order to interpret these results we compared our data with studies in different European forests (Fig. 3) involving two different methodologies: fototropic emergence traps (TE) in Germany (HILPERT 1989; ULRICH 1998) and Malaise traps (TM) in the Iberian Peninsula (NIEVES-ALDREY & REY DEL CASTILLO 1991; SEGADE *et al.*, 1997). Both methods sampled the fauna close to the ground, but they were used to provide different measurements. The emergence traps were used to measure density and biomass while Malaise traps measured activity frequency.

Taxonomic composition and relative abundances showed greater similarity with a mesotrofic mixed forest (TE(M)), particularly in relation to the importance of *Ceraphronoidea* and *Diapriidae* in both studies comparing each to other results obtained with its same methodology. In respect to Malaise traps studies conducted at ecotones (TM (EC) and TM(EV)), we found in our forest a poor representation of *Braconidae* (6% versus 14%) and a greater proportion of *Ceraphronoidea* (6% versus 3%) and *Diapriidae* (23% versus 6%). Results obtained in the mesotrofic mixed forest compared to the ones obtained in a eutrofic beechwood (TE(H)) with emergence traps showed significant differences in relation to the dominance in the former of *Ceraphronoidea* (19% versus 1%) and *Diapriidae* (16% versus 1%) over *Platygastridae* and *Chalcidoidea*.

In terms of trap efficiency, our results are poor with a maximum of 72 individuals per day during the second half of July in Artikutza contrast with the mean of 351 or a maximum of 312 in August in NIEVES-ALDREY & REY DEL CASTILLO (1991) and SEGADE *et al.* (1997) respectively.

Comparison among vegetation series and trap location

The mixed forest, with sixty percent of total abundance, recorded an average of 6,766 and 8,973 individuals per trap, and in contrast to only 5,621 and 4,716 in the beechwood in each year respectively. Trap efficiency in each of the series and cycles

(Tab. 2) showed differences between vegetation series for the whole period treated, with 21-22 individuals in the mixed forest traps per day, in contrast to 12-16 individuals counted in the beechwood traps. These differences are not consistent for both years, traps M-1 and M-3 were similar respectively to H-2 and H-3 in the first year. Trap H-1 showed a poor efficiency for both years with only 12 individuals per trap. Multivariate analysis among traps (Fig. 4) show that significant differences are being found between trap M-1 and the rest of the traps for *Symphyta* and *Aculeata*, with a total similarity between clusters in the former of 38.77% and 58.36% in the latter, and between vegetation serie traps in *Parasitica*. Similar results are obtained in each of the cycles except for *Parasitica* that show this pattern only in the second one.
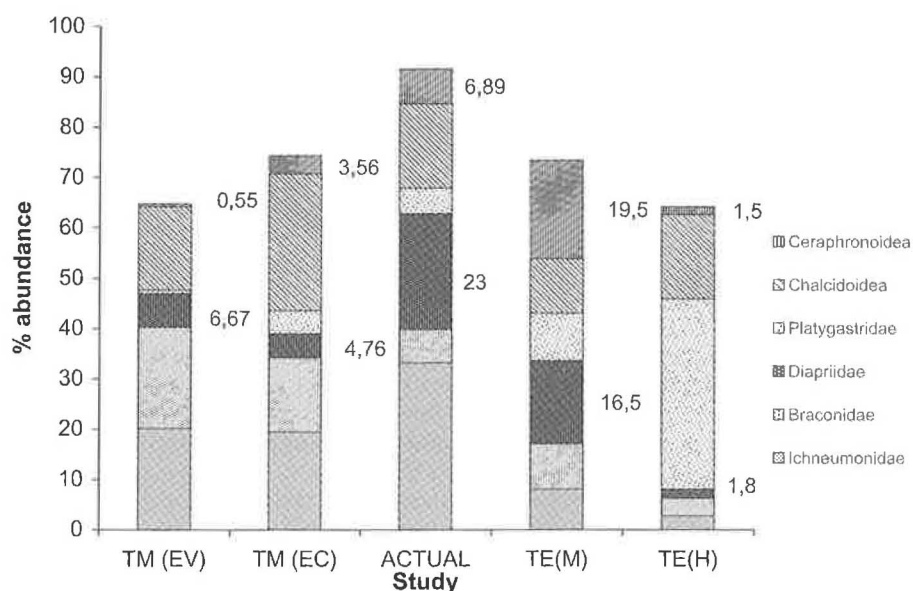
Fig. 3 - Comparison of taxa relative abundances, in percentages (%), obtained in different european studies. Values in the graphic correspond to *Diapriidae* and *Ceraphronoidea*. TM = Malaise trap; TE = Emergence trap; (EC) = Ecotone Santa Coloma (Andorra) (SEGADE *et al.*, 1997); (EV) = Ecotone El Ventorrillo (Madrid, Spain) (NIEVES-ALDREY & REY DEL CASTILLO, 1991); (M) = Mixed mesotrophic forest in Upper Rhine-Valley in Germany (HILPERT, 1989); (H) = Beechwood near Göttingen in Germany (ULRICH, 1987).

Raw abundance patterns of the most important families in each of the traps over the two years show different distributions (Fig. 5). Differences among vegetation series or significant greater abundances in all traps of the mixed forest (M-1, M-2 and M-3) are noted only for taxa *Cynipoidea*, *Ceraphronoidea*, *Trichogrammatidae*, *Proctotrupidae* and *Xyelidae*. Most abundant families, and particularly *Ichneumonidae*, *Braconidae*, *Diapriidae*, *Apidae* or *Tenthredinidae*, are represented in bigger numbers by traps M-1 and M-2 but not by trap M-3 in the mixed forest.

Location of trap M-1, at the edge of a clearcut, shows at the same time the poorest efficiency in respect to *Pteromalidae*, *Dryinidae*, *Formicidae*, *Vespidae* or *Xyelidae*

and trap M-3, inside the forest, the aggregation of individuals in *Diapriidae*, *Formicidae* and *Xyelidae*. The lowest abundances for most families are recorded in a steep slope at trap H-1 in the beechwood except for *Pteromalidae*, *Sphecidae*, *Dryinidae* and *Apidae*. Particularly in the case of *Pompilidae* and *Vespidae*, this location represents a site of individuals aggregation. Other families as *Platygastridae*, *Scelionidae*, *Mymaridae*, *Eulophidae*, *Encyrtidae* or *Sphecidae* show similar abundances in all traps irrespective to trap location.
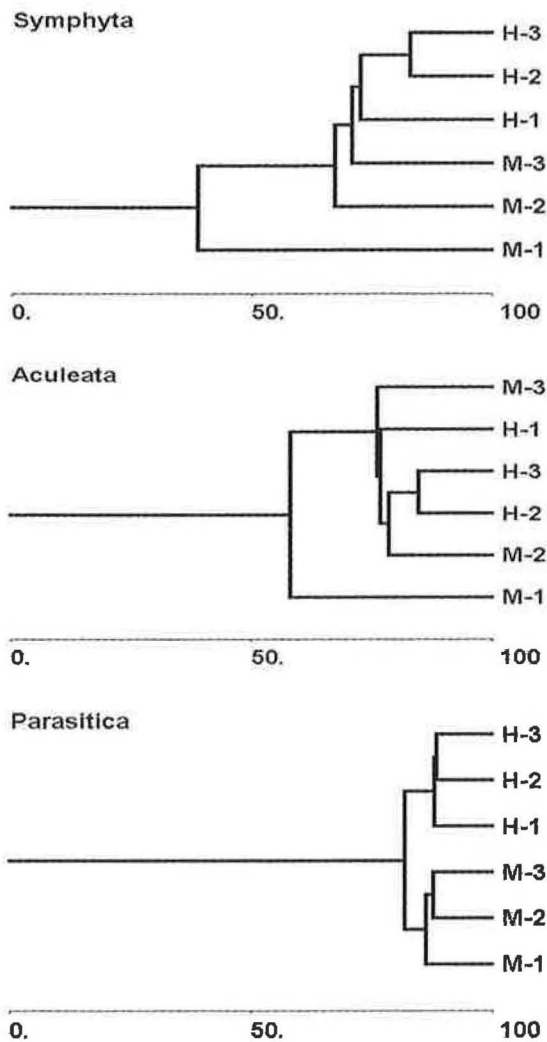
Fig. 4 - Dendrograms following Bray-Curtis similarity analysis for *Symphyta*, *Aculeata* and *Parasitica* for total data.

Variation between annual cycles

The second year recorded fifty two percent of the total specimens being 20 (69%) the number of taxa that showed greater frequencies in that period. The annual quan-
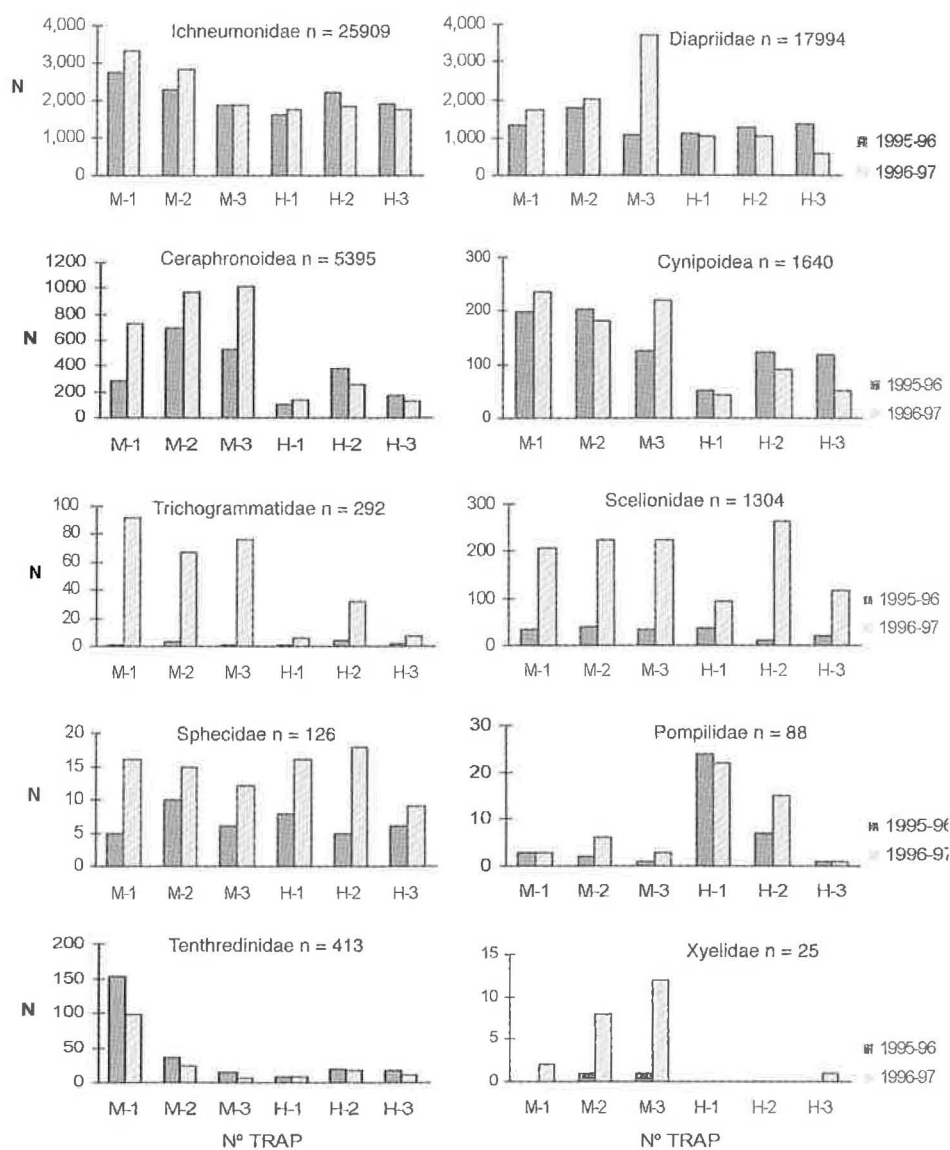
Fig. 5 - Number of individuals per trap of the different families in each of the two cycles studied (May 1995-April 1996 and May 1996-April 1997).

titative variation in different families among traps (Fig. 5) shows a major increase in the second year for *Trichogrammatidae*, *Scelionidae*, *Diapriidae* and *Formicidae* (in M-3) and a moderate increase in *Mymaridae* and *Sphecidae* for all traps. Among the families that show a slight decrease of abundance in the second year are *Braconidae*, *Proctotrupidae*, *Encyrtidae* (except in M-1) and *Apidae*. Families *Heloridae* and *Vespidae* indicate a significant reduction over this same period.

Monthly activity rhythms and seasonal variation

Total abundances indicate greater adult activity from spring to autumn and a lesser peak of activity during the winter months in the *Formicidae*, *Vespidae* and *Parasitica* with the exception of *Eurytomidae*, *Eupelmidae*, *Aphelinidae*, *Ormyridae*, *Perilampidae* and *Signiphoridae* (Tab. 2).

The annual activity of some important families represent the patterns found (Fig. 6). Seven families show an unique annual maximum abundance with *Xyelidae* in April, *Encyrtidae*, *Vespidae* and *Pompilidae* in July, *Proctotrupidae* and *Scelionidae* in August, and *Heloridae* in August/September. Other families show two maximum peaks along the year, in spring and in the summer. Among these, *Apidae* and *Tenthredinidae* do it early in April/May and July; *Ichneumonidae*, *Braconidae*, *Diapriidae*, *Eulophidae* and *Pteromalidae* in May/June and July/August; *Sphecidae* in June and July/August; *Dryinidae* and *Formicidae* in June/July and August/September. A third peak can be observed in some families in the early spring or in autumn, is the case of *Platygastridae* and *Mymaridae* in April and *Ceraphronoidea* and *Mymaridae* in October. There are four family maximum abundances in April, one in May, seven in June with all except one (*Diapriidae*) in the first half, 14 in July with five in the first half and nine in the second half, four in August and four in September and October.

Spearman's correlation coefficients for the number of individuals in each year with respect to temperature and rainfall show a significant association with temperature in both cycles (0.965** and 0.748** respectively; **P 0.01) and with rainfall only in the first year (0.755**) where maximum rainfall in September and February occurs at the same time that there is a temperature decrease (Fig. 2). The influence of rainfall in recording of activity is slight according to the curves in June of the first cycle in which clash a period of less rainfall (Fig. 2) with a generalized decrease of abundances for all families in the first half, excepting *Dryinidae* (Fig. 6).

DISCUSSION

Results of comparison of family composition and structure of *Hymenoptera* among different studies suggest that the cenosis in our habitat show important characteristics of the beechwoods arthropod fauna in moder soils; predominance of fungivorous groups, not too many species and a few extremely abundant (SCHAEFER & SCHAUERMANN, 1990). The number of families recorded was poor in respect to other inventories analyzed but its relative abundances showed great similarity with the ones obtained in a mesotrophic mixed forest in Germany (HILPERT, 1989). Significance of *Diapriidae* in our data indicates suitable damp habitat conditions known for this taxa and abundance of its hosts, fungivorous diptera in *Mycetophilidae* and *Sciaridae*, which are known to be specially abundant in soil acid conditions (SCHAEFER & SCHAUERMANN, 1990). For families analyzed to species, the abundance pattern was due

to one or two dominant species (MARTÍNEZ DE MURGUÍA, 2001). Sample processing observations support that other families show as well the abundance pattern of few species.

Rainfall did not seem to be influencing individual activity recording. Families annual abundance variability could be explained in the case of *Vespidae* and *Xyelidae* that show the behavior of the population dynamics of known species with years of exceptional abundance and rarity (ARCHER, 1985; GAULD & BOLTON, 1988). On the other side, the decrease in *Proctotrupidae* could be related to the simultaneous capture of its prey (*Caraboidea* and *Staphylinoidea*) done in a parallel study during the same periods on the soil. A high degree of variation in the species dominance among years is known for this cenosis (ULRICH, 1999b).
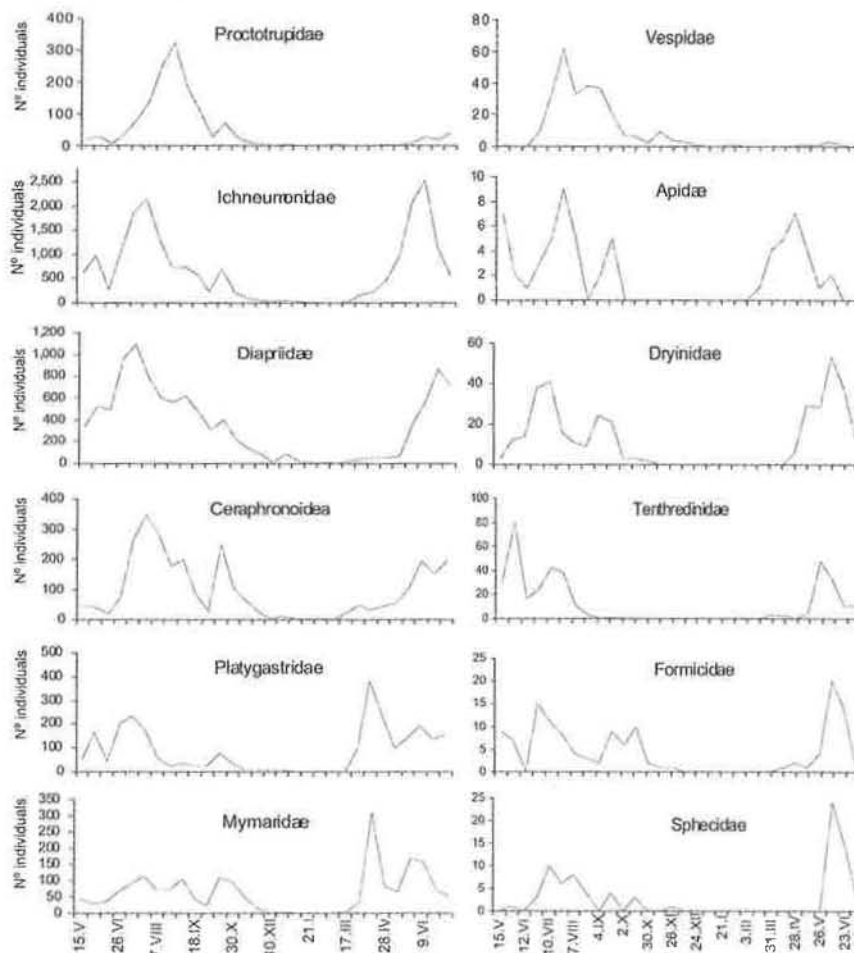

Fig. 6 - Seasonal abundance evolution of the different families at 14 day intervals, from the first of May of 1995 until the 14th of July of 1996.

Changes of behavior of predators and parasitoids indicate spatial activity patches that identify different resource searching strategies (BELL, 1990). In our case, the heterogenous abundance distributions of families among traps seem to be related with the spatial availability of resources. A greater collecting efficiency at open sites (traps M-1 and M-2) and particular variations at the edge of a clearcut in the mixed forest (trap M-1) might be reflecting the influence of the glade in hymenopteran abundances at those sites. Edge effect or greater insect abundances and richness at the forest edges is known to be due to an increase of species influx from nearby modified habitats (DENNIS, 1997). The poor efficiency of trap settled at a steep situation (H-1) might be related with the unstability of the litter layer, that kept accumulating at the base ot the trap. Changes in the litter layer have shown to affect hymenopteran species diversity (ULRICH, 1998).

Other family abundance patterns are in concordance with pine distribution (traps M-1, M-2 and M-3) to which species of *Xyelidae* and *Trichogrammatidae* are associated and species of *Ceraphronoidea* and *Cynipoidea* still remain to be analyzed. On the other hand, aggregations at one particular trap showed, when analyzed to species level (MARTÍNEZ DE MURGUÍA, 2001), the occurrence of an ants' (*Formicidae*) nest and its nuptial flight (trap M-3) or sex concentration in the river bank (trap H-1) of a species in *Pompilidae*. Presence of an aggregation of *Vespidae* at this last same location can be due to an inusual concentration of caterpillars observed at the foot of the tree where these predators congregate (RICHTER, 2000). In relation to *Sphecidae*, the homogenous abundance distribution could be reflecting the wide distribution of dead wood, in which these species nidify. These findings support the general statement that distribution of hymenopterous species and abundances in forests is related to availability o food, nidification or hibernation resources and is dependant of forest spatial structure (SKIBIŃSKA, 1989; BANASZAK & CIERZNIAK, 1994; PAPP, 1994; PAPP & JÓZAN, 1995; SHLYAKHTENOK, 1995; ULRICH, 1998).

Seasonal quantitative progression of the different families is highly correlated with temperature. Climate bondage favours long cycles extending the period of greater activity for seven months, from April to October, and in a lesser extent all along the year with presence of individuals that hibernate as adults corresponding to species mainly with idiobiont strategy that find their host in the soil (ULRICH, 1999c). Among the families with maximum abundance early in the season are those that include species phytophagues, *Xyelidae* and *Apidae* in April and *Tenthredinidae* in May, which flight periods are related with food availability (GAULD & BOLTON, 1988), and also hibernating *Mymaridae* and *Platygastridae* egg parasitoids females (ULRICH, 1999c). The two main emergence periods observed in *Parasitica* by this last author, May/June and August are observed for most of the families although in our site July, particularly the second half, is the summer period of greater activity. Aditional autumn peaks of activity are related, following this last author, with a new generation or with females looking for hibernating sites.

In respect the aculeates, as in *Apidae*, the two maximum activity periods agree with the ones obtained by ARCHER (1988) for solitary bees in May, that here is in April, and for social bees in July. The different flight periods of solitary and social wasps, indicated by this author in June and July respectively, are represented in these same periods in our data for *Sphecidae* and *Vespidae*.

Implications for conservation

Taxonomic richness and relative importance of different family abundances, according to spatial and temporal distributions, indicate that the *Hymenoptera* should

be taken into account in Artikutza and the adyacent natural park management practices to ensure their health and promote diversity conservation. For instance, among the major forest insect pests in Europe eighteen species belong to the *Hymenoptera*, mainly in the symphytans (DAY & LEATHER, 1997). Classical biological introductions of natural enemies that have resulted in successful control of woodland o plantations pests include species of *Formicidae, Braconidae, Encyrtidae, Aphelinidae, Eulophidae, Scelionidae, Mymaridae, Pteromalidae, Ichneumonidae* and *Ibaliidae* (LASALLE & GAULD, 1993; KIDD & JERVIS, 1997). On the other hand many species are threatened by loss of habitat or intensification of agriculture among which the aculeate are of particular significance (GAULD *et al.*, 1990; DAY, 1991; LASALLE & GAULD, 1993).

The main factors that affect conservation of *Hymenoptera* in managed environments are those that are related to practices over the vegetation, and particularly over its flowering where the adults feed, and to loss of suitable nesting sites, as sunny sandy spots, river banks, trails and dead wood, or oviposition, pupation and hibernating sites as the soil and litter layer (GAULD *et al.*, 1990). The steep slopes in our forest, altogether with a shallow soil covered by a thick litter layer, are specially sensitive to soil erosion, that should be minimized in management programs.

Our results indicate that open spaces in the forest encourage the presence of a herbaceous stratum and shrubby edge, to which many hymenopterans are associated and, in this sense, support the common management practice of favouring open spaces to promote insect diversity (DENNIS, 1997). The absence of sandy soils and the scarce distribution of vegetation in the understore highlights the importance of dead wood as nidifying resource for solitary wasps that prey in the canopy on conifer potential pest species (MARTÍNEZ DE MURGUÍA, 2001). In that sense, periodical herb cuttings and the use of machines to break down trunks and branches in *Pinus radiata* plantations is an example of management practices that does affect negatively the hymenopteran diversity and should be as well minimized. Monitoring family structure for comparison among habitats o silvicultural stands or methods can be achieved with a single Malaise trap settled at open forest the second half of July.

Restoration of natural deciduous forests combining with sustainable conifer plantations are the main objectives of the forest management program in the reserve of Artikutza and the adyacent natural park of Peñas de Aia. Hymenopterans taxonomic and ecological diversity should be taken into account for evaluating the conservation of biodiversity in managed forests. Spatial and temporal heterogenicity provided by clearings, bank rivers, trails and dead wood favours the availability of different resources that meet the species ecological requirements. Our data represent a local reference for potential studies on influence of management practices in family structure or in species of particular interest. Encouragement of a management strategy that favours the diversity of *Hymenoptera* will be contributing in a sound way to promote invertebrate biodiversity in these forests, one of the principles of sustainable management.

RIASSUNTO

Gli *Hymenoptera* vengono usati come un gruppo indicatore per valutare la biodiversità di una foresta acida semi-naturale in Artikutza (Navarra, Spain). In questo articolo si presentano i dati relativi alla composizione tassonomica, abbondanza relativa e attività spaziale e temporale delle famiglie di *Hymenoptera* raccolti in sei trappole "Malaise" in due serie adiacenti di successione vegetazionale (faggeta e foresta mista) per un periodo di due anni. Sono stati raccolti un totale di 78.229 esemplari appartenenti a 12 superfamiglie e 35 famiglie. *Ichneumonidae* e *Diapriidae* sono stati i taxa più abbondanti seguiti da *Braconidae* e *Platygastridae*, *Mymaridae* e *Pteromalidae*. Differenze tra le serie vegetazionali si sono riscontrate soltanto nel secondo anno, nel gruppo dei *Parasitica* con una maggiore abbondanza di *Ceraphronoidea*, *Cynipoidea* e *Trichogrammatidae* nella foresta mista. Simili differenze in *Xyelidae* sono attribuibili alla presenza delle specie ospiti. La localizzazione delle trappole al limite di una radura nella foresta mista è favorevole ai *Tenthredinidae* e sfavorevole a *Dryinidae* e *Vespidae*. Altre aggregazioni si hanno, a seconda della particolare localizzazione delle trappole, con una maggiore attività dei *Vespidae* dovuta alla concentrazione di prede o alla presenza di un volo nuziale di *Formicidae*. Le variazioni stagionali delle famiglie sono in accordo con quanto trovato in altri studi europei. Gli *Hymenoptera* adulti sono stati presenti per tutto l'anno e sono stati più abbondanti da Aprile a Ottobre, con il più grande numero di taxa nella seconda metà di Luglio.

SUMMARY

Hymenoptera were used as an indicator group to assess the diversity of the semi-natural acid forests in Artikutza (Navarra, Spain) contributing in that way to the conservation of the natural forests in the region. In this paper we describe the data relative to taxonomic composition, relative abundance and spatial and temporal activity for *Hymenoptera* families recorded from six Malaise traps in two adjacent vegetation succesional series (beechwood and mixed forest) over a two year period. We collected a total of 78,229 specimens representing 12 superfamilies and 35 families. *Ichneumonidae* and *Diapriidae* were the most abundant taxa followed by *Braconidae* and *Platygastridae*, *Mymaridae* and *Pteromalidae*. Differences between vegetation series were obtained in the *Parasitica* only in the second year with greater abundance of *Ceraphronoidea*, *Cynipoidea* and *Trichogrammatidae* in the mixed forest. Similar differences in *Xyelidae* were explained by the presence of host species. Trap location at the edge of a clearcut in the mixed forest favoured *Tenthredinidae* and underestimated *Dryinidae* and *Vespidae*. Other aggregations showed, in different locations, higher activity due to concentration of prey in *Vespidae* or to the ocurrence of a nuptial flight in *Formicidae*. Families seasonal variations conformed to patterns found in other European studies. Adult *Hymenoptera* were present throughout the year and most abundant from April until October with the greatest number of taxa in the second half of July.

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