Munibe (Ciencias Naturales-Natur Zientziak) • No. 53 (2002) • 183-204 • ISSN 0214-7688

Distributions of sawflies and aculeates in a heterogenous secondary acid forest in Artikutza (Navarre) (Insecta: Hymenoptera).

Leticia Martínez de Murguia[1], *Mª Angeles Vázquez*[2] & *José Luis Nieves-Aldrey*[3]

ABSTRACT

The distribution of a sawfly and aculeate species assemblage was investigated by means of six Malaise traps in two adjacent succesional vegetation series, mixed pine forest and beechwood, at the forest reserve of Artikutza (Navarre). Comparisons between vegetation series and trap locations in sawflies, wasps, bees and ants suggested that species distributions could be related to spatial distribution of different feeding, mating nesting and hibernating resources. Glades, river banks and dead wood have shown to provide a variety of diversity sources.

• KEY WORDS: Distribution, Sawflies, Aculeates, Hymenoptera, Mixed pine forest, Beechwood, Navarre.

LABURPENA

Malaise erako sei tranparen bitartez ikertu da sinfito eta akuleatuen espezieen banaketa; elkarren jarraian eta alboan dauden bi landaredi-serietan jarri dira tranpak (pinuen baso mistoa eta pagadia), Nafarroako Artikutzako baso erreserban. Sinfito, erle eta txindurrien kasuan landaredi-seriak eta tranpen kokapena elkarrekin alderatzean, pentsatu da espezieen banaketa lotuta egon daitekeela elikadura-baliabideen banaketa espazialarekin, ugalketarekin, habiagintzarekin edo hibernazioarekin. Argiguneak, ibai-ibilgua eta zur hila direla medio, dibertsitate iturrien aniztasuna ziurtatzen da.

• GAKO-HITZAK: Banaketa, sinfito, akuleatu, Hymenoptera, pinuen baso misto, pagadi, Nafarroa.

RESUMEN

La distribución de las especies de sínfitos y aculeados ha sido investigada por medio de seis trampas Malaise instaladas en dos series de vegetación adyacentes y sucesivas, bosque

[1] *Sociedad de Ciencias Aranzadi. Departamento de Entomología. Zorroagagaina, 11 • 20014 Donostia-San Sebastián.*

[2] *Universidad Complutense de Madrid. Departamento de Biología Animal I, Facultad de Ciencias Biológicas. Ciudad Universitaria • 28040 Madrid.*

[3] *Museo Nacional de Ciencias Naturales (CSIC), Dpto. de Biodiversidad y Biología Evolutiva (Entomología). C/ José Gutiérrez Abascal, 2 • 28006 Madrid.*

mixto de pinos y hayedo, en la reserva forestal de Artikutza (Navarra). La comparación entre series de vegetación y localización de las trampas en sínfitos, avispas, abejas y hormigas sugiere que la distribución de las especies puede estar relacionada con la distribución espacial de los distintos recursos de alimentación, reproducción, nidificación o hibernación. Los claros, el cauce del río y la madera muerta proveen variedad de fuentes de diversidad.

• Palabras clave: Distribución, sínfitos, aculeados, Hymenoptera, bosque mixto de pinos, hayedo, Navarra.

Introduction

Restoration of natural decidous forests combining with development of recreation values and other sustainable uses are the main concerns in the Aiako Harria natural park (Gipuzkoa) (B.O.P.V. 2002) and the adjacent forest reserve of Artikutza (Navarre). Recording of a sawfly and aculeate species assemblage in this last locality was framed in a wider study in which Hymenoptera were used as an indicator group to assess diversity of semi-natural acid forests in the region (Martínez de Murguía, 2001).

Woodland structure determines spatial resource distribution and affects in a great extent insect resource searching strategies (Dennis, 1997; Roland, *et al.* 1997; Humphrey *et al*, 1999). Changes in behavior can help identifying activity patches that indicate species strategies and conservation requirements (Bell, 1990). Malaise traps (Malaise, 1937; Townes, 1962) have been shown to provide a useful tool to measure insect flying adult activity and variability among trap locations has been used to identify changes in the use of different resources (Steyskal, 1981; Muirhead-Thomson; 1991, Papp & Józan, 1995; Shlyakhtenok, 1995; Precht & Cölln, 1996; Hagvar *et al*, 1998).

The aim of this paper is to analyze the spatial activity patterns of sawflies and aculeate wasps, bees, and ants at the space close to the ground b means of Malaise traps in a heterogenous forest stand, and identify potential species conservation requirements in relation to structural features. For this purpose we study the taxonomic and quantitative distributions of ecological groupings, as well as of the most abundant species, among six traps covering two successional adjacent vegetation series, mixed pine forest and beechwood. This information could be useful when planning management techniques to promote forest biodiversity.

Materials and methods

Study area

The study took place 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-Euskaldún phytogeografic sector of the Eurosiberian region (Fig. 1). It is characterized by nutrient poor, acidic soils with a humus moder of granitic origin, that tends to support a vegetation dominated by *Quercus robur* L. (*Hyperico pulchri-Quercetum roboris*) and *Fagus sylvatica* L. (*Saxifrago hirsutae-Fagetum*) (CATALÁN, 1987). 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.) (CATALÁN, *ET AL*, 1989). The present-day landscape supports a heterogenous mosaic of remanent forest, pine plantations and derived secondary mixed forests.

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

Sampling was conducted in 5 ha located in the northwest of the reserve (30TWN972868 U.T.M.) at an elevation of 575-652 m altitude and includes two adjacent successional series defined by a stream: mixed pine forest and beechwood. The mixed pine forest represents a secondary forest (70 years old) dominated by pine, oak and beech, and the beechwood is partially restocked with young plantings and surrounded by conifer plantations. Other tree species are *C. sativa* Mill., *Taxus baccata* L., *Salix atrocinerea* Brot., *Fraxinus excelsior* L., *Betula celtiberica* Rothm.& Vasc. and *Sorbus aucuparia* (L.) Crantz. The shrub and herbaceous zones are composed of *F. sylvatica* L., *Ilex aquifolium* L., *Blechnum spicant* (L.) Roth., *Deschampsia flexuosa* (L.) Trin., *Vaccinium myrtillus* L., *Euphorbia amygdaloides* L., *Daphne laureola* L., and *Oxalis acetosella* L. Adjacent to clearcut areas the following species are common: *Crataegus monogyna* Jacq., *Corylus avellana* L., *Pyrus cordata* Desv., *Malus sylvestris* Miller, *Pteridium aquilinum* (L.) Kuhn., *Erica vagans* L. and *Asphodelus albus* Miller (CATALÁN, 1987). 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.

SAMPLING DESIGN AND DATA COLLECTION

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) (Fig. 2). Trap collection jars were filled with 70 % ethanol along with three drops of glycerine to soften specimens.

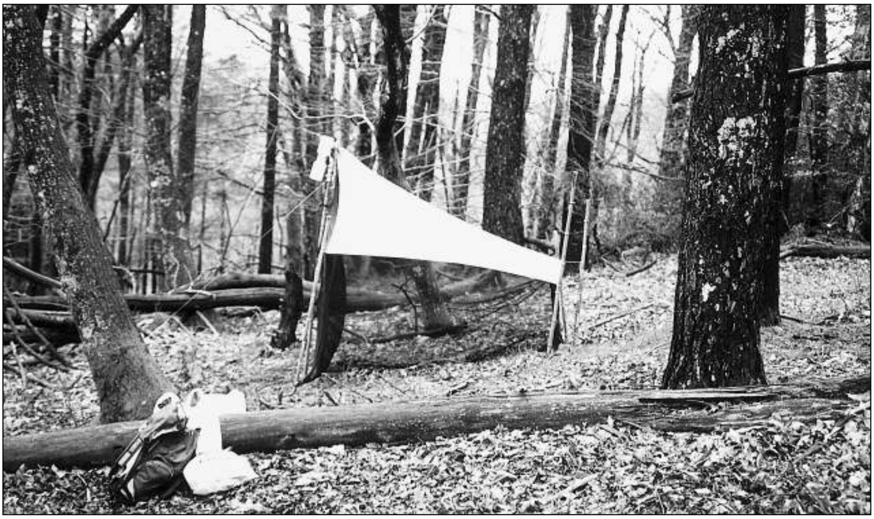


Figure 2.- Malaise trap model used (trap M-2).

A total of six Malaise traps were placed, three in each vegetation series: M-1, M-2 and M-3 in the mixed pine forest and H-1, H-2 and H-3 in the beechwood (Table I). Traps were settled along the direction of the slope, NE-SO in the mixed pine forest and NO-SE in the beechwood but all had similar orientation of the colector pole (SO) and direction of captures (N-S). First trap in each vegetation series was placed at 50 m from the ride 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. Heterogenous tree coverage and differences in the slope in each of the series resulted in particular trap locations. In the mixed pine forest, trap M-1 was located at the edge of a clearcut, trap M-2 in open forest and trap M-3 was under a mature beech in an area of major pine densities. In the beechwood, trap H-1 was

TRAP	ORIENTATION HILL	ORIENTATION COLLECTOR POLE	ORIENTATION CAPTURES	ALTITUDE	SLOPE	TRAP DISTANCES
MIXED PINE FOREST						
M-3	NE-SO	N216E	N-S	652 m	20º	82 m
M-2	NE-SO	N210E	N-S	631 m	15º	121 m
M-1	NE-SO	N230E	N-S	611 m	12º	206 m
BEECHWOOD						
H-3	NO-SE	N242E	N-S	620 m	9º	92 m
H-2	NO-SE	N210E	N-S	595 m	18º	206 m
H-1	NO-SE	N235E	N-S	576 m	19º	75 m

Table I.- Trap locations parameters in two adjacent vegetation series, mixed pine forest and beechwood (Artikutza, Navarre).

under a big beech in a steep slope which affected in a lesser extent to trap H-2, settled near a small clearcut and surrounded by a shrub beech layer, and trap H-3 standed under the shade of a mature beech on a landing.

Sampling was conducted continuously during two seasonal cycles, from May 1995 to April 1997, and produced a total of 46 samples per trap in 733 days. Species identification was made available by several taxonomists: G. Llorente Vigil (Symphyta), M.D. Martínez (Formicidae), S.F. Gayubo (Sphecidae), C. Ornosa (Bombinae), M. Díaz (Eumeninae), J.P. Pedrero (Pompilidae). The material was labelled and stored in the collections of the Aranzadi Society of Sciences in San Sebastián (Gipuzcoa) and Faculty of Biological Sciences of the University Complutense (Madrid).

ANALYSES

Quantitative data recorded from Malaise traps refers to adult abundance, mobility or level of activity and selection by phototropic response of species, sex or caste (SOUTHWOOD 1978). Quantitative comparison among traps was measured using differences in the efficiency or the quotient between the number of individuals caught by day sampled. Similarity among traps and vegetation series in each of the groups (Sawflies, social and solitary bees and wasps, and ants) were determined using the Bray-Curtis (Single link) method that clusters the samples according to similarity of relative abundances for species present (LUDWIG & REYNOLDS, 1988) and was represented graphically by dendrograms using BiodiversityPro (LAMBSHEAD *ET AL*, 1997). Species distributions among trap locations were represented and compared using bar graphs. The influence of trap location was assessed by comparing different community parameters as abundance (N), richness (S), diversity indices as the Shannon-Weaver (H´), Hill (N1) and Simpson (λ), equitability (E5) and Berger-Parker dominance index (D) (LUDWIG & REYNOLDS, 1988).

RESULTS

The hymenopteran assemblage consisted in 1248 individuals representing 105 species in seven superfamilies and ten families according the classification of HANSON & GAULD, (1995) that represent different trophic levels, phytophagues, predators and parasites. It includes the sawflies (Xyeloidea, Xyelidae; Megalodontoidea, Pamphilidae; Cephoidea, Cephidae and Tenhredinoidea, Tenthredinidae), solitary bees and bumblebees (Apoidea, Apidae), solitary wasps (Apoidea, Sphecidae; Vespoidea, Pompilidae, Vespidae; Chrysidoidea, Bethylidae), social wasps (Vespoidea, Vespidae) and ants (Vespoidea, Formicidae).

The number of species and individuals by trap and cycle in each of the studied groups are shown in Table II. The species list and number of individuals by trap and cycle are

Trap	M-1		M-2		M-3		BM		H-1		H-2		H-3		H		Total	
	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S	N	S
1995-1996																		
Sawflies	154	15	38	10	16	7	208	20	8	5	21	8	17	9	46	16	254	29
Xyelidae	0	0	1	1	1	1	2	1	0	0	0	0	0	0	0	0	2	1
Cephidae	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1
Tenhredinidae	154	15	37	9	15	6	206	19	8	5	20	7	17	9	45	15	251	27
Solitary wasps	8	5	21	10	7	4	36	14	35	10	15	6	8	6	58	15	94	21
Sphecidae	5	3	10	7	6	3	21	10	8	6	5	3	6	4	19	10	40	15
Pompilidae	3	2	2	1	1	1	6	2	25	2	7	2	1	1	33	2	39	2
Eumeninae	0	0	2	1	0	0	2	1	1	1	0	0	1	1	2	2	4	3
Betylidae	0	0	7	1	0	0	7	1	1	1	3	1	0	0	4	1	11	1
Solitary bees Apidae	8	6	3	2	1	1	12	7	6	5	5	5	2	2	13	10	25	14
Social wasps Vespidae	20	2	59	2	43	2	122	2	75	3	41	2	24	3	140	3	262	3
Bumblebees Apidae	6	3	9	2	4	2	19	3	4	2	3	1	5	3	12	3	31	4
Ants Formicidae	11	4	23	5	14	4	48	8	12	5	5	4	5	4	22	8	70	8
Total 1995-96	**207**	**35**	**153**	**31**	**85**	**20**	**445**	**54**	**140**	**30**	**90**	**26**	**61**	**27**	**291**	**55**	**736**	**79**
1996-1997																		
Sawflies	101	14	32	11	18	6	151	19	8	6	16	9	11	8	35	15	186	27
Xyelidae	2	1	8	1	12	11	22	1	0	0	0	0	1	1	1	1	23	1
Pamphilidae	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Tenhredinidae	98	12	24	10	6	5	128	17	8	6	16	9	10	7	34	14	162	25
Solitary wasps	21	10	28	11	19	10	68	14	39	11	36	15	11	9	86	18	154	20
Sphecidae	16	7	15	8	12	7	43	10	16	8	18	11	9	7	43	13	86	13
Pompilidae	3	2	6	2	3	2	12	3	21	1	15	2	1	1	37	2	49	4
Eumeninae	0	0	0	0	0	0	0	0	1	1	1	1	0	0	2	2	2	2
Betylidae	2	1	7	1	4	1	13	1	1	1	2	1	1	1	4	1	17	1
Solitary bees Apidae	8	4	0	0	1	1	9	4	7	3	5	5	4	3	16	8	25	9
Social wasps Vespidae	1	1	3	1	1	1	5	1	2	1	0	0	1	1	3	1	8	1
Bumblebees Apidae	2	1	2	2	2	2	6	3	1	1	1	1	2	2	4	2	10	3
Ants Formicidae	3	2	39	5	71	5	113	7	8	2	5	5	3	3	16	7	129	10
Total 1996-97	**136**	**32**	**104**	**30**	**112**	**25**	**352**	**48**	**65**	**24**	**63**	**35**	**32**	**26**	**160**	**51**	**512**	**70**
TOTAL 1995-97	**343**	**53**	**257**	**43**	**197**	**35**	**797**	**72**	**205**	**45**	**153**	**49**	**93**	**43**	**451**	**77**	**1248**	**105**

Table II.- Number of individuals (N) and species (S) in each of the faunistic groups studied by trap and cycle. BM=Mixed pine forest; H=Beechwood.

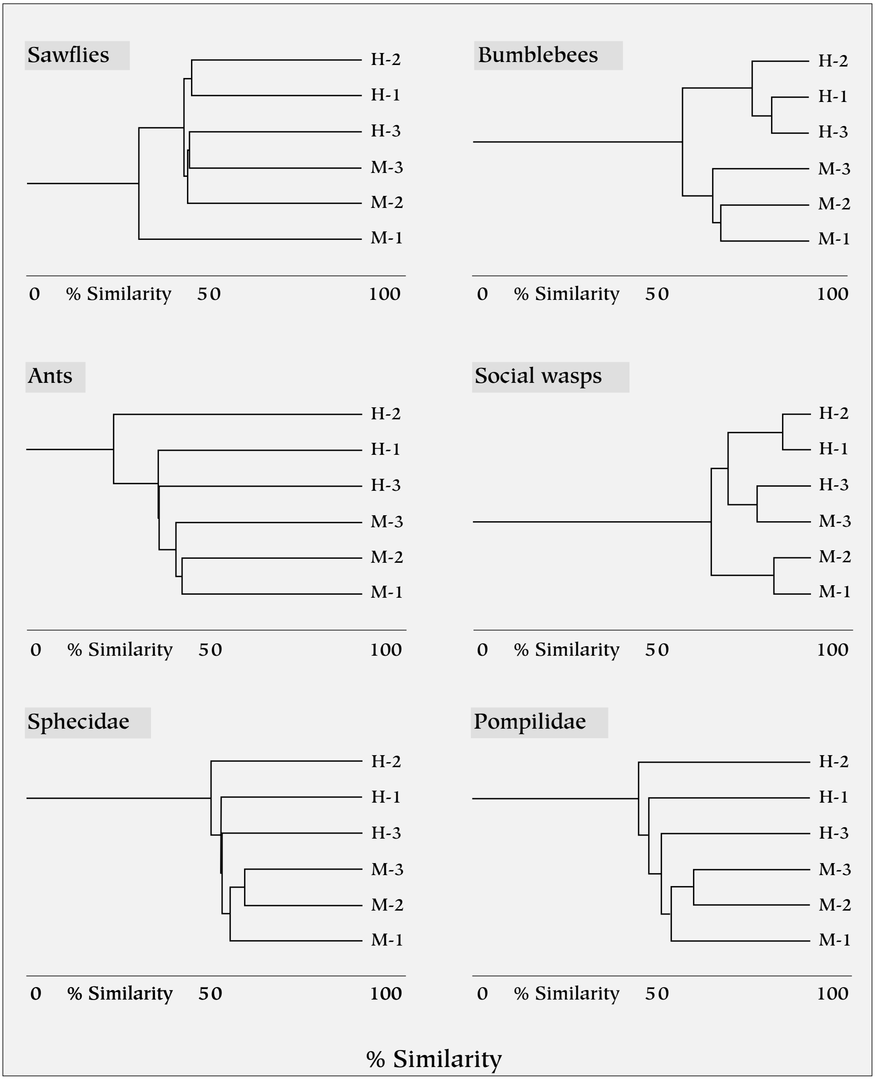


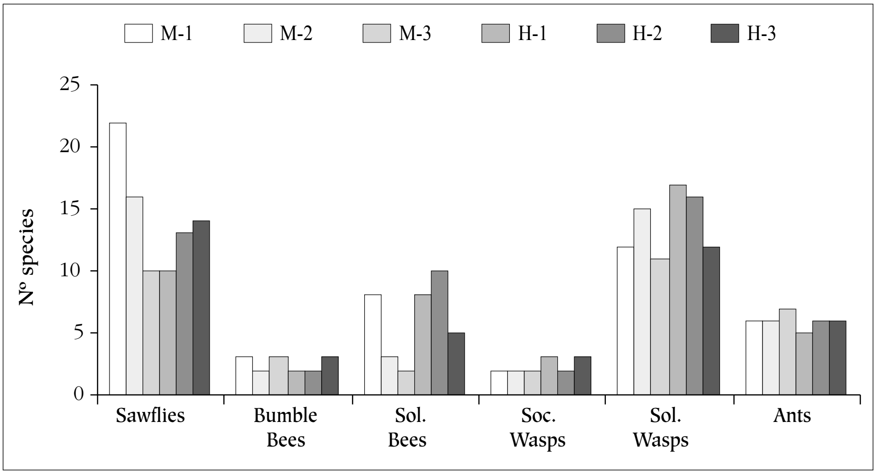
Figure 3.- Dendrograms for different groups following Bray-Curtis similarity percentage classification analysis (Single link) for total data.

shown in the apendix. Mean values in a complete seasonal cycle were 74 species and 624 individuals. The first year recorded 75,23% of total species and 58,97% of total abundances, both parameters in ants and abundance in solitary wasps were greater the second cycle.

If we group traps by vegetation series we obtain a subtotal in the mixed pine forest (BM) of 63,86% abundance, with means of 90 and 117 individuals per trap versus the ones obtained in the beechwood (H), 97 and 42 individuals respectively in each cycle. In relation to the number of species the total number was slightly higher in the beechwood (77 species) compared with the mixed pine forest (72 species). In relation to species groups, sawflies and bumblebees showed both years a greater number of species and abundances in the mixed pine forest. On the other hand, social wasps and solitary bees and wasps showed greater values in the beechwood. The ants, with similar species richness between series, were more abundant in the mixed pine forest. Similarity among traps, represented by dendrograms, indicated for each of the groups studied different clusters and only showed significant differences between vegetation series in bumblebees (Fig. 3). Location of trap M-1 showed for sawflies significant differences with the rest of the traps and so did trap M-3 in relation to ants. In the same way location at trap H-1 showed these differences for Sphecidae and Pompilidae among the solitary wasps. For other groups, as social wasps, no informative clusters were differentiated. Thus the general finding was that variation among trap locations seemed to be more important than variation between vegetation series.

Comparisons in species numbers of each of the groups studied among all trap locations have been analyzed graphically (Fig. 4). In the mixed pine forest, trap M-1 at the edge of a clearcut was specially effective for sawflies, with about half of total species (22) and individuals (255). At location inside the forest near the edge of trap M-2, sawflies and solitary wasps were well represented. The bulk of the pine stand or trap M-3 showed the smaller number of solitary bees. In the beechwood, trap H-1 settled on a steep slope over the river bank was rich in solitary wasps (particularly of Sphecidae), as well as trap H-2 that, less affected by the slope and nearby a clearing, showed also the higher number of solitary bees. Trap location H-3, in the bulk of the beechwood on a landing, did not outstand in any group.

Figure 4.- Total number of species of each of the groups studied in six Malaise traps covering two adjacent vegetation series, mixed pine forest (traps M-1, M-2 and M-3) and beechwood (traps H-1, H-2 and H-3) (Artikutza, Navarre). Soc.=social; Sol.=solitary.



		S	N	N1	H´	λ	E	D	Efficiency
M-1	1995-96	35	207	8.252	2.110	0.241	0.432	0.430	0.571
	1996-97	32	136	11.970	2.482	0.165	0.458	0.321	0.396
	1995-97	53	343	11.273	2.422	0.207	0.371	0.386	0.486
M-2	1995-96	31	153	11.512	2.443	0.171	0.458	0.379	0.422
	1996-97	30	104	15.466	2.738	0.111	0.548	0.301	0.280
	1995-97	43	257	16.402	2.797	0.108	0.530	0.239	0.350
M-3	1995-96	20	85	8.284	2.114	0.236	0.444	0.471	0.234
	1996-97	25	112	6.983	1.943	0.272	0.446	0.575	0.333
	1995-97	35	197	12.041	2.488	0.160	0.472	0.330	0.282
H-1	1995-96	30	140	7.600	2.028	0.286	0.377	0.507	0.417
	1996-97	24	65	12.593	2.533	0.128	0.583	0.313	0.175
	1995-97	45	205	12.211	2.502	0.179	0.406	0.356	0.290
H-2	1995-96	26	90	9.520	2.253	0.217	0.421	0.444	0.257
	1996-97	35	63	25.785	3.249	4.096	0.944	0.167	0.169
	1995-97	49	153	21.516	3.068	0.095	0.466	0.261	0.212
H-3	1995-96	27	61	14.365	2.664	0.128	0.505	0.344	0.168
	1996-97	26	32	23.881	3.173	0.016	2.665	0.094	0.086
	1995-97	43	93	24.543	3.200	0.071	0.559	0.237	0.126

S= number species; **N**= number individuals; **N1** = Hill index; **H´**= Shannon-Weaver index; **λ**= Simpson index; **E**= E5; **D**= Berger-Parker index.

Table III.- Diversity parameters obtained for each trap and cycle studied.

Mean anual number of species in most efficient trap was 14 in sawflies (M-1), 10 in solitary wasps (M-2, H-1), 5 in solitary bees (M-1 y H-2), 2 in social wasps (H-3, H-1), 2 in bumblebees (H-3) and 5 in ants (M-2). If we compare different parameter values for all species in each of the traps and cycles (Table III), we obtain that trap M-1 showed total higher efficiency, richness and dominance values, traps M-2, M-3 y H-1 did not outstand in any parameter, trap H-2 showed greatest richness in the second year and one of the highest values of diversity and equitability; and trap H-3 showed the lowest efficiency and dominance and greater diversity and equitability. With a same number of species in traps M-2 and H-3, diversity values did vary due to the influence in the former of species associated with edge plants that showed higher relative abundances.

SPECIES DISTRIBUTIONS

SAWFLIES.- The number of species related to each of the different host plant group at each trap was used to determine the influence of host proximity in species recording (Table IV). Trap M-1 recorded the greatest number of species associated to each of the host plant groups, trees and shrubs (5 species), monocotyledoneous herbs (6 species) and other dicotyledoneous herbs (6 species). The greatest number of species associated to

Host	M-1	M-2	M-3	H-1	H-2	H-3	TOTAL
Trees and Srubs	5	3	3	3	3	6	15
Pinaceae	2	1	1	1	1	1	3
Fagaceae	1	0	1	0	1	0	2
Ulmaceae	0	1	0	0	0	0	1
Salicaceae	1	0	0	1	1	4	5
Betulaceae	0	1	0	0	0	0	1
Oleaceae	1	0	0	0	0	0	1
Rosaceae	0	0	1	1	0	1	3
Ferns	2	3	0	1	2	0	4
Gramineae	6	3	4	4	5	4	9
Other herbs	6	3	2	2	3	3	10
Various	1	2	1	0	0	1	2
No record	3	2	0	0	0	0	3
TOTAL	**23**	**16**	**10**	**10**	**13**	**14**	**43**

Table IV.- Total number of sawfly species in each Malaise trap which are associated to different group plants recorded in the bibliography (Martínez de Murguía, 2001). Subtotals in trees and shrubs include species with more than one host record.

ferns (3 species) was recorded in mixed pine forest trap M-2. Among the species associated to trees a higher number was associated to Salicaceae (4 species) in the beechwood trap H-3. The individuals of most abundant species related to trees were aggregated in different traps close to their hosts; *Nematus fuscomaculatus* in trap M-1, *Xyela julii* in traps M-2 and M-3 and *Pristiphora laricis* in trap H-2 (Fig. 5). In relation to species related to herbs, a greater number of species were distributed among more than four traps, as in *Dolerus aeneus*, *Tenthredopis nassata*, *Pachynematus obductus*, *Pristiphora pallidiventris*, *Tenthredo livida* and *Ametastegia pallipes.* The two former species showed a significant individual concentration both cycles in trap M-1. Other species less abundant were aggregated in different traps: *D. puncticollis*, *D. gonager* in trap M-1 and *P. vagus*, *P. moerens* in traps M-1 and M-2.

Aculeates.- Trap abundance distributions of most common species within social and solitary species are shown in Figure 6. Among social species, *Bombus pascuorum* was recorded in higher abundances in traps settled in the mixed pine forest while in the beechwood traps *B. lucorum* was of greater importance. Individuals of *Vespula vulgaris* showed variation at two particular locations, a minimum in the mixed pine forest trap M-1 and a maximum in the beechwood trap H-1. In relation to ants few species were abundant enough to analyze their activity. Most abundant species were restricted to the mixed pine forest traps as *Leptothorax* sp.2, *Formica fusca*, and *Myrmica scabrinodis* which was aggregated in trap M-3 by the occurrence of a nuptial flight. The species *Lasius brunneus* showed a wide distribution among all traps. Most solitary species were distributed in all or most traps (Fig. 7). Among those that feed and nidify in

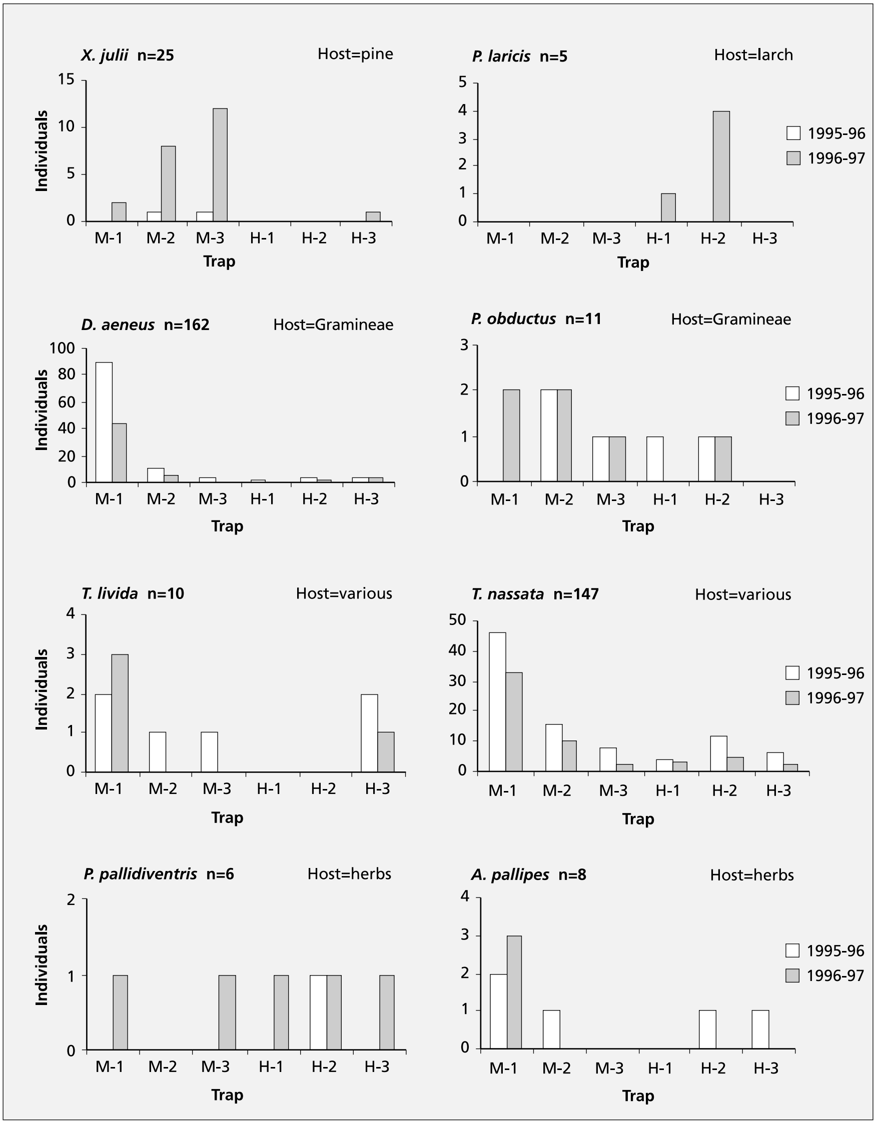


Figure 5.- Sawfly species abundance distributions among six Malaise traps, covering two adjacent vegetation series, mixed pine forest (traps M-1, M-2 and M-3) and beechwood (traps H-1, H-2 and H-3), and between cycles.

this layer several species concentrated in large amounts in different locations: *Trypoxylon clavicerum* and *Entomobora crassitarsis* in trap H-1, *Priocnemis* sp. in trap H-2 and *Bethylus fuscicornis* in trap M-2. Many other species among those that predate in vegetation and enter this layer looking for nesting resources were widely dispersed as *Crossocerus styrius*, *C. binotatus*, *Rhopalum clavipes*, *Pemphredon lugubris*,

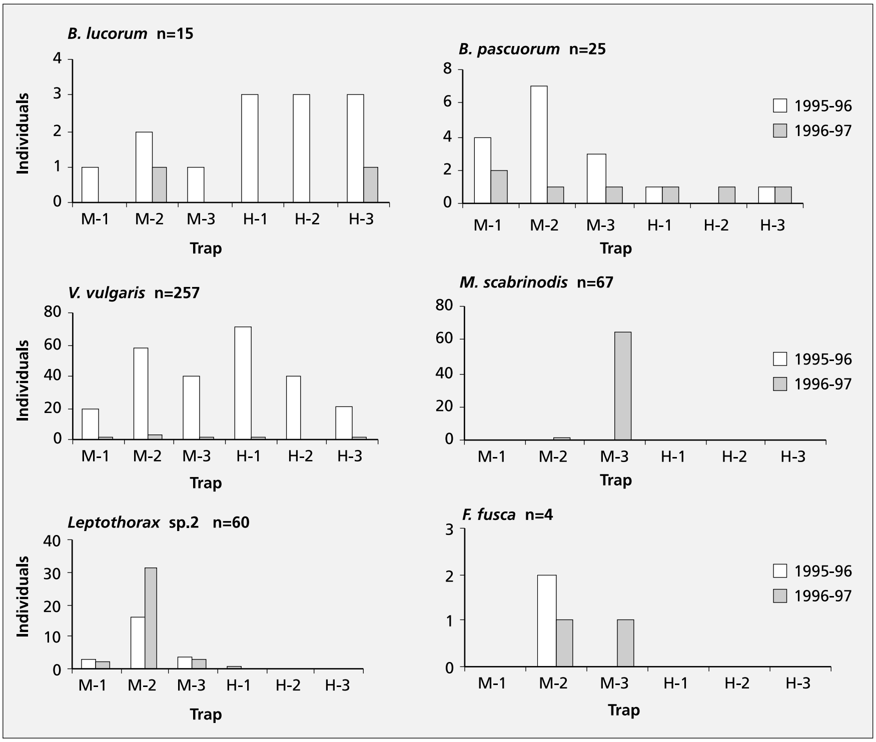


Figure 6.- Aculeate social species abundance distributions among six Malaise traps, covering two adjacent vegetation series, mixed pine forest (traps M-1, M-2 and M-3) and beechwood (traps H-1, H-2 and H-3), and between cycles.

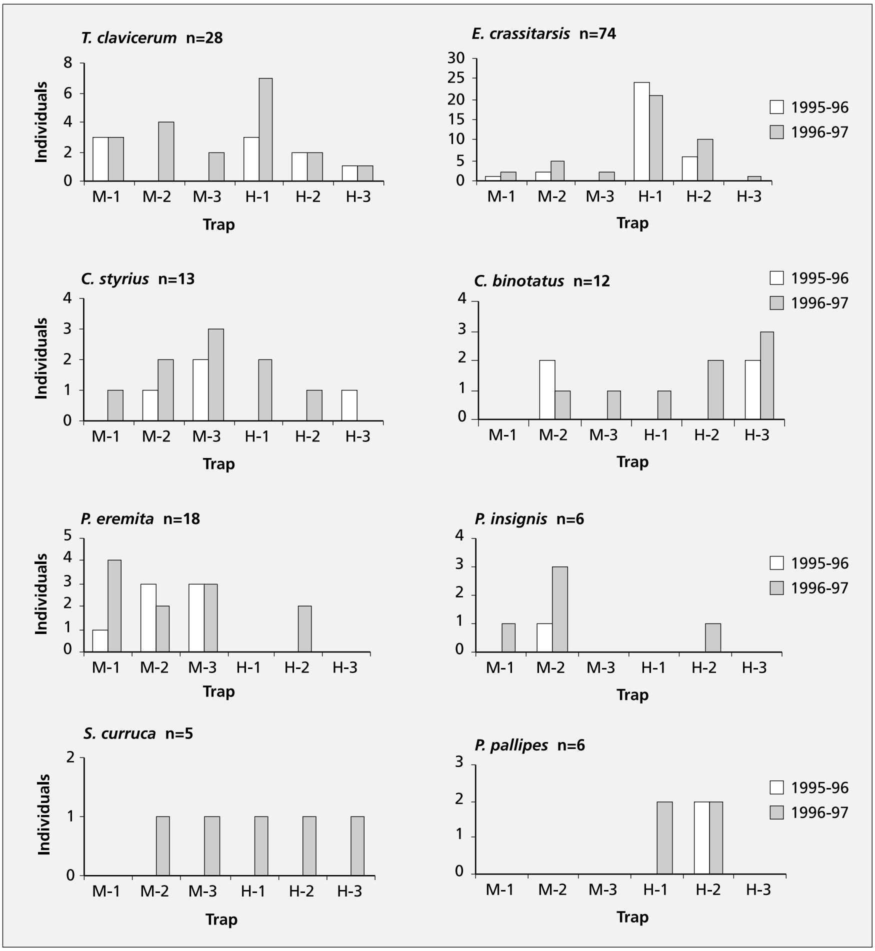
C. quadrimaculatus. Other species showed a more restricted distribution, *Passaloecus eremita* was mainly recorded in the mixed pine forest traps, *P. insignis* in trap M-2 and *Psenulus pallipes* in trap H-2.

Discussion

Adult activity in each forest layer is known to be related to availability of feeding, mating, nesting or hibernating resources (Archer, 1988, 1989; Skibińska, 1989, 1995; Banaszak & Cierzniak, 1994; Shlyakhtenok, 1995; Papp & Józan, 1995). In our data, species and abundances variability among trap locations suggested distributions according to spatial availability of resources, plant, soil conditions or dead wood. In general terms, differences between vegetation series indicated a greater number of species associated to vegetation in the mixed pine forest and a higher number associated to dead wood in the beechwood. These differences were not significant due to the high variability of trap locations within each vegetation series.

Sawflies have in common that their larvae feed on vegetation. Recording of half of total species and abundances at open areas near a clearing in the mixed pine stand, and particularly at the edge, was related with the proximity of their hosts, shrub, herbs and ferns at the glade. At this location, some species were found to concentrate in large amounts. Under the canopy the least number of sawfly species and densities were recorded. The distributions of species related to trees were similar to their hosts distributions; it is the case of *X. julii* in relation to pine, *P. laricis* in relation to larch and other species in relation to willow. Species related to more nemoral herbs showed an ample activity inside the forest but those associated to plants at the glade were restricted to the edge of the clearing. The distributions of two congeneric species with same number of individuals, *P. lari-*

Figure 7.- Aculeate solitary species abundance distributions among six Malaise traps, covering two adjacent vegetation series, mixed pine forest (traps M-1, M-2 and M-3) and beechwood (traps H-1, H-2 and H-3), and between cycles.



cis was aggregated at the foot of its plant host and *P. pallidiventris* was distributed among most traps, could be reflecting their different activity in this layer; the former oviposits in tree crowns and the last one in the herb layer. Thus the sawfly distribution could be depending in the heterogenous distribution of their hosts and the dispersing ability of these species in this forest layer.

Among the groups associated to vegetation, bumblebees was the only group that showed significant differences between vegetation series. When analyzed to species level these differences were shown to be due to a greater activity of *B. pascuorum* in the mixed forest and of *B. lucorum* in the beechwood. These two species are known to have different preferences in relation to the size of flower nectaries they visit (Brian, 1983). Most species in solitary bees were obtained in the beechwood near a small clearing but small species abundances did not allow to draw any conclusions on species distribution.

The data obtained for solitary wasps, and particularly for Sphecidae, suggested that the greater number of species in the beechwood and particularly at a steep slope could be related to the abundance of dead wood in sunny conditions that accumulated in the nearby stream bank (Fig. 8). In absence of vegetation and adequate soil conditions, pre-excavated galeries in wood seems to provide a common nesting resource for these species (Martínez de Murguía, 2001). Two species typical of this layer that prey on spiders, *T. clavicerum* and *E. crassitarsis*, concentrated in large amounts in this site, which seems to be important in their biological strategies. Few species were not distributed over the whole area studied. Differences between vegetation series were observed in the case of *P. eremita* that showed a distribution related to pine in which crowns females prey on

Figure 8.- Dead wood accumulated in stream banks (Artikutza, Navarre).

great black spruce bark aphid (*Cinara pinea* [Panz]) and nest in herb stems or dead wood (LOMDHOLT, 1975).

Among social wasps, *Vespula vulgaris* was the most widely distributed. Its concentration under an old beech in a steep slope was related to an inusual large amount of caterpillars observed in the samples. These are an important prey source for social wasps and prey density can influence the choice of hunting sites (RICHTER 2000).

The distribution of ants indicated different biological strategies. Three species were restricted to the mixed pine forest; *Leptothorax* sp. which workers might be attending aphids in pine crowns and *F. fusca* which is known to nest in hedgerows or woodland borders (COLLINGWOOD 1979). Recording of a nuptial flight in *M. graminicola* indicated the proximity of a nest (CZECHOWSKI *ET AL*, 1995).

IMPLICATIONS FOR CONSERVATION

Importance of economic processes in which are involved sawflies and aculeates, as defoliation, polinization or predation, indicate that they should be taken into account when planning management practices to promote diversity conservation and ensure forest health (LASALLE & GAULD, 1993). For instance, among the major forest insect pests in Europe eighteen species are sawflies (DAY & LEATHER, 1997). Classical biological introductions of natural enemies that have resulted in successful control of woodland o plantations pests include species of ants –Formicidae– (KIDD & JERVIS 1997). On the other hand many species are threatened by loss of habitat or intensification of agriculture (GAULD *ET AL* 1990). The main factors that affect conservation of aculeates in managed environments are those that are related to practices over the vegetation, and particularly over its flowering, and to loss of suitable nesting sites, as sunny sandy spots, river banks, trails or dead wood (DAY 1991, ARCHER 1998).

Conifer plantations in our region are an important economic resource and the greatest threat to forest biodiversity. Plantation configuration, structure and harvest techniques and cycles should be as “friendly” as possible to native biodiversity (EHRLICH, 1996). Our results indicate that glades in the forest encourage the presence of vegetation in which many hymenopterans feed and create adequate soil conditions for species nesting. Furthemore, they might be useful for supporting natural enemies of potential pine pests. In this sense they are in agreement with the management practice of favouring open spaces to promote insect diversity (DENNIS, 1997). Clearance and maintenance of woodland glades and hedgerows, coppicing or creation of sandy sunny situations are common forestry practices to create or re-create habitats for conservation of arthropods (COLLINS & THOMAS, 1989).

The presence of a stream in the stand provides in our forest an important source of diversity. Among sawflies associated to trees, the greatest number of species is related to riparian trees. The stream banks provide sunny conditions and retain large amounts of dead wood that are of particular importance in the diversity of solitary wasps as the main nesting resource (MARTÍNEZ DE MURGUÍA, 2001). Dead wood retrieval and the use of machines to break down trunks and branches to favour decay in *Pinus radiata* plantations are examples of current management practices in our region that reduce diversity, and should be minimized. Retention of woody debris is a modern ecosystem-based forest management technique to reduce loss of biodiversity and habitat in plantations (NOSS, 1999).

Restoration of natural deciduous forests combining with sustainable conifer plantations are the main objectives of forest management in the region. Hymenopterans taxonomic and ecological diversity should be taken into account for evaluating the conservation of biodiversity in managed forests. Spatial heterogenicity provided by clearings, bank rivers and dead wood favours the availability of different resources that meet species ecological requirements. Encouragement of forest management strategies in favour of Hymenoptera diversity will be contributing in a sound way to promote invertebrate biodiversity, one of the principles of sustainable forest management.

ACKNOWLEDGEMENTS

This study was financed by the Department of Education, University and Research of the Basque Government. In respect to cooperating institutions we are grateful to the Department of Animal Biology of the University Complutense in Madrid, City Hall of San Sebastián/Donostia and to the Aranzadi Society of Sciences. Our special thanks to taxonomists, G. Llorente Vigil (Symphyta), M.D. Martínez (Formicidae), S.F. Gayubo (Sphecidae), C. Ornosa (Bombinae), M. Díaz (Eumeninae) and J.P. Pedrero (Pompilidae) for species identification. Many thanks to John R. Grehan for continuous advice. We are also grateful for technical support to Iñaki Uranga (Artikutza administrator), Lourdes Martínez de Murguía, Alfredo Martínez de Guereñu, Patxi Amunarriz, Alberto De Castro, Imanol Zabalegui, Juan Angel Alvárez and Leticia Villalobos. J.L. Nieves-Aldrey was partially funded from DGES (PGC, PB97-1241).

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APENDIX. Species abundances recorded in each Malaise trap and cycle studied (Artikutza, Navarre).

	1995-96						1996-97						
	M-1	M-2	M-3	H-1	H-2	H-3	M-1	M-2	M-3	H-1	H-2	H-3	N
Sawflies													
Acantholyda posticallis Mat.	0	0	0	0	0	0	1	0	0	0	0	0	**1**
Amauronematus viduatus (Zett.)	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Ametastegia carpini (Hart.)	1	1	0	0	0	0	0	0	0	0	0	0	**2**
Ametastegia equiseti (Fallén)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Ametastegia pallipes (Spin.)	2	1	0	0	1	1	3	0	0	0	0	0	**8**
Aneugmenus padi (L.)	0	0	0	0	0	0	0	0	0	1	1	0	**2**
Athalia circularis (Klug)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Athalia cornubiae (Ben.)	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Cladius pectinicornis Geof.	1	0	0	0	0	1	0	0	0	0	0	0	**2**
Dolerus aeneus Hart.	89	10	3	1	3	3	44	5	0	0	1	3	**162**
Dolerus gonager (Fab.)	0	0	0	0	0	0	4	0	0	0	0	0	**4**
Dolerus madidus Klug	0	0	0	1	0	0	0	0	0	0	0	1	**2**
Dolerus niger (L.)	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Dolerus puncticollis Thom.	2	0	0	0	0	0	1	0	1	0	0	0	**4**
Dolerus sanguinicollis (Klug)	1	0	0	0	1	0	0	0	0	0	0	0	**2**
Empria tridens (Konow)	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Euura mucronata (Hart.)	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Euura venusta (Zadd.)	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Heptamelus ochroleucus (Steph.)	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Janus femoratus (Curtis)	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Macrophya teutona (Panz.)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Monophadnus monticola (Hart.)	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Nematus fuscomaculatus Förs.	4	0	0	0	0	0	0	0	0	1	1	0	**6**
Nematus hypoxanthus Förs.	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Pachynematus moerens (Förs.)	0	1	0	0	0	0	3	0	0	0	0	0	**4**
Pachynematus obductus (Hart.)	0	2	1	1	1	0	2	2	1	0	1	0	**11**
Pachynematus vagus (Fab.)	1	4	0	0	0	0	2	1	0	0	0	0	**8**
Pachyprotasis antenata (Klug)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Periclista albida (Klug)	0	0	0	0	0	0	1	0	1	0	0	0	**2**
Priophorus pallipes (Lep.)	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Pristiphora abrreviata (Hart.)	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Pristiphora laricis (Hart.)	0	0	0	0	0	0	0	0	0	1	4	0	**5**
Pristiphora pallidiventris (Fallén)	0	0	0	0	1	0	1	0	1	1	1	1	**6**
Pristiphora punctifrons (Thom.)	0	0	1	0	0	0	0	0	0	0	0	1	**2**
Pseudodineura fuscula (Klug)	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Scolioneura betuleti (Klug)	0	0	0	0	0	0	0	1	0	0	0	0	**1**

	1995-96						1996-97						
	M-1	M-2	M-3	H-1	H-2	H-3	M-1	M-2	M-3	H-1	H-2	H-3	N
SAWFLIES *(Cont.)*													
Strombocerina delicatula (Fallén)	1	1	0	0	0	0	0	0	0	0	0	0	**2**
Strongylogaster lineata (Christ)	0	0	0	0	0	0	1	1	0	0	1	0	**3**
Trichiocampus ulmi (L.)	0	0	0	0	0	0	0	1	0	0	0	0	**1**
Tenthredo livida L.	2	1	1	0	0	2	3	0	0	0	0	1	**10**
Tenthredopis litterata (Geoff.)	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Tenthredopis nassata L.	46	16	8	4	12	6	33	10	2	3	5	2	**147**
Xyela julii Bréb.	0	1	1	0	0	0	2	8	12	0	0	1	**25**
SOLITARY WASPS													
Ancistrocerus nigricornis (Curtis)	0	2	0	0	0	0	0	0	0	0	0	0	**2**
Ancistrocerus trifasciatus (Müll.)	0	0	0	1	0	0	0	0	0	0	1	0	**2**
Bethylus fuscicornis Jur.	0	7	0	1	3	0	2	7	4	1	2	1	**28**
Crossocerus annulipes (Lep. & Brull.)	0	1	0	1	0	0	0	0	0	0	1	1	**4**
Crossocerus binotatus Lep. & Brull.	0	2	0	0	0	2	0	1	1	1	2	3	**12**
Crossocerus megacephalus (Ross.)	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Crossocerus quadrimaculatus (Fab.)	0	0	0	1	0	0	3	1	1	0	0	1	**7**
Crossocerus styrius (Kohl)	0	1	2	0	0	1	1	2	3	2	1	0	**13**
Entomobora crassitarsis (Costa)	1	2	0	24	6	0	2	5	2	21	10	1	**74**
Gorytes planifrons (Wesm.)	0	1	0	0	0	0	0	0	0	1	0	0	**2**
Nysson spinosus (Förs.)	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Passaloecus corniger Shuck.	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Passaloecus sp. *aff. eremita* Kohl	1	3	3	0	0	0	4	2	3	0	2	0	**18**
Passaloecus gracilis (Curt.)	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Passaloecus insignis Van.Lin.	0	1	0	0	0	0	1	3	0	0	1	0	**6**
Pemphredon lugubris (Fab.)	0	0	1	0	0	0	1	1	1	1	2	1	**8**
Pompilidae sp.1	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Pompilidae sp.2	0	0	0	0	0	0	1	0	0	0	0	0	**1**
Priocnemis sp.	2	0	1	1	1	1	0	1	0	0	5	0	**12**
Psenulus pallipes (Panzer)	0	0	0	0	2	0	0	0	0	2	2	0	**6**
Rhopalum clavipes (L.)	0	1	0	1	0	2	3	0	0	1	3	1	**12**
Spilonema curruca (Dahl.)	0	0	0	0	0	0	0	1	1	1	1	1	**5**
Symmorphus bifasciatus (L.)	0	0	0	0	0	1	0	0	0	1	0	0	**2**
Trypoxylon clavicerum Lep. & Serv.	3	0	0	3	2	1	3	4	2	7	2	1	**28**
Trypoxylon minus de Beaum.	1	0	0	0	0	0	0	0	0	0	0	0	**1**
SOLITARY BEES													
Andrenidae, sp.1	0	0	0	2	0	0	1	0	0	0	0	0	**3**
Andrenidae, sp.2	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Andrenidae, sp.3	0	0	0	0	0	0	0	0	0	1	1	0	**2**

	1995-96						1996-97						
	M-1	M-2	M-3	H-1	H-2	H-3	M-1	M-2	M-3	H-1	H-2	H-3	N
Solitary bees *(cont.)*													
Andrenidae, sp.4	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Andrenidae, sp.5	0	0	0	0	0	0	1	0	1	5	0	0	**7**
Andrenidae, sp.6	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Andrenidae, sp.7	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Colletidae, sp.1	0	0	0	0	1	0	0	0	0	1	0	2	**4**
Colletidae, sp.2	1	1	0	0	1	0	0	0	0	0	0	0	**3**
Hylaeus sp.	0	0	0	0	0	0	0	0	0	0	1	1	**2**
Halictidae, sp.1	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Halictidae, sp.2	2	2	0	1	0	1	5	0	0	0	1	0	**12**
Halictidae, sp.3	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Halictidae, sp.4	1	0	0	1	0	0	1	0	0	0	0	1	**4**
Halictidae, sp. 5	2	0	0	0	0	0	0	0	0	0	1	0	**3**
Halictidae, sp.6	0	0	0	0	1	0	0	0	0	0	0	0	**1**
Halictidae, sp.7	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Nomada sp.	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Social wasps													
Vespula germanica (Fabr.)	0	0	0	3	0	1	0	0	0	0	0	0	**4**
Vespula rufa (L.)	1	1	3	1	1	2	0	0	0	0	0	0	**9**
Vespula vulgaris (L.)	19	58	40	71	40	21	1	3	1	2	0	1	**257**
Bumblebees													
Bombus hortorum (L.)	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Bombus lucorum (L.)	1	2	1	3	3	3	0	1	0	0	0	1	**15**
Bombus pascuorum (Scop.)	4	7	3	1	0	1	2	1	1	1	1	1	**23**
Bombus pratorum (L.)	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Psithyrus silvestris Lep.& Brull.	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Ants													
Formica fusca L.	0	2	0	0	1	0	0	2	1	0	1	0	**7**
Lasius meridionalis (Bondr.)	1	0	0	0	0	1	0	0	0	0	0	0	**2**
Lasius niger (L.)	0	0	4	3	1	0	0	0	0	1	1	0	**10**
Lasius brunneus (Bondr.)	5	2	5	3	1	0	0	3	0	7	1	1	**28**
Lasius mixtus (Nyl.)	0	0	0	0	0	0	0	0	0	0	1	0	**1**
Leptothorax sp.1	2	2	1	1	0	1	0	0	1	0	1	0	**9**
Leptothorax sp.2	3	16	4	1	0	0	2	31	3	0	0	0	**60**
Myrmecina graminicola (Latr.)	0	1	0	0	2	1	1	1	0	0	0	1	**7**
Myrmica scabrinodis Nyl.	0	0	0	0	0	0	0	2	65	0	0	0	**67**
Stenamma westwoodii Westw.	0	0	0	4	0	2	0	0	1	0	0	0	**7**
Strongylognathus testaceus Schen.	0	0	0	0	0	0	0	0	0	0	0	1	**1**
TOTAL INDIVIDUALS	207	153	85	140	90	61	136	104	112	65	63	32	**1248**
TOTAL SPECIES	35	31	20	30	26	27	32	30	25	24	35	26	**105**

Date of reception: 09/07/2002 / Date of acceptance: 24/09/2002