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**THE ACULEATE WASPS AND BEES (HYMENOPTERA:  
ACULEATA) OF HOLMEHOUSE WOOD, NEAR KEIGHLEY,  
IN WATSONIAN YORKSHIRE, INCLUDING A JACKKNIFE  
STATISTICAL PROCEDURE FOR ESTIMATING  
SPECIES RICHNESS**

MICHAEL E. ARCHER

Holmehouse Wood, near Keighley, is a very good locality for aculeate wasps and bees, having 83 recorded species, four species of possible national importance and eight of regional importance. The area, about 15 hectares, is situated to the west of Keighley, West Yorkshire (VC 63, SE0340). The locality is a mixed deciduous valley woodland on a clay soil around the North Beck stream. The wood is mainly oak and birch with some elm and sycamore. Open grassy areas are rich in shrubs, e.g. bramble and broom, and herbs, e.g. dandelion and lesser celandine, which provide important food sources for the aculeates. The nesting areas of the aculeates are in the open sunny parts of the wood. The subterranean nesters mainly nest in bare ground or ground with a short vegetation cover, often on slopes. The aerial nesters use upright and horizontal dead wood and dead plant stems such as bramble.

Holmehouse Wood was recorded extensively from the 1910s until about the middle of the 20th century. The main collector was J. Wood whose undetermined specimens were found at Manchester University, Keighley and Leeds Museums (Wood sample). I am grateful to the curators of these museums, C. Johnson, M. Hartley and A. Norris, for permitting access to the Wood specimens. Between 1918 and 1951 I have been able to establish that Wood made 189 collecting visits to Holmehouse Wood, distributed throughout the year as follows: March (1 visit), April (9), May (53), June (46), July (33), August (27), September (17) and October (3).

Between 1988 and 1996, I made 15 visits distributed throughout the year as follows: April (1 visit), May (3), June (3), July (3), August (4) and September (1). One of the visits during August was unsuitable for recording aculeate wasps and bees because of poor weather conditions. During these approximately three-hour visits all species of aculeate wasps and bees were recorded (Archer sample) and usually collected with a hand-net for identification.

A comparison will be made between the Archer and Wood samples although the activities of these two recorders were not exactly the same, Archer being a specialist recorder of aculeate wasps and bees, whilst Wood was a generalist collector of many groups of free-living insects.

A few records were also found of R. Butterfield (collecting from 1916 until 1919) and an unknown collector (1918 until 1928). In addition I am grateful to J. Burn who found the dryinid *Anteon scapulare* taken at Holmehouse Wood at Manchester University museum.

In the following account, biological names are according to Kloet and Hincks (1978).

#### SPECIES PRESENT

A full list of the species recorded with their collectors is given in the Appendix. At the family level, Table 1 shows the taxonomic distribution of species and records. A record represents a specimen differing in one of the following three variables: name, sex and day of visit. The solitary wasp families, Pompilidae and Sphecidae, and the solitary bee families, Andrenidae, Halictidae and Anthophoridae, are the dominant families either in terms of the number of species and/or number of records.

The recorded number of species from Holmehouse Wood is of a magnitude expected from its area in terms of species-area relationship for northern and north midlands of England (Archer 1995). Because the number of species is so related to the area of the

TABLE 1

The number of species and records of aculeate wasps and bees from Holmehouse Wood in the Archer and Wood samples and from all records.

	Archer		Wood		All	
	No. spp.	No. records	No. spp.	No. records	No. spp.	No. records
<b>Solitary Wasps</b>						
Dryinidae	0	0	0	0	1	1
Chrysididae	0	0	1	1	2	2
Pompilidae	3	19	4	40	5	60
Eumenidae	2	5	3	8	4	13
Sphecidae	10	27	13	35	18	63
Total	15	51	21	84	30	139
<b>Solitary Bees</b>						
Colletidae	1	8	0	0	1	8
Andrenidae	12	52	11	111	15	165
Halictidae	9	61	12	91	12	165
Megachilidae	1	1	0	0	1	1
Anthrophoridae	9	44	8	121	10	170
Total	32	166	31	323	39	509
Total Solitary Wasps & Bees	47	217	52	407	69	647
Social Wasps					5	
Social Bees					9	
Total Social Species					14	

locality, two further comments can be made. Firstly, the community characteristics of the species of aculeate wasps and bees of Holmehouse Wood can be compared with other northern and north midland localities of England. Secondly, species richness, or the number of species, of the clay locality of Holmehouse Wood is similar to the species richness of sandy localities. Traditionally, sandy localities have been considered to have a higher species richness than non-sandy localities.

#### SEASONAL PROGRESSION OF SPECIES

June, July and August were the best months for recording species of solitary wasps with June and July the most productive months for new species (Table 2). The species most evident were the pompilids, *Priocnemis schioedtei* and *Arachnospila anceps*, and the sphecid, *Crossocerus pusillus*. These species are all subterranean nesters with the pompilids hunting spider prey and the sphecid small fly prey. The pompilids were particularly noticeable at the east end of the wood, flying rapidly over bare earth and short grass surfaces.

April until August were the best months for recording species of solitary bees with April the most productive month for new species (Table 2). The species most evident were the subterranean nesters with their cleptoparasites: *Andrena cineraria* with *Nomada lathburiana*, *A. haemorrhhoa* with *N. ruficornis*, *A. scotica* with *N. marshallia*, *A. saundersella* with *N. flavoguttata*, *Halictus rubicundus* with *Sphecodes monilicornis* or *S. gibbus* and *Lasioglossum calceatum* with *S. monilicornis*. The colonial nesting *A. cineraria* was particularly noticeable.

TABLE 2

The number of species and new species of solitary wasps and bees recorded per month at Holmehouse Wood.

	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
No. species								
Solitary Wasps*	0	0	0	15	23	14	4	2
Solitary Bees	1	22	26	27	23	16	9	1
No. new species								
Solitary Wasps	0	0	0	15	11	2	0	0
Solitary Bees	1	21	6	8	2	0	1	0

\*No data available for *Anteon scapulare* and *Arachnospila spissa*.

Figure 1 shows the number of new species found each month. The spring fauna appearing mainly in April is clearly separated from the summer fauna appearing in June and July.

#### ARCHER-WOOD COMPARISON

Wood made nearly twice the number of records of solitary species than Archer (Table 1), but Archer, on average, made more records per visit (14.5 records) than Wood (2.2 records). Wood recorded more species of solitary wasps than Archer (Table 1) although only nine species (33%) were common to both samples. Archer and Wood recorded a similar number of species of solitary bees, with 24 species (62%) being common to both samples. Three solitary wasp species were recorded by neither Archer or Wood.

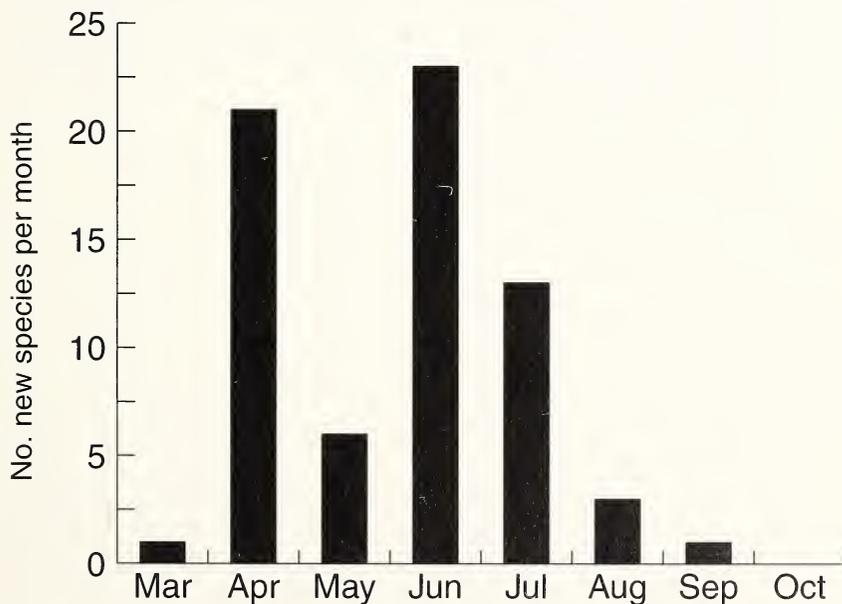


FIGURE 1

The number of new species of solitary wasps and bees recorded per month at Holmehouse wood.

Thirty-three solitary species were recorded by both Archer and Wood, 14 species only by Archer and 19 species only by Wood. These data can be compared by calculating similarity indices. Using the simple Jaccard index (Ludwig & Reynolds 1988), which depends upon the presence or absence of species, gives an index of 50.0%. The Morisita-Horn index, which uses quantitative information on the relative abundance of species, is relatively independent of sample size but gives more importance to the more abundantly occurring species (Magurran, 1988). Abundance was determined from the number of records of each species. The Morisita-Horn index is 75.8% which is higher than the Jaccard index. This indicates that the Archer and Wood samples are more similar to one another in terms of the more abundant species.

#### QUALITY ASSESSMENT OF THE SOLITARY SPECIES

According to Shirt (1987) and Falk (1991), *Nomada lathburiana* is a nationally rare or "Red Data Book" species (RDB3) and is probably on the northern edge of its range in Yorkshire. Three species are nationally scarce (Falk 1991: *Andrena humilis* on the northern edge of its range in Yorkshire and *Priocnemis schioedtei* and *Crossocerus walkeri* which are widely distributed in Britain. Two species, *Crossocerus styrius* and *C. walkeri*, are Yorkshire rarities (Archer 1998a). Six species which have a local distribution in a Yorkshire context (Archer 1994) are indicated in the Appendix.

Current work being carried out by members of the Bees, Wasps and Ants Recording Society indicates that the status of *Priocnemis schioedtei* and *Nomada lathburiana* will need to be down-graded and lose their national status. In a Yorkshire or regional context *P. schioedtei* has a common status and *N. lathburiana* a frequent status (Archer 1993). In a regional context *Andrena humilis* has an occasional status.

By giving each of the 68 species of solitary wasps and bees a regional status (Archer 1993) a regional quality score of 139 and a regional species quality score of 2.0 (139/68) can be calculated (Table 3). Within Watsonian Yorkshire this regional species quality score is between those of Cave Wold (1.7), Swincarr Plantation (2.1) and Skipwith Common (2.2). The dryinid *Anteon scapulare* cannot be included in this analysis as insufficient information is available to give a status.

TABLE 3  
The regional status scheme of the 68\* species of solitary wasps and bees recorded at Holmehouse Wood.

Status	Status value (A)	No. species (B)	Status Score (A*B)
Common	1	41	41
Frequent	2	19	38
Occasional	4	5	20
Rare	8	1	8
Nationally Scarce	16	2	32

\*Status of *Anteon scapulare* unknown.

Using a national status for each species (Archer 1998b) Holmehouse Wood has a national quality score of 101 (Table 4) and a national species quality score of 1.5 (101/68). In these calculations provisionally *Priocnemis schioedtei* is given a universal status and *Nomada lathburiana* a widespread status. Within Watsonian Yorkshire this national species quality score is between those of Cave Wold (1.2), Burton Leonard Lime Quarries (1.6) and Skipwith Common (1.6).

National quality and species quality scores have also been calculated for 14 Archer visits from April until September (Table 5). Table 5 also shows the overall quality and species

TABLE 4  
The Archer national status scheme of the 68\* species of solitary wasps and bees recorded at Holmehouse Wood.

Status	Status value (A)	No. species (B)	Status Score (A*B)
Universal	1	47	47
Widespread	2	19	38
Restricted	4	0	0
Scarce	8	2	16

\*Status of *Anteon scapulare* unknown.

TABLE 5  
The national daily quality scores of the solitary wasps and bees of the Archer sample recorded from Holmehouse Wood.

Date	No. spp.	Quality score	Sp. quality score
29 Apr. 1993	20	27	1.35
7 May 1989	10	12	1.20
11 May 1994	17	23	1.35
16 May 1992	17	21	1.24
11 Jun. 1992	25	39	1.56
12 Jun. 1998	9	10	1.11
17 Jun. 1989	14	18	1.29
6 Jul. 1990	12	14	1.67
17 Jul. 1991	9	18	2.00
29 Jul. 1992	12	15	1.25
1 Aug. 1995	10	12	1.20
14 Aug. 1994	8	9	1.13
25 Aug. 1991	6	9	1.50
15 Sep. 1996	9	9	1.00
Overall	47	65	1.38

quality scores of the Archer sample. Quality scores are likely to be greatly influenced by recording effort, but species quality scores should largely correct for variation in recording effort (Ball 1992; Foster 1996). Although recording effort was more-or-less constant for each Archer visit, the percentage variation of daily quality scores (433%) is greater than that for species quality scores (100%). The greater percentage variation of the quality scores is a consequence of the variation in the number of species recorded on each visit (varied from 9-25 species, % variation 278%). Thus species quality scores can correct, like variation in recording effort, for the variation in the number of species recorded.

Can a species quality score from one or two visits to a locality be used to give a relatively good prediction of the overall species quality score for the locality? To attempt to answer this question it is necessary to know the range of species quality scores for localities in Britain. For solitary wasps and bees, species quality scores have been found to vary from 1.2 to 5.5, although lower values down to 1.0 are possible. As such, three visits to Holmehouse Wood would probably be necessary to get a reasonable prediction of its national species quality score. The daily species quality scores (Table 5) fall within the 25% range (1.03-1.73) of the overall species quality score except for those of 17 July and 15 September.

## ESTIMATING THE POTENTIAL NUMBER OF SPECIES AT HOLMEHOUSE WOOD

Heltshe and Forrester (1983) described a jackknife statistical procedure to estimate species richness after a number of samples have been taken from a locality. The estimate is based on the observed frequency of species that are only observed on one occasion during sampling (=unique species). Krebs (1999) describes the statistical procedure in detail and Haeseler and Ritzau (1998) demonstrate its use with the aculeate Hymenoptera.

Based on the 14 Archer samples, with their ten unique species, the jackknife estimate of the potential number of species of solitary wasps and bees at Holmehouse Wood is 55 species with 95% confidence limits of 48-63 species.

This jackknife estimate is less than the total number (69) of species of solitary wasps and bees recorded from Holmehouse Wood. This underestimate of species could be a consequence of either the jackknife procedure tending to produce underestimates or suggest that Holmehouse Wood has lost some of the species recorded by Wood and earlier collectors. Heltshe and Forrester (1983) state that the jackknife procedure gives an overestimate of species richness while Palmer suggest (in Krebs, 1999) a slight underestimate.

To try and resolve this problem the jackknife procedure was performed on data from Shipley Glen (Archer 1996) and Gibraltar Point NNR (Archer 1998c). Like Holmehouse Wood, the records from Shipley Glen were made by early collectors (mainly Wood) and current collectors (mainly Archer), while the records from Gibraltar Point NNR were all made by current collectors during the 1980s and 1990s. It is predicted that if the jackknife estimate of species richness is an underestimate then the estimates for Shipley Glen and Gibraltar Point NNR, based on the Archer samples, will both be lower than the number of species recorded from these localities. However, if there has been a loss of species recorded by the early collectors then the jackknife estimate for Shipley Glen should still be an underestimate, but that for Gibraltar Point NNR should be more-or-less correct.

The jackknife estimate of species richness of solitary wasps and bees for Shipley Glen is 64 species, with 95% confidence limits of 53-75 species, which is an underestimate of the 75 species recorded from Shipley Glen. The jackknife estimate for Gibraltar Point NNR is 88 species, with 95% confidence limits of 75-101 species, which is more-or-less similar to the 86 species recorded from Gibraltar Point NNR.

Thus, it can be cautiously concluded that there has been a loss of species from Holmehouse Wood and Shipley Glen since the time of the early collectors.

## CLEPTOPARASITIC LOAD

The cleptoparasitic load (CL) is the percentage of aculeate species that are cleptoparasitic (or parasitoids) on other host aculeates. The CL for the species of solitary wasps is about one-third of the CL for the species of solitary bees (Table 6). Wcislo (1987) showed that the amount of parasitic behaviour among the aculeate Hymenoptera correlated with geographical latitude, being higher in the temperate, compared with the tropical regions. As such, CL for localities in Britain should have similar values.

TABLE 6

The relative frequency of the cleptoparasitic species among the solitary wasps and bees at Holmehouse Wood.

	No. hosts (H)	No. cleptoparasites (C)	Cleptoparasitic load $CL = 100 * C / (H + C)$
Solitary Wasps*	26	3	10.3
Solitary Bees	26	13	33.3

\**Anteon scapulare* not parasitic on an aculeate species.

In Watsonian Yorkshire the CL for species of solitary wasps varies from 13.2-20.0 (range 6.8). The CL for Holmehouse Wood is a little lower, so increasing the range to 9.7,

probably because of the lack of chrysid species which are parasites on the eumenids.

In Watsonian Yorkshire the CL for species of solitary wasps varies from 25.8-36.6 (range 10.8). The CL for Holmehouse Wood falls within this range.

#### AERIAL NESTER FREQUENCY

The aerial nester frequency (AF) is the percentage of host aculeate species that have aerial nest sites. Holmehouse Wood is rich in aerial nesters for species of solitary wasps but poor in aerial nesters for species of solitary bees (Table 7).

TABLE 7  
The nesting habits of the host species of solitary wasps and bees recorded from Holmehouse Wood.

	No. aerial nesters (A)	No. subterranean nesters (S)	Aerial Nester Frequency AF = 100*A/(A+S)
Solitary Wasps	14	12	53.8
Solitary Bees	2	24	7.7

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## APPENDIX

Aculeate wasp and bee species recorded from Holmehouse Wood, near Keighley.  
 \*Yorkshire local species. Collectors: A = Archer, B = Butterfield, W = Wood,  
 U = Unknown.

Dryinidae: *Anteon scapulare* (U).

Chrysididae: *Chrysis ignita* (U), *C. ruddii* \*(W).

Pompilidae: *Priocnemis parvula* (A,W), *P. schoedtei* (A,W), *Arachnospila anceps* (W),  
*A. spissa* (B), *Anoplius nigerrimus* (A).

Eumenidae: *Ancistrocerus nigricornis* (W), *A. oviventris* (A,W), *A. parietinus* (A),  
*A. scoticus* (W).

Vespidae: *Dolichovespula norwegica*, *D. sylvestris*, *Paravespula germanica*, *P. vulgaris*,  
*Vespula rufa*.

Sphecidae: *Ectemnius cavifrons* (A), *E. cephalotes* (A), *E. lapidarius* (W), *Rhopalum clavipes* (A,W), *Crossocerus annulipes* (A), *C. dimidiatus* (A,W), *C. elongatulus* (A,W), *C. megacephalus* (W), *C. ovalis* (A), *C. pusillus* (A,W), *C. quadrimaculatus* (W), *C. styrius* (W), *C. tarsatus* (W), *C. walkeri* (W), *C. wesmaeli* (W), *Pemphredon lugubris* (A), *Nysson spinosus* (A,W), *Argogorytes mystaceus* (B,W).

Colletidae: *Colletes succinctus* \*(A).

Andrenidae: *Andrena fucata* (A), *A. fulva* (A,W), *A. helvola* (W), *A. lapponica* (A,W), *A. scotica* (A,W), *A. angustior* (A), *A. cineraria* \*(A,W), *A. haemorrhoea* (A,W), *A. nigroaenea* (A,B), *A. barbilabris* \*(W), *A. chrysoceles* (A,W), *A. humilis* (A), *A. saundersella* (A,W,U), *A. subopaca* (A,W), *A. wilkella* (W).

Halictidae: *Halictus rubicundus* (A,W), *Lasioglossum cupromicans* (B,W), *L. leucopum* (A,B,W), *L. morio* (W), *L. albipes* (A,W), *L. calceatum* (A,W,U), *L. fratellum* (A,W,U), *L. rufitarse* (A,B,W), *Sphecodes geoffrellus* (=fasciatus) (A,W), *S. gibbus* (A,W), *S. hyalinatus* (B,W,U), *S. monilicornis* (A,B,W,U).

Megachilidae: *Megachile willughbiella* (A).

Anthophoridae: *Nomada fabriciana* (A,B,W,U), *N. flavoguttata* (A,B,W), *N. goodeniana* (A,B), *N. lathburiana* \*(A,W), *N. leucophthalma* \*(W), *N. marshamella* (A,W), *N. panzeri* (A,W), *N. ruficornis* (A,W), *N. striata* (A,W,U), *Anthophora furcata* (A).

Apidae: *Bombus hortorum*, *B. lapidarius*, *B. lucorum*, *B. pascuorum*, *B. pratorum*, *B. terrestris*, *Psithyrus bohemicus*, *P. vestalis*, *Apis mellifera*.