THE SOLITARY WASPS AND BEES (HYMENOPTERA: ACULEATA) OF THE 'GREEN SPACES' OF URBAN SHEFFIELD

BY MICHAEL ARCHER

There is a growing awareness of the nature conservation value of urban habitats, not only for their biodiversity, but also because they are valued by local people (Tucker *et al.*, 2005). Although only 10% of England is urbanised, some 90% of the population lives in these urban areas so 'green spaces' are important in bringing people into contact with the natural environment. As such, it is important that biological surveys of urban 'green spaces' are made to record their biotopes and species with their resource needs. Such information can then be incorporated into land development proposals. The following report on the solitary aculeate wasps and bees of urban Sheffield is a small contribution to provide such information.

During the 1970s and 1980s with the decline of Sheffield's steel industry, decisions were taken by the city planners to relocate large numbers of residents and to demolish and clear factories and terraced housing for possible future development. The demolition sites with their bare areas, sand, brick and mortar rubble were sometimes used as industrial tips. Not all such sites were re-developed and they gradually became flower-rich fields with a variety of 'weeds' and 'garden escapes'. Such sites are called Urban Commons (Gilbert, 1989). Records of solitary wasps and bees from these urban commons and other green spaces, e.g. woodlands, gardens, are considered in this report. An attempt is made to characterise these biotopes mainly using the indices of cleptoparasitic load and aerial nester frequency besides their characteristic and rare species.

The main requirements of solitary wasps and bees are food sources and nesting sites besides over wintering, sunning and mating sites and sometimes building materials to make their nests. Nesting sites can be in subterranean burrows usually excavated by themselves or by using pre-existing crevices. Subterranean nesters usually require bare or sparsely vegetated ground in sheltered sunny situations. The soil needs to be dry and friable (loose or firm) and may be sandy, clayey or calcareous. The aspect of the nesting site may be flat ground, slopes or vertical banks. Aerial nesters usually use hollow stems of herbs or shrubs, e.g. bramble, or old beetle burrows in dry dead wood again in sheltered sunny situations. Solitary bees require flower-rich areas with good pollen sources which are needed as a food source for their larvae. Some species are dependent on pollen from only a limited number of plant species. Solitary wasps require hunting areas for specific prey species which are needed as a food resource for their larvae. Suitable hunting areas are found in a range of habitats from grassland, scrub and woodland. Some solitary wasps and bees are parasites on other solitary wasps and bees either as

cleptoparasites stealing the food stores of their host or as parasitoids eating the body of their host. These parasites often require specific host species and the host species need to be in sufficient numbers so that they can be found. All species need nectar as a food source so again there is a need for flower-rich areas.

METHODS

The administrative boundary of the city of Sheffield includes an area of more than 360km^2 which includes farmland and a part of the Peak District National Park. The study area was the predominately urbanised area of the city which is about 140km^2 (Smith *et al.*, 2005).

The data used in this study came from records collected by members of the Sorby Natural History Society (Whiteley, 1988) and from Malaise trap catches from the Biodiversity of Urban Areas in Sheffield (BUGS) project administered by the University of Sheffield during 2000, 2001 and 2002. The author identified most of the specimens. The Sorby records are mainly from the 1970s, 1980s, 1990s and 2000s with a few earlier records.

RESULTS – THE SPECIES

The Sheffield data base consists of 977 records of 134 solitary wasp and bee species. Table 1 shows the taxonomic distribution of these species and the appendix shows a full list of the species. The wasp family, Sphecidae, is the dominant solitary wasp taxon in terms of both numbers of species and records. Overall, the solitary wasps are presented by 387 records from 65 species, i.e. about 6.0 records per species. The bee subfamilies Andreninae, Halictinae and Anthophorinae are the dominant solitary bee taxa in terms of both number of species and records. Overall,

TABLE 1. — NUMBER OF SOLITARY WASPS AND BEES SPECIES AND RECORDS FROM URBAN SHEFFIELD

	Species	Records
Solitary wasps		
Chrysididae	7	20
Mutillidae	1	2
Sapygidae	1	2
Pompilidae	8	26
Eumeninae	7	58
Sphecidae	41	279
Total solitary wasps	65	387
Solitary bees		
Colletinae	6	61
Andreninae	21	154
Halictinae	17	196
Megachilinae	9	60
Anthophorinae	16	119
Total solitary bees	69	590
Total solitary species	134	977

the solitary bees are represented by 590 records from 69 species, i.e. about 8.6 records per species.

There are a similar number of solitary wasp and bee species (1.1 bee: 1.0 wasp) but solitary bees are represented by more records (1.5 bee: 1.0 wasp). One species, *Eumenes papillarius*, is not a British species, but is a vagrant species from mainland Europe.

How many more species are likely to be found in urban Sheffield? With the data available it is not possible to carry out a potential species richness estimate (Archer, 2002). However, discounting the vagrant species, 24 species (18.0% of species) have only been recorded once. Such a low percentage gives some confidence that sufficient species have been recorded so that further analysis of the data is justified. The species list from urban Sheffield represents 61.9% of the species recorded from South Yorkshire (Archer, 2007a). The commonest 15 species (5 wasps and 10 bees), as determined by number of records, are given in Table 2. All the species are non-parasitic species except for *Nomada marshamella* which is the cleptoparasite of *Andrena scotica*. The non-parasitic species consist of five aerial and nine subterranean nesters.

TABLE 2. — THE FIFTEEN COMMONEST SPECIES OF SOLITARY WASPS AND BEES RECORDED FROM URBAN SHEFFIELD

	No. records
Lasioglossum fratellum	34
Andrena scotica	32
Lasioglossum smeathmanellum	32
Pemphredon lugubris	29
Halictus rubicundus	29
Nomada marshamella	28
Ectemnius cavifrons	25
Lasioglossum calceatum	23
Osmia rufa	23
Crossocerus elongatulus	22
Crossocerus pusillus	22
Hylaeus communis	22
Andrena haemorrhoa	22
Lasioglossum cupromicans	22
Ancistrocerus gazella	20

Species Quality

The solitary aculeate wasps and bees in a Yorkshire context can be given one of four statuses: Rare, Occasional, Frequent and Common (Archer, 2002). The urban Sheffield list, discounting the vagrant species, consists of seven Rare (*Pseudomalus auratus*, *Chrysis rutiliventris*, *Spilomena curruca*, *Anthidium manicatum*, *Coelioxys rufescens*, *Nomada flava* and *N. obtusifrons*), 30 Occasional, 44 Frequent and 52 Common species. Two of the Rare species, *Anthidium manicatum* and *Nomada flava*, are recent additions to Watsonian Yorkshire, so their rare status could be lost if these species continue to increase in abundance and

distribution. The Rare and Occasional status species can be considered as High Quality Species and the Frequent and Common species as Low Quality Species. From the recent publication of the aculeates of South Yorkshire (Archer, 2007a), in comparing the solitary wasps and bee species, South Yorkshire has relatively more High Quality Species (46.6%) than urban Sheffield (27.8%). A 2×2 chi-squared test of High and Low Quality Species versus urban Sheffield and South Yorkshire gives statistical support to this difference ($p < 0.001$).

According to Shirt (1987) and Falk (1991) the following species have a Red Data Book status (National rare): *Ectemnius ruficornis* and *Nomada lathburiana*. Falk (1991) downgraded *E. ruficornis* to Nb status (Nationally scarce list B) and *N. lathburiana* should now lose its national rare status. Two species have a Na status (Nationally scarce list A): *Crossocerus binotatus* and *Nomada integra* and five species an Nb status: *Pseudomalus violaceus*, *Ectemnius sexcinctus*, *Hylaeus signatus*, *Andrena humilis* and *A. nigriceps*.

From recent work carried out by the Bees, Wasps and Ants Recording Society an attempt has been made to keep the national statuses up-to-date by Archer (2002) who also gives a status to all species. One of six national statuses can be given to each species (Archer, 2002). The Archer national statuses are divided into High Quality Species (Very rare, Rare and Scarce statuses) and Low Quality Species (Restricted, Widespread and Universal statuses). The urban Sheffield list consists of three Rare (*Passaloecus monilicornis*, *Nomada obtusifrons* and *N. integra*), seven Scarce (*Pseudomalus violaceus*, *Anoplius concinnus*, *Crossocerus binotatus*, *Ectemnius dives*, *Hylaeus signatus*, *Andrena humilis* and *A. nigriceps*), 44 Widespread and 79 Universal species. The nationally Rare species have an Occasional status in a Yorkshire context. Table 3 summarises the national statuses to give a Quality Score of 271 and a Species Quality Score (SQS) of 2.0. For South Yorkshire the Quality Score is 615 and the SQS is 2.9 (Archer, this paper).

Using the Archer national statuses, South Yorkshire (Archer, 2007a) has relatively more High Quality Species (34 species, 16.1%) than urban

TABLE 3. — ARCHER NATIONAL QUALITY SCORES OF SOLITARY WASPS AND BEES RECORDED FROM URBAN SHEFFIELD*

National status	Status value (A)	No. species (B)	Quality scores (A × B)
Universal	1	79	79
Widespread	2	44	88
Scarce	8	7	56
Rare	16	3	48
Total		133	271
	Species Quality Score 271/133 = 2.0		

*Excluding the vagrant *Eumenes papillarius*

Sheffield (10 species, 7.5%). A 2×2 chi-squared test gives statistical support to this difference ($p = 0.02$). In addition, since South Yorkshire has relatively more High Quality Species, its Species Quality Score (SQS) is also higher (2.9). In a Yorkshire context, the SQS for South Yorkshire is first class while urban Sheffield is second class (Archer, 2008).

These results indicate that it is more difficult for High Quality Species from the source species in South Yorkshire to find suitable habitats in urban Sheffield.

Cleptoparasitic Load

The cleptoparasitic load (CL) is the percentage of aculeate species that are cleptoparasitic (or parasitoids) on other host aculeates. Wcislo (1987) showed that parasite behaviour among aculeate Hymenoptera correlated with geographical latitude. Thus parasitic rates are higher in temperate regions, as host populations are more synchronised in their life-history characteristics than in tropical regions. This finding probably does not hold for desert regions where the occurrence of rainfall would tend to synchronise life history characteristics. From a review of the literature Wcislo found that the CLs for bees varied between 16% and 33%, with a range of 17%. The CLs from 27 Yorkshire sites vary between 25.0%–40.0%, a range of 15% (Archer, unpublished). The CL for the solitary bees (Table 4) falls within this Yorkshire range. Wcislo gave no CLs for solitary wasps but from 27 Yorkshire sites CLs vary between 10.3% and 25.0%, a range of 14.7% (Archer, unpublished). The CL for the solitary wasps falls within this Yorkshire range.

TABLE 4. — THE RELATIVE FREQUENCY OF THE CLEPTOPARASITIC (OR PARASITOID) SPECIES AMONG THE SOLITARY SPECIES RECORDED FROM URBAN SHEFFIELD *

	No. parasites (C)	No. non-parasites (H)	Cleptoparasitic Load $CL = 100 \times C/(H+C)$
Solitary wasps	11	53	17.2
Solitary bees	21	48	30.4

*Excluding the vagrant *Eumenes papillarius*

A 2×2 chi-square test of the number of species of either solitary wasps or solitary bees recorded from urban Sheffield and Britain versus the number of parasitic and non-parasitic species shows distributions as expected by chance ($p = 0.68$ for solitary wasps and $p = 0.58$ for solitary bees).

Aerial Nester Frequency

The aerial-nester frequency (AF) is the percentage of host aculeate species that have aerial nest sites. Aerial nesters use old beetle burrows in dead wood, central stem cavities (e.g. bramble), old snail shells, or crevices in cob walls, old mortar or exposed on the surface of rock or other hard material. Subterranean nesters nest in the soil, usually in burrows

TABLE 5. — THE NESTING HABITS OF THE SOLITARY SPECIES RECORDED FROM URBAN SHEFFIELD*

All species	No. aerial Nesters (A)	No. subterranean Nesters (S)	Aerial nester frequency $AF = 100 \times A/(A + S)$
Solitary wasps	36	17	67.9
Solitary bees	11	37	22.9

*Excluding the vagrant *Eumenes papillarius*

which they dig, but sometimes in holes and crevices are used after being altered. The AFs for the solitary species are given in Table 5. The AFs for all the British species of solitary wasps is 48.2% and solitary bees is 18.8%.

The AF for the urban Sheffield solitary bees is similar to, but the AF for solitary wasps is much higher, than the British percentage. A 2×2 chi-squared test of the number of solitary bees recorded from urban Sheffield and Britain versus the number of species of aerial and subterranean nesters shows distributions as expected by chance ($p = 0.54$). A similar test for the solitary wasps confirms that more species than expected are associated with aerial nesting sites reaching a statistically significant level ($p = 0.01$).

A further 2×2 chi-squared test of the solitary wasps of urban Sheffield versus South Yorkshire (Archer, 2007a) also shows statistically more aerial nesters associated with urban Sheffield ($p = 0.35$), but a similar test between South Yorkshire and Britain shows no statistical significance ($p = 0.777$). This analysis indicates that the urban environment is easier to survive or invade by aerial-nesting, than subterranean-nesting, solitary wasp species compared to the source species of South Yorkshire.

THE HABITATS

With the help of D. Whiteley many of the sites could be allocated to single or mixed broad biotopes. Three single habitats (Woodlands, Gardens and Urban Commons) and one mixed (Woodland/Heathland) were represented with sufficient data to consider for possible further analysis. Table 6 shows the number of species and records obtained from these habitats. The number of species represented by one record for these

TABLE 6. — NUMBER OF SPECIES AND RECORDS OF SOLITARY WASPS AND BEES FROM SELECTED HABITATS RECORDED FROM URBAN SHEFFIELD

Biotope	No. wasps		No. bees	
	Species	Records	Species	Records
Garden	35	120	32	137
Woodland	48	140	49	146
Mixed Woodland & Heathland	2	6	24	51
Urban Common	25	36	31	56

habitats indicates that further analysis of gardens (38.8% species with one record) and possibly mixed woodland/heathland (45.8% species with one record) and woodlands (46.4% species with one record) can be justified.

Urban Common Biotope

For urban commons the database contains 92 records (36 wasps, 56 bees) representing 56 species (25 wasps, 31 bees). The urban common with the most species was Holbrook Heath with 24 species (9 wasps, 15 bees) from 29 records (10 wasps, 19 bees). Holbrook Heath is a lowland former colliery spoil heap colonised by heather and birch. The site which was flower-rich with open bare areas also consisted of some grassland, marsh, ponds and *Sphagnum* areas. The number of species with one record (67.9%) is so high that it is unlikely that sufficient species have been recorded so as to characterise the habitat and proceed with further analysis. Only one species, *Nomada flava*, has a Yorkshire Rare status, but as previously noted it is a recent introduction. Five species, *Pseudomalus auratus*, *Hylaeus brevicornis*, *Andrena denticulata*, *Lasioglossum leucozonium* and *Sphecodes ephippius*, have a Yorkshire Occasional status. No recorded species has an Archer high quality status at the national level.

Mixed Woodland/Heathland

For this mixed habitat from the database there are 57 records (6 wasps, 51 bees) representing 26 species (2 wasps, 24 bees). This mixed biotope is represented by only three sites although two of these, Fox Hagg and Loxley Common, are amongst the sites with the higher number of records and species. At Fox Hagg 17 species (1 wasp, 16 bees) were recorded. Fox Hagg is a north-facing heather and bilberry moor with some bare sandy areas and birch dominated woodland. At Loxley Common 16 species (2 wasps, 14 bees) were recorded. Loxley Common is an open heather and bilberry moor with birch encroachment and some areas of ancient deciduous woodland.

The six species with the most records were the subterranean fly-hunting wasp, *Crossocerus pusillus*, the subterranean nesting bees, *Colletes succinctus*, *Andrena haemorrhoa*, *A. lapponica* and *Lasioglossum fratellum*, and the cleptoparasite *Nomada panzeri* whose hosts were probably *A. lapponica* and *A. fulva*. The cleptoparasite of *A. haemorrhoa*, *N. ruficornis*, was also found.

Using the Yorkshire statuses, 17 species are Common; eight species are Frequent; and one species, *Epeolus cruciger*, Occasional. Using the Archer national statuses, 22 species are Common and four species are Widespread giving a Quality Score of 30 and a Yorkshire third-class Species Quality Score of 1.2 (Archer, 2008).

The two wasp species are non-parasitic species and subterranean nesters. Ten of the bee species are parasitic species giving a high cleptoparasitic load (41.7%). All the non-parasitic bee species are subterranean nesters. However, the number of recorded species is too low

to give reliable cleptoparasitic loads and aerial nester frequency that are characteristic of this mixed habitat.

The Garden Habitat

For gardens the database contains 257 records from 67 species (Table 6). The garden with the most species was Blackbrook Avenue, the home of T.H. Riley, with 19 species (6 solitary wasps, 13 solitary bees) from 35 records (13 solitary wasps, 22 solitary bees). This garden is situated in the outer suburbs of Sheffield at an altitude of 275m, close to Fox Hagg. The largest contribution was from the BUGS project with 226 records representing 57 species. The seven species with the most records were the fly-hunting wasps, *Crossocerus elongatulus* and *Ectemnius cavifrons* and the solitary bees, *Hylaeus communis*, *Lasioglossum cupromicans*, *L. smeathmanellum*, *Osmia rufa* and *Anthophora furcata*. *E. cavifrons*, *H. communis* and *A. furcata* are aerial nesters while the other four species are usually considered subterranean nesters although they are often use crevices in brick and stone walls and bare vertical banks.

Using the Yorkshire statuses, 33 species are Common, 19 species Frequent, 12 species Occasional and 3 species, *Pseudomalus violaceus*, *Spilomena curruca* and *Anthidium manicatum*, Rare, although *A. manicatum* is a recent new species for Yorkshire. *S. curruca* is an aerial nester while *P. violaceus* is a parasitoid of aerial-nesting sphecid wasps such as *Pemphredon lugubris* and *Passaloecus*.

Using the Archer national statuses, 43 are Universal species, 19 Widespread species, 3 (*Pseudomalus violaceus*, *Hylaeus signatus* and *Andrena nigriceps*) Scarce species and 2 species (*Passaloecus monilicornis* and *Nomada integra*) Rare species. The National Quality Score is 137 with a Yorkshire second-class Species Quality Score 2.0 (Table 7) (Archer, 2008).

TABLE 7. — THE RELATIVE FREQUENCY OF THE CLEPTOPARASITIC (OR PARASITOID) SPECIES AMONG THE SOLITARY SPECIES RECORDED FROM GARDENS AND WOODLANDS OF URBAN SHEFFIELD

	No. non-parasites (H)	No. parasites (C)	Cleptoparasitic Load $CL = 100 \times C/(H+C)$
Gardens			
Solitary wasps	29	6	17.1
Solitary bees	30	2	6.3
Woodlands			
Solitary wasps	42	6	12.5
Solitary bees	30	19	38.8

The cleptoparasitic load (CL) for the solitary wasp species falls within the range for other Yorkshire sites, but CL for the solitary bees falls well below the range for Yorkshire sites. The low value of the CL for solitary bees is due to the lack of cleptoparasitic species. No species of *Sphecodes* and only two species of *Nomada* were recorded. Knowing the *Andrena*

species that were recorded, the following *Nomada* species which are found in urban Sheffield, might have been recorded: *N. fabriciana*, *N. goodeniana*, *N. panzeri*, *N. ruficornis* and *N. rufipes*. A 2 × 2 chi-square test of the number of solitary wasps found in gardens and present on the national list versus the number of parasitic and non-parasitic species is statistically non-significant ($p = 0.74$) so reinforcing the normal range of parasites and non-parasites found in gardens. A similar 2 × 2 chi-square for the solitary bee species is statistically significant ($p = 0.01$) indicating that the gardens have fewer species of cleptoparasites than would be expected by chance, so confirming the relative lack of cleptoparasites found in gardens.

The aerial nester frequencies (AF) for solitary wasps and bees are shown in Table 8. Compared with the national AFs (48.2% for solitary wasps, 18.8% for solitary bees), the garden AFs are high. A 2 × 2 chi-square test of the number of solitary wasp and bee species found in gardens and present on the national list versus the number of aerial and subterranean nester species supports the higher aerial nester frequencies for the solitary wasps ($p < 0.001$) but not quite for the solitary bees ($p = 0.075$).

TABLE 8. — THE NESTING HABITS OF THE SOLITARY SPECIES RECORDED FROM GARDENS AND WOODLANDS OF URBAN SHEFFIELD

	No. aerial Nesters (A)	No. subterranean Nesters (S)	Aerial nester frequency $AF = 100 \times A/(A+S)$
Gardens			
Solitary wasps	25	4	86.2
Solitary bees	10	20	33.3
Woodlands			
Solitary wasps	29	13	69.0
Solitary bees	5	25	16.7

The Woodland Biotope

For woodlands the database contains 286 records from 97 species (Table 6). The three most recorded woodlands were Smelter (66 records, 38 species, 2.2 records per species), Shirtcliff (54 records, 38 species, 1.4 records per species) and Wharncliffe (78 records, 37 species, 2.1 records per species). Shirtcliff and Smelter Woods are small suburban deciduous woodlands in the Shirtcliff Valley which include some grassland slopes with areas of bare ground, with a sunny aspect. Wharncliffe Wood is a large woodland with areas of ancient deciduous trees and conifer plantations and some open areas.

The nine species with the most records were the solitary wasps: fly-hunters *Crossocerus megacephalus*, *C. pusillus* and *Ectemnius cavifrons* and aphid-hunter *Pemphredon lugubris* and the subterranean-nesting solitary bees: *Andrena scotica* with its cleptoparasite *Nomada*

marshamella, *Halictus rubicundus*, *Lasioglossum fratellum* and the cleptoparasite *Nomada panzeri*.

Using the Yorkshire statuses, 44 species are Common, 31 species Frequent, 17 species Occasional and 5 species (*Pseudomalus violaceus*, *Chrysis rutiliventris*, *Coelioxys rufescens*, *Nomada flava* and *Nomada obtusifrons*) Rare.

Using the Archer national statuses, 63 species are Universal, 27 species Widespread, 5 species (*Pseudomalus violaceus*, *Anoplius concinnus*, *Crossocerus binotatus*, *Ectemnius dives* and *Andrena humilis*) Scarce and 2 species (*Nomada obtusifrons* and *N. integra*) Rare. *N. obtusifrons* is a cleptoparasite of *A. coitana* and *N. integra* a cleptoparasite of *A. humilis*. Both of these host species have been recorded from woodlands. The Quality Score is 181 with Yorkshire second-class Species Quality Score 1.9 (Archer, 2008).

The cleptoparasitic loads for the solitary wasps and bees (Table 7) fall within the ranges for Yorkshire sites and 2×2 chi-square test with national data concur in showing no statistical significances ($p = 0.26$ for solitary wasps and $p = 0.10$ for solitary bees).

The aerial nester frequencies (AFs) (Table 8) compared with national AFs (48.2% for solitary wasps and 18.8% for solitary bees) show a much higher percentage for solitary wasps but a similar percentage for solitary bees. The 2×2 chi-square test with national data for solitary wasps show statistically significance ($p = 0.02$) indicating the woodlands have more aerial-nesters than would be expected by chance. The 2×2 chi-square test for solitary bees lacks statistical significance ($p = 0.78$) so reinforcing the normal range of aerial-nesters found in woodlands.

THE SITES

From the site with the largest recorded number of species and records, Wharncliffe Woods, an attempt can be made to establish the potential number of solitary wasp and bee species that could be present on this site. These estimates are made using the statistical presence/absence Chao (in Colwell & Coddington, 1994), the first order Jackknife (Heltshe & Forrester, 1983) and second order Jackknife (Burnham & Overton, 1978) procedures. The software to carry out these procedures was provided by Pisces Conservation Ltd.

TABLE 9. — NON-PARAMETRIC ESTIMATES OF SPECIES DIVERSITY AT WHARNCLIFFE WOOD

	Chao	1st Order Jackknife	2nd Order Jackknife
No. species recorded	39	39	39
No. species estimated	62	57	67
95% confidence limits	39–85	47–67	–
% of estimated spp. found	62.9	68.4	58.2

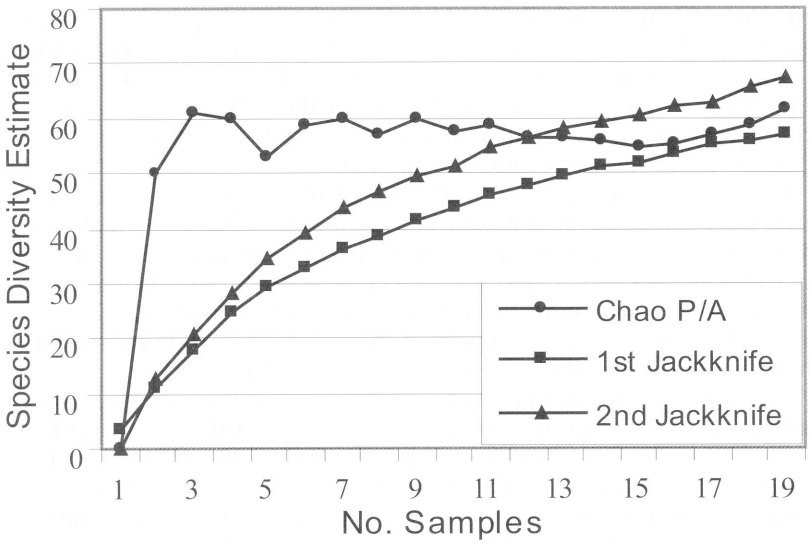

Fig. 1. — Species diversity estimates for Wharncliffe Wood using the presence/absence Chao, first and second order Jackknife procedures.

The Wharncliffe Woodland data were divided into 19 samples according to year and month. The statistical procedures were run 50 times. Figure 1 and Table 9 show the outcomes of these statistical procedures. The differences between the final species diversity estimates (Table 9) of the three statistical procedures are such that further sampling is needed to get closer agreement. The percentage of estimated species recorded is less than the usually well in excess of 70% needed for a reliable estimate, so again further sampling is needed. However, the species diversity estimates of the three statistical procedures are beginning to converge and stabilize (Fig. 1) so it is likely that between 60 and 70 solitary species of wasps and bees are present at Wharncliffe Wood.

With the unsatisfactory analysis of the best recorded site of Wharncliffe Wood, no attempt has been made to apply analysis to other sites.

DISCUSSION

Urban Sheffield has a good representation of solitary wasp and bee species with 134 species recorded, about 55% of Watsonian Yorkshire Species (Archer, 2002). Seven Yorkshire rarities and ten species of national importance have also been found. Other urban studies have also found a comparatively high insect diversity (Frankie & Ehler, 1978). Gardens, in particular, have been found to be an important refuge for insects (Owen & Owen, 1975; Owen, 1991; McIntyre (2000). Frankie & Ehler (1978) relate this high species diversity to the heterogeneous environments of urban habitats where a great variety of the resource needs

of the insects can be found. Smith *et al.* (2005, 2006) provide evidence from the study of invertebrates in 61 Sheffield gardens for the importance of this heterogeneous environment. Haeseler (1982) showed the adaptability of solitary wasps and bees to the urban environment by recording the presence of 20 subterranean nesting species in pavements, car parks and streets of Odenburg, Germany.

Davis (1978) and Davis & Glick (1978) illustrated how urbanisation causes the fragmentation of natural and semi-natural habitats which result in a general reduction of species richness, particularly of sensitive species. The fewer species of national importance recorded from urban Sheffield compared South Yorkshire illustrates this loss of High Quality Species. Perhaps these lost nationally important species could be re-introduced into urban Sheffield with the use of wildlife corridors (Barker, 1997).

The relatively low cleptoparasitic load for solitary bees and high aerial nester frequency for solitary wasps and bees for gardens has also been shown in other gardens studies (Archer, 1990, 2004: Harvey, 2001). Archer (2007b) came to the conclusion that gardens are an unfavourable habitat for subterranean nesters due to human disturbance, so selecting for aerial nesting species. The lack of cleptoparasitic bee species was due to the subterranean nesting solitary bee species nesting outside the garden. Cleptoparasitic bee species tend to be found around the nests and the nest sites of their hosts (Archer, 2007b). In effect, the subterranean nesting bee species were really using the garden only as a food source and not as a nesting site.

The relatively high aerial-nesting frequency of solitary wasps, but not the solitary bees, in woodlands could be due to a possible lower temperature regime of the subterranean environment. Archer (1990) found that solitary wasps were more sensitive to summer weather conditions than solitary bees. It is, therefore, possible that the solitary bees were better able to be subterranean nesters in woodlands than solitary wasps.

SUMMARY

1. Urban Sheffield has 134 recorded species of solitary wasps and bees (61.9% of South Yorkshire species) including seven Yorkshire rare species and ten species of national importance.
2. Compared with South Yorkshire, urban Sheffield has relatively fewer High Quality Species indicating the difficulty for High Quality Species of invading or surviving in urban Sheffield due to the lack of suitable habitats.
3. The cleptoparasitic load for urban Sheffield falls within the range recorded for other Yorkshire sites. However, the cleptoparasitic load for solitary bees in gardens has a relatively low value. An explanation is offered for this low value.
4. A relatively high aerial nester frequency was found for urban Sheffield compared with South Yorkshire and Britain. Also, relatively high aerial nester frequencies were found for solitary wasps in gardens and woodlands and solitary bees in gardens. Explanations are offered for these high values.
5. The characteristics of the following biotopes of urban Sheffield (urban commons, mixed woodland/heathlands, gardens, and woodlands) are described in terms of characteristic species, Yorkshire rare species, nationally important species and where data were

available for Quality Scores, Species Quality Scores, Cleptoparasitic Loads and Aerial Nester Frequencies.

6. There was no site with sufficient data to estimate potential species diversity. The best data are for Wharncliffe Wood which probably would potentially have between 60 and 70 species of solitary wasps and bees.

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17 Elmfield Terrace, York YO31 1EH, U.K.
April 8th, 2008.

APPENDIX – LIST OF RECORDED SPECIES

CHRYSIDIDAE: *Pseudomalus auratus* (Linn.), *P. violaceus* (Scopoli), *Chrysis angustula* Schenck, *C. ignita* (Linn.), *C. impressa* Schenck, *C. rutiliventris* Abeille de Perrin, *Trichrysis cyanea* (Linn.).

MUTILLIDAE: *Myrmosa atra* Panzer.

SAPYGIDAE: *Sapyga quinquepunctata* (Fab.).

POMPILIDAE: *Priocnemis exaltata* (Fab.), *P. schioedtei* Haupt, *Dipogon variegatus* (Linn.), *Anoplius concinnus* (Dahlbom), *A. nigerrimus* (Scopoli), *A. viaticus* (Linn.), *Arachnospila anceps* (Wesmael), *A. spissa* (Schiødte).

EUMENINAE: *Eumenes papillarius* (Christ), *Ancistrocerus gazella* (Panzer), *A. parietinus* (Linn,), *A. parietum* (Linn.), *A. trifasciatus* (Müller), *Symmorphus bifasciatus* (Linn.), *S. gracilis* (Brullé).

CRABRONIDAE: *Tachysphex pompiliformis* (Panzer), *Trypoxylon attenuatum* Smith, *T. clavicerum* Lepeletier & Serville, *T. figulus* (Linn.), *Crossocerus annulipes* (Lepeletier & Brullé), *C. binotatus* Lepeletier & Brullé, *C. capitosus* (Shuckard), *C. cetratus* (Shuckard), *C. dimidiatus* (Fab.), *C. elongatulus* (Van der Linden), *C. megacephalus* (Rossi), *C. nigritus* (Lepeletier & Brullé), *C. ovalis* Lepeletier & Brullé, *C. podagricus* Van der Linden, *C. pusillus* Lepeletier & Brullé, *C. tarsatus* (Shuckard), *C. wesmaeli* (Van der Linden), *Ectemnius cavifrons* (Thomson), *E. cephalotes* (Olivier), *E. continuus* (Fab.), *E. dives* (Lepeletier & Brullé), *E. ruficornis* (Zetterstedt), *E. sexcinctus* (Fab,), *Lindenius albilabris* (Fab.), *Entomognathus brevis* (Van der Linden), *Rhopalum clavipes* (Linn.), *R. coarctatum* (Scopoli), *Mimumesa dahlbomi* (Wesmael), *Psenulus concolor* (Dahlbom), *Spilomena curruca* (Dahlbom), *S. troglodytes* (Van der Linden), *Pemphredon lethifera* (Shuckard), *P. lugubris* (Fab.), *Diodontus luperus* Shuckard, *Passaloecus gracilis* (Curtis), *P. insignis* (Van der Linden), *P. monilicornis* Dahlbom, *P. singularis* Dahlbom, *Mellinus arvensis* (Linn.), *Nysson spinosus* Forster, *Argogorytes mystaceus* (Linn.).

COLLETINAE: *Colletes daviesanus* Smith, *C. succinctus* (Linn.), *Hylaeus brevicornis* Nylander, *H. communis* Nylander, *H. hyalinatus* Smith, *H. signatus* (Panzer).

ANDRENINAE: *Andrena angustior* (Kirby), *A. bicolor* Fab., *A. chrysosceles* (Kirby), *A.cineraria* (Linn.), *A. clarkella* (Kirby), *A. coitana* (Kirby), *A. denticulata* (Kirby), *A. fucata* Smith, *A. fulva* (Müller *in* Allioni), *A. fuscipes* (Kirby), *A. haemorrhoa* (Fab.), *A. helvola* (Linn.), *A. humilis* Imhoff, *A. lapponica* Zetterstedt, *A. minutula* (Kirby), *A. nigriceps* (Kirby), *A. nigroaenea* (Kirby), *A. scotica* Perkins, *A. semilaevis* Pérez, *A. subopaca* Nylander, *A. wilkella* (Kirby).

HALICTINAE: *Halictus rubicundus* (Christ), *H. tumulorum* (Linn.), *Lasioglossum albipes* (Fab.), *L. calceatum* (Scopoli), *L. cupromicans* (Pérez), *L. fratellum* Pérez, *L. fulvicorne* (Kirby), *L. leucopus* (Kirby), *L. leucozonium* (Schrank), *L. rufitarse* (Zetterstedt), *L. smeathmanellum* (Kirby), *L. villosulum* (Kirby), *Sphecodes ephippius* (Linn.), *S. geoffrellus* (Kirby), *S. gibbus* (Linn.), *S. hyalinatus* von Hagens, *S. monilicornis* (Kirby).

MEGACHILINAE: *Anthidium manicatum* (Linn.), *Osmia caerulescens* (Linn.), *O. leaiana* (Kirby), *O. rufa* (Linn.), *Megachile centuncularis* (Linn.), *M. circumcincta* (Kirby), *M. versicolor* Smith, *M. willughbiella* (Kirby), *Coelioxys rufescens* Lepeletier & Serville.

ANTHOPHORINAE: *Nomada fabriciana* (Linn.), *N. flava* Panzer, *N. flavoguttata* (Kirby), *N. goodeniana* (Kirby), *N. integra* Brullé, *N. lathburiana* (Kirby), *N. leucophthalma* (Kirby), *N. marshamella* (Kirby), *N. obtusifrons* Nylander, *N. panzeri* Lepeletier, *N. ruficornis* (Linn.), *N. rufipes* Fab., *N. striata* Fab., *Epeolus cruciger* (Panzer), *E. variegatus* (Linn.), *Anthophora furcata* (Panzer).

REVIEW

'DRAGONFLIES AND DAMSELFLIES OF HERTFORDSHIRE' by ALAN REYNOLDS, TOM GLADWIN & CHRISTINE SHEPPERSON. Hertfordshire Natural History Society, 2008, 143 pp. ISBN 978-0-9521685-6-0. £14.00.

In the last two decades or so there has been a large increase in the number of books devoted to county faunas of the more popular insect groups. This is a welcome development in insect recording. How many of us have had an impossible wish for a full and accurate account from the distant past of a favourite group in his or her home county? The value of a county review of the distribution and abundance of a taxonomic group, quoting from Steve Cham's foreword to the present work, is in establishing 'a benchmark on which to judge future trends and changes'. It is the entomologists of the future who will probably most appreciate county-based faunistic surveys.

The *Dragonflies and Damselflies of Hertfordshire* is intended to be a 'reference for the status of dragonflies in Hertfordhire [sic] in the early part of the 21st century'. 119 recorders, working between 2000 and the end of 2005, provided in excess of 14,000 records of Odonata in the administrative county of Hertfordshire. This book is based upon these records. It is the second Hertfordshire Natural History Society publication dealing with a group of insects and follows Colin Plant's recent *The Moths of Hertfordshire*.

Dragonflies in the county are relatively well studied and a full history of dragonfly recording is described in chapter 2, commencing with J. F. Stephens' (1835) listing of four species in volume VI of *Illustrations of British Entomology*. E. R. Speyer (1910, 1911) reported twelve species, and thereafter published records appeared with increasing frequency through the remainder of the 20th century. The county list now stands at 19 breeding species (9 Zygoptera, 10 Anisoptera) with a further eleven species known to have occurred in Hertfordshire. Notable absentees from the list of breeding species are *Aeshna juncea* (L.), *Gomphus vulgatissimus* (L.) and *Cordulia aenea* (L.).

An account of the county's aquatic habitats, and how they have changed over the years, constitutes chapter 3. Although pollution, drainage, water abstraction and other human activities have had an undoubtedly detrimental effect on the dragonfly fauna, other factors and especially the increasing number of garden ponds have been beneficial. The authors are able to conclude that 'although the biological quality and nature of Hertfordshire's aquatic habitats at the end of the 20th century is very different from that which existed even 50 years ago, it now supports a dragonfly fauna probably richer than at any time in its post mediaeval history'.

The bulk of the book (chapter 5) is an account of the 19 species regularly breeding in Hertfordshire. For each of these species there is a map of its distribution over the 458 tetrads (2km × 2km) in Hertfordshire, notes on how it may be recognised in the field and distinguished from similar species, observations on its behaviour, habitat and flight period, together with a history, so far as is known, of its status in the county. There is a colour photograph of each species, but unfortunately the sex of the insect is not stated.