THE SOLITARY WASPS AND BEES (HYMENOPTERA: ACULEATA) OF URBAN AND SUBURBAN GARDENS

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ABSTRACT

The species and numbers of solitary wasps and bees found in 12 gardens are analysed. Analysis includes the use of the species indices of quality, parasitic (mainly cleptoparasitic) behaviour and nesting habits. An attempt is made to explain the differences in wasp and bee numbers and diversities between the gardens to increase understanding of the ecology of these species and their conservation requirements in urban and suburban gardens.

Keywords: Hymenoptera, Aculeata, ecology, conservation, urban gardens

INTRODUCTION

There is a growing awareness of the importance of urban gardens for biological conservation (Good, 2000; Tucker, Ash & Plant, 2005; Gaston, 2010). In England, 7% of the land area is covered by cities and towns of more than 10,000 people and with 80% of the human population living in such urban areas, gardens are important in bringing people into contact with wildlife (Loram *et al.*, 2007). Owen (1991) estimated that 27.6% of urban and suburban Leicester consisted of gardens. The BUGS (Biodiversity in Urban Gardens in Sheffield, 2004) project estimated that 23% (33km^2) of the city consisted of gardens. These estimates are supported by the finding that from 21.8% to 26.8% of five cities in England, Wales and Scotland, not including Sheffield, consisted of gardens, with gardens in Leicester covering 26.8% of the area (Loram *et al.*, 2007). It has been estimated that urban and suburban households have access to about 432,964ha across the UK, which is equivalent to 9.2% of the 4.7 million hectares of statuary protected areas (Davies *et al.*, 2009).

From the early 1980s, the idea of turning gardens into habitats for wildlife took hold (Good, 2000), although Chinery had suggested changes to gardens for increasing their use by wildlife as early as 1977. These changes included the use of tubes (holes drilled in wood, hollow plant stems such as hogweed, straws and ventilation bricks) to attract nesting solitary wasp and bee species. Chinery (1986) repeated the advice that tubes be provided for solitary wasps and bees, and indicated species of vascular plant most suitable as nectar and pollen sources. Garbuzov & Ratnieks (2014) recorded the attractiveness of 32 garden plant varieties (including 19 species and hybrids) to bees. Carlton has established a web site (www.foxleas.com) giving a list of vascular plants attractive to insects. The BUGS (Biodiversity in Urban Gardens in Sheffield, 2001) project found during 2000 that tubes were used by solitary bees and wasps in 15 out of 20 Sheffield gardens, although only a small number of tubes were used in each garden. Gaston (2010) reported that 52% of households

(based on a telephone survey from 671 respondents of 2916 households) carried out nature observation activities in their gardens.

Gardens are often very heterogeneous (e.g. flower beds, shrubs and trees, lawns, vegetable and herb areas, rockeries, ponds, compost heaps, paths, dead wood and old walls). These components provide many microhabitats capable of supporting a rich biodiversity. In the U.K., the average size of a garden is 190m^2 (0.02ha), with the total area of gardens supporting 287 million trees. This accounts for just under a quarter of the trees located outside woodlands (Davies *et al.*, 2009). The BUGS (Biodiversity in Urban Gardens in Sheffield, 2004) project recorded 1166 vascular plant species in 61 Sheffield gardens with an average of 119 (48–268) plant species per garden.

The main requirements of solitary wasps and bees are food sources and nesting sites. They also need overwintering, sunning and mating sites and, sometimes, building materials to make their nests. Suitable nesting sites generally need to be in sunny situations. Aerial nesters use old beetle burrows in dead wood, central stem cavities (e.g. in bramble), old snail shells, or crevices in cob walls, old mortar, or nests exposed on the surface of rock or other hard material. Subterranean nesters nest in the soil, usually in burrows that they dig themselves, but sometimes in existing holes and crevices that are used after alteration. Solitary bees require flower-rich areas with pollen sources, and solitary wasps require hunting areas for specific prey species that are needed as food resources for their larvae. Suitable hunting areas are found in a range of habitats including grasslands, scrubs and woodlands. Some solitary wasps are cleptoparasites or parasitoids and some bees are cleptoparasites on other, often specific, solitary wasps and bees. All species need nectar as a food source and so require flower-rich areas. Further information is given by Grissell (2010).

The aim of this paper is to survey and analyse the species and numbers of solitary wasps and bees found in a twelve gardens. The analysis includes the use of the species indices of quality, parasitic (mainly cleptoparasitic) behaviour and nesting habits. An attempt is made to explain the differences found between the gardens.

METHODS

Lists of solitary aculeate wasps and bees found in twelve gardens were obtained from literature or personal communications. Table 1 indicates the locations and sizes of these gardens (where known), and the length of study time (where known). The gardens were mainly located in England: (North, Midlands and particularly the South). One garden was in Ireland. 'Hampstead' was a collection of six gardens. In some gardens (e.g. Leaside, Allerthorpe, Dublin) field identification and net collection with later identification were the only source of recording species present in a garden. In some gardens (e.g. Nightingales, York) decaying wood stumps

were introduced to attract aerial nesting wasps and bees. In other gardens (e.g. Buckingham, Hampton, Dublin) old fences were observed to attract aerial nesters. Stelfox (1957) describes the nesting of *Crossocerus pusillus* Lepeletier & Brullé in an old clothes-line post. Aerial nesters were also observed nesting in loose mortar of walls (e.g. York, Dublin). Bare patches of sandy soil had been created by removing the vegetation and forming the spoil soil into a sandy bank that attracted subterranean nesters in the Nightingales garden.

Flowers that provide a good nectar and/or pollen resource were introduced at Northcroft (e.g. catmint, fennel, asters, geranium, Oregon-grape). White bryony arrived by natural process and particularly attracted *Andrena florea* (Fabricius.). Species were often recorded visiting flowers: at Leicester (e.g. bramble, tansy, deadnettle, gooseberry, flowering current), at Buckingham (e.g. hawthorn), at York (e.g. yarrow, white deadnettle, dandelion, tansy, bramble, hawthorn, sycamore besides a variety of herbs) and at Allerthorpe (e.g. grape hyacinth, rock cresses, aubretia, raspberry, gooseberry, flowering current). Several gardens (e.g. Nightingales, Leicester, Buckingham, York) had shrubs and trees providing a variety of habitats for the solitary wasps to find their insect and spider prey.

Species were also recorded from Malaise (e.g. Nightingales for one year and Leicester for 27 years) and yellow pan traps (Nightingales). Identification of specimens was usually carried out by the owners of the gardens or use was made of experts. The only difficulty noted in the validity of identification was the species *Chrysis ignita* (Linnaeus), which may has been of one of several species. Each species was given one of six statuses (Archer, 1999; 2002; 2013) consisting of three high quality statuses (Very rare, Rare, Scarce) and three low quality statuses (Universal, Widespread, Restricted).

TABLE 1 — THE CHARACTERICTICS OF THE TWELVE URBAN OR SUBURBAN STUDY GARDENS

Name	Location	No. Species	Size (ha.)	Length of Study (yrs)	Source
Nightingales	Surrey	238	1.00	6	D.W. Baldock (pers. com.)
Lea-side	West Sussex	124	Unknown	Several	M. Edwards (pers. com.)
Leicester	Leicestershire	100	0.07	27	Archer (1990; 2013)
Northcroft	Hampshire	91	0.30	Several	G.R. Else (pers. com.)
Buckingham	London	72	16.00	3	Harvey (2001)
Oxford	Oxfordshire	72	Unknown	Several	C. O'Toole (pers. com.)
Hampstead	London	56	Unknown	Several	Guichard & Yarrow (1948)
York	North Yorkshire	56	9.70	7	Archer (2004)
Hampton	Middlesex	50	Unknown	6	Yeo (1956)
Allerthorpe	East Riding, Yorkshire	34	Unknown	Several	Fordham (1938)
Grays	Essex	30	0.03	Several	P.R. Harvey (pers. com.)
Dublin	Dublin	28	0.02	15	Stelfox (1937)

RESULTS

Table 1 shows the number of species recorded from each of the twelve study gardens. The number recorded in each garden was very variable with a range of 210 (28–238) species representing 6–53% of the British list. The sizes of several gardens are not known exactly, but are likely to be less than 0.3ha. The total number of species from all the gardens was 280 representing 62% of the British list (Table 2). Slightly more bee (51.8%) than wasp (48.2%) species were found. The dominant families, in terms of the number of species, for the wasps was the Crabronidae and for the bees the Andrenidae and Halictidae.

The number of gardens in which each species was recorded is given in Fig. 1. No species was found in all twelve gardens. Fig. 1 shows a rapid decline from a species being found only in one garden through to its being found in five gardens, after which the decline is much slower. The 71 species (33 wasps, 38 bees, 25.4%, Appendix) found in 5–11 of the gardens can be regarded as garden characteristic species. The remaining 209 species (102 wasps, 107 bees, 74.6%) were non-garden characteristic species and only recorded in 1–4 of the gardens, with 84 species (40 wasps, 44 bees, 30.0%) only recorded in one garden. This division into the non-garden characteristic species (present only in 1–4 of the gardens) and the garden characteristic species (present in 5–11 of the gardens) will be considered in the analysis below.

Table 3 shows the Quality Scores and Species Quality Scores for all the gardens, the 1–4 gardens with non-garden characteristic species and the 5–11 gardens with the garden characteristic species. Table 4 shows the number of high quality species and Species Quality Scores (SQS) for each of the twelve gardens. The relatively low SQS of the garden characteristic

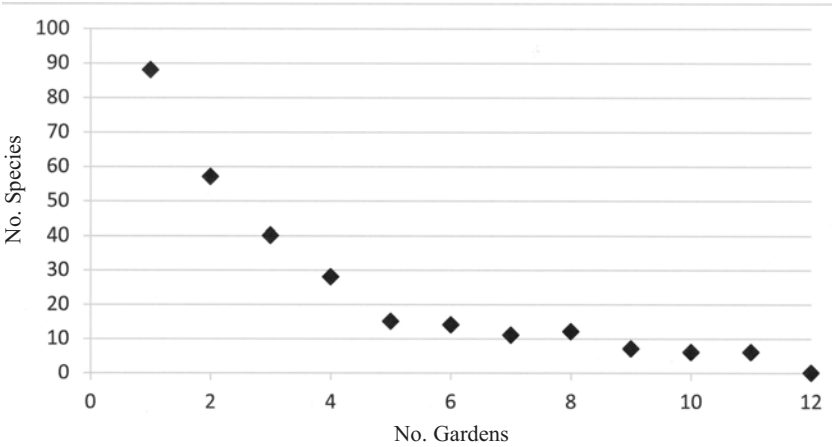

Fig. 1. — The number of gardens in which each species was recorded.

species (present in 5–11 gardens) is a consequence of the lack of high quality species that tend to be in the non-garden characteristic species (present in only 1–4 gardens), resulting in a much higher SQS (Table 3). The SQS tend to be higher in south-east England (1.8–3.8) and lower in northern England (1.3–1.4) (Tables 1 & 4).

The cleptoparasitic load (CL) is the percentage of aculeate species that are cleptoparasites (or parasitoids) on nesting aculeate species. From a review of the literature, Wcislo (1987) found that the CLs for Palearctic bees varied between 12% (Iran) and 33% (Finland), a range of 17%. For 52 English semi-natural sites, the CLs for solitary bees varied between 25–40%, a range of 15% (Archer, unpublished) so supporting the narrow range recorded by Wcislo (1987). Wcislo (1987) also reviewed the wasp

TABLE 2 — THE NUMBER OF SPECIES AND SOLITARY WASP AND BEE FAMILES RECORDED IN TWELVE URBAN OR SUBURBAN GARDENS

Solitary Wasps	No. Species	Solitary Bees	No. Species
Chrysididae	16	Colletidae	13
Tiphiidae	2	Andrenidae	40
Mutillidae	2	Halictidae	38
Sapygidae	2	Melittidae	5
Pompilidae	20	Megachilidae	24
Vespidae – Eumininae	14	Apidae	25
Sphecidae	1		
Crabronidae	78		
Total Solitary Wasps	135	Total Solitary Bees	145
Total Solitary Species		280	

TABLE 3 — ARCHER'S NATIONAL SCORES FOR THE SOLITARY WASPS AND BEES FOUND IN ALL TWELVE URBAN OR SUBURBAN GARDENS, FOR THE NON-GARDEN CHARACTERISTIC SPECIES (FOUND IN 1–4 GARDENS) AND FOR THE GARDEN CHARACTERISTIC SPECIES (FOUND IN 5–11 GARDENS) (not including the vagrant species *Eumenes papillarius* (Christ))

Status	Status Value	No. Species			Quality Score		
	(A)	All spp. (B1)	1–4 (B2)	5–11 (B3)	All spp. (A*B1)	1–4 (A*B2)	5–11 (A*B3)
Universal	1	81	42	39	81	42	39
Widespread	2	106	76	30	212	152	60
Restricted	4	22	21	1	88	84	4
Scarce	8	51	50	1	408	400	8
Rare	16	8	8	0	128	128	0
Very rare	32	11	11	0	352	352	0
Total		279	208	71	1269	1158	111

Species Quality Scores: All species 1269/279 = 4.55; Non-garden characteristic species (found in 1–4 gardens) 1158/208 = 5.57; Garden characteristic species (found in 5–11 gardens) 111/71 = 1.56.

literature, reaching the same conclusion as for the bees, but did not carry out a numerical analysis. For 52 English semi-natural sites, the CLs for solitary wasps varied between 10–25%, a range of 15% (Archer, unpublished).

The wasp CLs for all the gardens, the non-garden characteristic species (present only in 1–4 gardens) and the garden characteristic species (present in 5–11 gardens) fall within the 'Archer narrow range', as do the CLs for the bees for all gardens and the non-garden characteristic species (present only in 1–4 gardens) (Table 5). The garden characteristic bee species (found in 5–11 gardens) have a smaller CL than the 'Archer narrow range' due to a lack of parasitic species (Table 5). The CLs for the wasps of the individual gardens fall within the 'Archer narrow range' except in Oxford where it is slightly higher. The CLs for the bees are lower than the 'narrow range', except for Nightingales and Oxford; these are on the border of the narrow range (Table 4).

TABLE 4 — THE NUMBER OF HIGH QUALITY SPECIES (HQS), SPECIES QUALITY SCORES (SQS), CLEPTOPARASITIC LOADS (CLs) AND AERIAL NESTERS FREQUENCIES (AFs) OF THE TWELVE URBAN OR SUBURBAN GARDENS

Garden	No. HQS	SQS	CL		AF	
			Wasps	Bees	Wasps	Bees
Nightingales	53	3.8	18.6	25.4	53.6	23.9
Lea-side	18	3.1	13.3	12.9	55.8	29.6
Leicester	8	2.1	15.1	24.4	82.2	35.3
Northcroft	7	2.5	13.6	21.7	78.9	29.6
Buckingham	5	2.1	10.5	18.2	61.8	29.6
Oxford	9	2.8	25.9	25.0	76.2	33.3
Hampstead	3	1.9	10.7	21.4	80.0	45.5
York	0	1.3	16.0	16.7	77.3	40.0
Hampton	1	1.8	12.5	15.3	66.7	27.3
Allerthorpe	1	1.4	22.2	20.0	71.4	10.0
Grays	2	2.7	18.2	21.1	66.7	53.3
Dublin	0	1.2	14.2	7.1	83.3	30.8

TABLE 5 — THE RELATIVE FREQUENCY OF THE PARASITIC (CLEPTOPARASITES AND PARASITOIDS) SPECIES FOUND IN ALL TWELVE URBAN OR SUBURBAN GARDENS, AMONG THE NON-GARDEN CHARACTERISTIC SPECIES (FOUND IN 1–4 GARDENS) AND AMONG THE GARDEN CHARACTERISTIC SPECIES (FOUND IN 5–11 GARDENS)

	No. Parasites* (P)			No. Nesters (N)			Cleptoparasitic Load CL=100*P/(P+N)		
	All species	1–4	5–11	All species	1–4	5–11	All species	1–4	5–11
Wasps	24	19	5	108	80	28	18.2	19.2	15.2
Bees	41	36	5	104	71	33	28.3	33.6	13.2

**Ceptes semiauratus*, *Tiphia femorata*, *T. minuta* excluded as they are parasites of non-aculeates.

TABLE 6 — THE NESTING HABITS OF THE SPECIES FOUND IN ALL TWELVE URBAN OR SUBURBAN GARDENS, OF THE NON-GARDEN CHARACTERISTIC SPECIES (FOUND IN 1–4 GARDENS) AND OF THE GARDEN CHARACTERISTIC SPECIES (FOUND IN 5–11 GARDENS)

	No. Aerial Nesters (A)			No. Subterranean Nesters (S)			Aerial Nester Frequency AF=100*A/(A+S)		
	All species	1–4	5–11	All species	1–4	5–11	All species	1–4	5–11
Wasps	59	37	23	49	43	5	54.6	46.2	82.1
Bees	23	11	12	81	60	21	22.1	15.4	36.4

The aerial-nester frequency (AF) is the percentage of aculeate species that have aerial nest sites. The AFs for all the British species of solitary wasps is 46.2% and for solitary bees is 17.9%.The AFs for the wasps and bees of all species and the garden characteristic species (present in 5–11 gardens) are higher than the British value, but are of similar value for the non-garden characteristic species (found in 1–4 gardens), although the AFs for bees are slightly low (Table 6). The AFs for the individual gardens for the wasps and bees are high except for the bees of Allerthorpe (Table 4).

DISCUSSION

Table 1 show that gardens can have a high diversity of species. Frankie & Ehler (1978) comment on high diversity found in urban areas and McIntyre (2000) found gardens, in particular, to be an important refuge for insects. Frankie & Ehler (1978) related this high species diversity to the heterogeneous environments of urban habitats where a great variety of the resource needs of insects can be found. Smith *et al.* (2005; 2006) provide evidence for the importance to insects of heterogeneous gardens from an invertebrate study in 61 Sheffield gardens.

The relatively higher number of solitary species found in some gardens (Table 1) requires further explanation. The exceptionally high number of species in the Nightingales garden is probably a consequence of its larger size with a large number of habitats, its sandy soil, its location surrounded by Lowland heathland National Nature Reserves (NNRs), and the efforts made to attract species. This garden is located in south-eastern England, which has the highest diversity of aculeate species. The sandy garden of Lea-side is in south-eastern England and located close to Lowland heathland NNRs. Research in the Leicester garden is outstanding for the length of the study (27 years) conducted with the use of a Malaise trap. The garden at Northcroft is also in south-eastern England, next to coastal sand dunes and an effort was made to attract species.

The relatively low Species Quality Scores (SQSs) of the garden characteristic species found in 5–11 of the gardens was also noted by Davis (1978) and Davis & Glick (1978) who illustrated how urbanisation

causes the fragmentation of natural and semi-natural habitats. This fragmentation results in a general reduction of species richness, particularly of sensitive species. SQSs can be used to compare sites of varying size since although the Quality Scores for sites are significantly correlated with their size; the SQSs are not (Archer, 1999). It would seem that the Low and High Quality Species increase together as the area of a site increases. Certainly the lower SQS of the Leicester garden (2.1, Table 4) in comparison with semi-natural Midland sites (SQS 2.6–3.4; Archer, 2006) and the SQS from the garden in suburban York (1.3, Table 4) compared with surrounding semi-natural sites (2.2–2.5, Archer, 2011, 2012) supports these comments. Presumably semi-natural sites with higher SQSs have the resource requirements of the High Quality Species, which have been lost or greatly reduced and isolated in an urban setting. Gardens are an important refuge for the commoner, but less so for the rarer, species. Jacob-Remacle (1984) also found that the majority of aculeate wasp and bee species found in the city of Liège, Belgium, were common and widespread species.

The smaller CLs for the garden characteristic species (found in 5–11 gardens in the present study) was also noted by Jacob-Remacle (1984) who found that in the city of Liège aculeate parasites of bees were less frequently observed, while the chrysid parasites of solitary wasps were frequently observed. Matheson, Ascher & Langellotto (2008) also noted the rarity of bee parasites in the city of New York, U.S.A.

The higher Aerial Nester Frequencies (AFs) for the garden characteristic species (found in 5–11 gardens, Table 6) and generally for the individual gardens (Table 4) were also noted by Jacob-Remacle (1984) who found that in the centre of the city of Liège the aerial nesting solitary wasps and bees were twice as numerous as subterranean nesters. Matheson, Ascher & Langellotto (2008) found there was a lack of subterranean nesting bees in the city of New York. Gayubo & Torres (1991) found a lack of subterranean nesting sphecid wasps in the city of Salamanca, Spain.

To understand the lack of parasitic bee specimens in gardens, Archer (2013) proposed that bee parasites are usually found around their hosts' nesting sites which, if subterranean, would tend not to be present in a garden. The implication is that bees would be only visiting the garden for collecting pollen (not needed by the parasites) and nectar. Matheson, Ascher & Langellotto (2008) also suggested that a lack of subterranean nesting bees would result in the lack of their parasites. Gardens are often unsuitable for subterranean nesters because of the lack of bare and sparsely vegetated soil surface and soil disturbance by the gardener.

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APPENDIX
THE 71 SPECIES OF GARDEN CHARACTERISTIC SOLITARY WASP AND BEE FOUND IN 5–11 URBAN OR SUBURBAN GARDENS

Chrysididae: *Pseudomalus auratus* (Linn.), *Chrysis angustula* Schenck, *C. ignita* (Linn.)
Sapygidae: *Sapyga quinquepunctata* (Fab.)
Pompilidae: *Dipogon variegatus* (Linn.)
Eumeninae: *Ancistrocerus gazella* (Panzer), *A. parietinus* (Linn.), *A. parietum* (Linn.), *A. trifasciatus* (Müller), *Symmorphus bifasciatus* (Linn.)
Crabronidae: *Trypoxylon attenuatum* (Smith), *T. clavicerum* Lepeletier & Serville, *T. figulus* (Linn.), *Crossocerus annulipes* (Lepeletier & Brullé), *C. distinguendus* (Morawitz), *C. elongatulus* (van der Linden), *C. megacephalus* (Rossi), *C. pusillus* Lepeletier & Brullé, *Ectemnius cavifrons* (Thomson), *E. cephalotes* (Olivier), *E. continuus* (Fab.), *Rhopalum clavipes* (Linn.), *Psenulus pallipes* (Panzer), *Spilomena troglodytes* (Van der Linden), *Pemphredon inornata* Say, *P. lethifer* (Shuckard), *P. lugubris* (Fab.), *Passalaceus corniger* Shuckard, *P. gracilis* (Curtis), *P. insignis* (Van der Linden), *Mellinus arvensis* (Linn.), *Nysson trimaculatus* (Rossi), *Cerceris rybyensis* (Linn.)
Colletidae: *Colletes daviesanus* Smith, *Hylaeus communis* Nylander, *H. hyalinatus* Smith
Andrenidae: *Andrena bicolor* Fab., *A. carantonica* Pérez, *A. flavipes* Panzer, *A. fulva* (Müller *in* Allioni), *A. haemorrhoa* (Fab.), *A. minutula* (Kirby), *A. nigroaenea* (Kirby), *A. nitida* (Müller), *A. semilaevis* Pérez, *A. wilkella* (Kirby)
Halictidae: *Halictus rubicundus* (Christ)*, H. tumulorum* (Linn.), *Lasioglossum albipes* (Fab.), *L. calceatum* (Scopoli), *L. leucopus* (Kirby), *L. morio* (Fab.), *L. smeathmanellum* (Kirby), *L. villosulum* (Kirby), *Sphecodes geoffrellus* (Kirby)

Megachilidae: *Anthidium manicatum* (Linn.), *Chelostoma campanularum* (Kirby), *Osmia bicornis* (Linn.), *O. caerulescens* (Linn.), *O. leaiana* (Kirby), *Megachile centuncularis* (Linn.), *M. ligniseca* (Kirby), *M. versicolor* Smith, *M. willughbiella* (Kirby)
Apidae: *Nomada flava* Panzer, *N. goodeniana* (Kirby), *N. marshamella* (Kirby), *Ahthophora furcata* (Panzer), *A. plumipes* (Pallas), *A. quadrimaculatus* (Panzer), *Melecta albifrons* (Forster).