

## THE WASPS AND BEES (*HYMENOPTERA: ACULEATA*) OF POLLINGTON QUARRY IN WATSONIAN YORKSHIRE

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Pollington Quarry was brought to my notice by P. Kendall. It is rare to find a Yorkshire site with more than 100 species of aculeate wasps and bees, and even rarer to find such a site that had not been previously explored. Only four other sites, Allerthorpe Common before its coniferization, Strensall and Blaxton Commons and Crow Wood have more than 100 species.

Pollington Quarry (SE6119, SE6120) is a disused sand quarry of c.9 ha situated in the Humberhead Levels Natural Area, c.3 km south-east of Snaith and c.16 km north of Doncaster. The site has extensive bare sandy areas varying from flat to vertical surfaces which provide nesting sites for subterranean nesters. There are a variety of flowers providing pollen and nectar resources including herbs (White Dead Nettle, Bird's Foot Trefoil), shrubs (Bramble, Broom, Hawthorn, Sallow) and trees (Sycamore). There are also a few pieces of dead wood in sunny situations which provide nesting sites for some aerial nesters.

### METHODS

Between 1998 and 2002, 28 visits (c.3 hours) were made to Pollington Quarry distributed throughout the year as follows: April (4 visits), May (5), June (5), July (5), August (5) and September (4). During each visit, all species of aculeate wasps and bees were recorded and usually collected with a hand net for identification. These records represent the Archer sample.

In addition, P. Kendall made two visits (30 July 1997, 17 June 2000) and J.T. Burn made nine visits (May 2000–July 2003), and made their records available to the author. Specimens collected by P. Kendall have been seen by the author. The records of Archer, Kendall and Burn represent the composite sample.

In the following account, the nomenclature is mainly according to Kloet and Hincks (1978). An up-to-date checklist can be found on the Bees, Wasps and Ants Recording Society (BWARS) web pages at <http://www.bwars.com/>.

### SPECIES PRESENT AND SEASONAL PROGRESSION OF SPECIES

A full list of the species recorded is given in Appendix 1. 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 wasp family, Sphecidae, is the dominant solitary wasp taxon in terms of the number of species and records and the Chrysididae and Pompilidae are well represented as records, although with a smaller number of species. Among the solitary bee taxa, the Andreninae and Halictinae are dominant in terms of both the number of species and records, although the Colletinae are well represented as records.

Based on the Archer sample, Table 2 shows the average number of solitary species recorded during each visit for each month. June and July were the best months, with an average of c.22 species per visit. The average number of species for all visits was c.16 species.

May to August were the best months for recording solitary wasp species, with May, June and July the most productive months for first recording of species (Table 3). The most frequent species found were the fly hunters *Oxybelus uniglumis* and *Crossocerus quadrimaculatus*, the caterpillar hunter *Ammophila sabulosa*, the aphid hunters *Diodontus minutus* and *D. tristis*, the beetle hunter *Entomognathus brevis* and the spider hunter *Episyron rufipes*. All these species are subterranean nesters in bare sandy areas. Also prominent was the parasite *Trichrysis cyanea*, probably using the aerial-nesters of the

TABLE 1  
Number of species and records from Pollington Quarry based on the Archer and Composite (Archer + Kendall + Burn) samples

	Archer Sample		Composite Sample	
	Species	Records	Species	Records
Solitary wasps				
Dryinidae	0	0	5	7
Bethylidae	0	0	1	2
Chrysididae	7	37	7	42
Mutillidae	1	1	1	1
Sapygidae	2	5	2	6
Pompilidae	9	37	9	37
Eumeninae	7	15	7	18
Sphecidae	21	127	24	142
Total solitary wasps	47	222	56	255
Solitary bees				
Colletinae	4	26	4	26
Andreninae	18	86	18	88
Halictinae	19	127	19	129
Megachilinae	5	13	6	15
Anthophorinae	10	36	12	45
Total solitary bees	56	288	59	303
Total solitary species	103	510	115	558
Social wasps & bees				
Vespinae	4		4	
Apinae	9		9	
Total social species	13		13	
Total wasps & bees	116		128	

genus *Trypoxylon* as its host, and the cleptoparasite *Evagetes crassicornis*, whose host was probably the subterranean-nesting *Arachnospila anceps*.

April to August were the best months for recording solitary bee species, with April the most productive month for first recording of species (Table 3). The species most frequently recorded were the following subterranean nesters with their cleptoparasites in brackets: *Colletes daviesanus* (*Epeolus variegatus*), *Andrena bicolor* (*Nomada fabriciana*), *A. nigroaenea* (*N. goodeniana*), *A. barbilabris* (*Sphecodes pellucidus*), *Lasioglossum leucozonium* (*S. ephippius*), *L. villosulum* (*S. geoffrellus*, *S. puncticeps*) and *L. smeathmanellum* (possibly *S. geoffrellus*). One aerial nester, *Hylaeus hyalinatus*, which probably nested in dead plant stems, was also frequently recorded. The mason bee, *Osmia rufa*, was also frequently recorded nesting in hard sandy banks.

#### SPECIES QUALITY OF THE SITE

Archer (2002) developed a regional quality scoring scheme for the solitary species based upon four statuses: Common, Frequent, Occasional and Rare. Ten regionally rare species have been recorded: *Chrysis rutiliventris*, *Crossocerus leucostomus*, *Stigmus solskyi*, *Cerceris arenaria*, *Philanthus triangulum*, *Andrena tibialis*, *A. ovatula*, *Lasioglossum morio*, *Sphecodes reticulatus* and *Nomada fulvicorne* (Table 4). None of the species of social wasps and bees, Dryinidae and Bethyidae are considered regionally rare species.

Few Yorkshire sites have ten or more regionally rare species. At present, only Blaxton Common with ten rare species and Crow Wood with 15 rare species can be grouped with Pollington Quarry although Strensall Common with six rare species and Rossington Bridge with seven rare species are also outstanding sites.

TABLE 2  
Mean number and range of species of solitary wasps and bees recorded per month at Pollington Quarry from the Archer sample

April	May	June	July	August	September
11.0	17.4	23.8	20.8	14.8	5.5
7-14	11-21	19-29	17-25	11-20	5-7

According to Shirt (1987), six species are national Red Data Book status species: *Crossocerus leucostomus*, *Philanthus triangulum*, *Andrena tibialis*, *Sphecodes reticulatus*, *Nomada fulvicornis* and *N. lathburiana*. According to Falk (1991), *C. leucostomus*, *A. tibialis* and *S. reticulatus* should be downgraded to Notable A status, while *Nomada integra* should be given Notable A status and *Monosapyga clavicornis*, *Hylaeus signatus*, *Andrena humilis* and *A. nigriceps* should be given Notable B status.

More investigations by members of BWARS indicate that further status changes are necessary. Archer (1999, 2002) has developed a national quality scoring scheme for the solitary species based on the following six statuses with their official equivalences in brackets: Very rare (Red Data Book status), Rare (Notable A status), Scarce (Notable B status), Restricted, Widespread and Universal. Those with a Very rare, Rare or Scarce status are high quality species, while those with a Restricted, Widespread or Universal status are low quality species. Using this updated scheme, three Rare species (*C. leucostomus*, *N. fulvicornis* and *N. integra*) and eight Scarce species (*Chrysis viridula*, *M. clavicornis*, *Diodontus tristis*, *H. signatus*, *A. humilis*, *A. nigriceps*, *A. tibialis* and *S. reticulatus*) have been recorded from Pollington Quarry. The distributions of *Philanthus triangulum* and *Nomada lathburiana* are now better known partly due to recent increases in range so that they no longer merit national significance, both being low quality species with Widespread status. Status rank cannot be given to species of Dryinidae and Bethyliidae as there is insufficient information about their British distributions.

By giving each of the 109 solitary species of the Composite sample an Archer national quality status, a national quality score of 244 can be calculated (Table 4) with a national species quality score (SQS) of 2.24 (244 divided by the 109 solitary species). How does this SQS compare with SQSs from other Watsonian Yorkshire sites? Archer (2003) divided the SQSs of studied Yorkshire sites into three classes as follows: first class 2.4-2.9; second class 1.8-2.3; and third class 1.2-1.7. Pollington Quarry, rather surprisingly, is a second class site. Currently, Strensall Common and Crow Wood are the only first class Yorkshire sites, although previously Allerthorpe Common, before its coniferization, and Spurn Point were first class sites. The reason why Pollington Quarry fails to qualify as a first class site will be considered in the next section.

TABLE 3  
The number of species, and when species first recorded, per month of solitary species at Pollington Quarry (Archer sample)

	Apr	May	Jun	Jul	Aug	Sep
No. species – Wasps	1	18	26	25	21	9
– Bees	27	31	31	25	21	6
No. species first recorded						
– Wasps	1	18	12	10	6	0
– Bees	27	11	9	5	4	0

#### ESTIMATE THE POTENTIAL NUMBER OF SOLITARY WASP AND BEE SPECIES

One of the problems in the study of any site is the difficulty of not knowing how many more species are present at the site, but as yet unrecorded. Recent advances in non-parametric statistical procedures offer a way of addressing this problem. Chao and

TABLE 4

The Archer regional and national quality scores of the solitary species recorded from Pollington Quarry based on the Composite sample (excluding Dryinidae and Bethylinidae)

Regional Status		No. Species			
Common		36			
Frequent		33			
Occasional		30			
Rare		10			
Total		109			
National Status	Status Value	No. Species		Quality Scores	
		All spp	Tourists removed	All spp.	Tourists removed
	(A)		(B)	(A x B)	
Universal	1	64	52	64	52
Widespread	2	34	26	68	52
Restricted	4	0	0	0	0
Scarce	8	8	8	64	64
Rare	16	3	3	48	48
Total		109	89	244	216
Species Quality Score (SQS) (All species) $244/109 = 2.24$					
Species Quality Score (SQS) (Tourists removed) $216/89 = 2.43$					

Bootstrap estimates (in Colwell & Coddington, 1994) and Jackknife estimates (Heltsh & Forrester, 1983) describe procedures to estimate the potential number of species (species richness) likely to be found on a site after a number of samples have been taken. The presence/absence quantitative estimate of Chao is based on the number of species that are recorded in one (unique species) or two samples. The Jackknife procedure is based on the unique species while the Bootstrap procedure is based on the relative abundance of each species. Because some aculeate species are only active in the spring or summer, it is advisable that samples be distributed throughout the months of adult activity. The software to carry out these statistical procedures was provided by Pisces Conservation Ltd. In practice the software takes 1, 2, etc. samples at random, each time calculating a mean estimate of species richness. The procedure is continuously repeated, 50 times for the Pollington Quarry samples. With a small number of samples the estimates are highly variable, but as more samples are selected these may stabilise, giving confidence in them.

The estimates based on the Archer sample at different sample sizes are given in Figs 1a, 2a and 3a. The estimates do not stabilize. Table 5 shows the species richness estimates for the three procedures; with their 95% confidence limits (except for the Bootstrap procedure) after all 28 samples have been considered. The three estimates differ from each other too widely to have confidence in them.

The recorded species at any site could be resident, tourist or vagrant species. Resident species obtain all their resources, mainly nesting sites and food, from the site under study while tourist species, although living in the geographical area of the site under study, do not normally obtain their resources from the site. Vagrant species normally occur away from the geographical area of the site. It is often difficult to separate resident from tourist species. Probably tourist species will tend to be found on one or a few visits, as only small numbers would be expected to be present on the site and hence less likely to be found. Unfortunately, species found on one or a few visits could also be rare resident species which again have small numbers on site and are less likely to be found. No vagrant species were found at Pollington Quarry.

Two suggestions can be proposed to separate out some tourist species: (1) species that

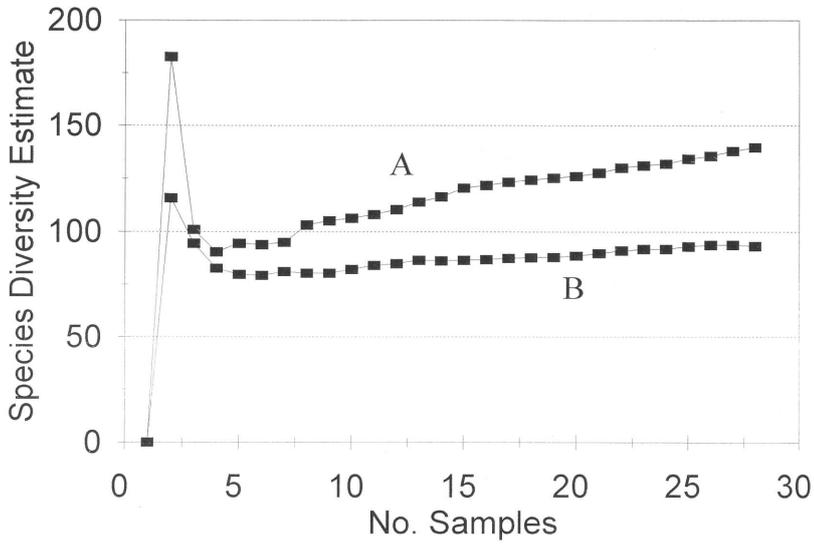


FIGURE 1.

The Chao presence/absence estimate of species richness for Pollington Quarry based on the Archer sample (A) and the Archer sample (B) with tourist species removed.

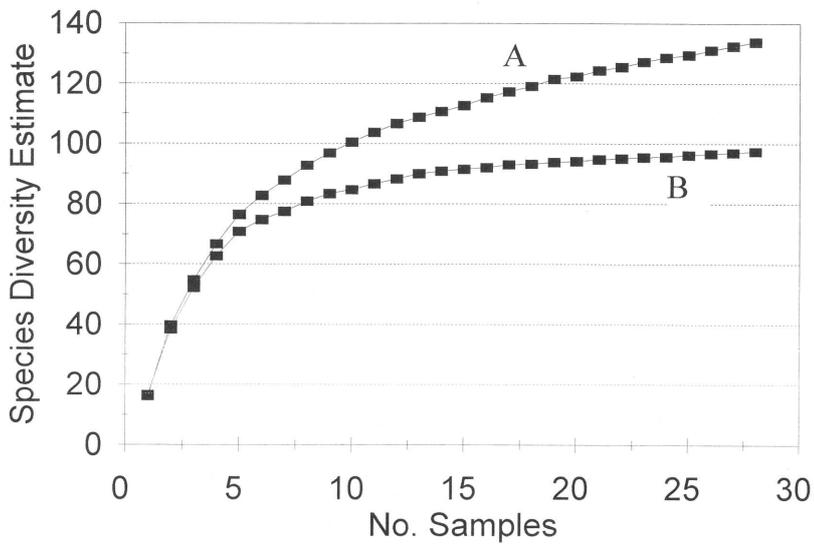


FIGURE 2.

The Jackknife estimate of species richness for Pollington Quarry based on the Archer sample (A) and the Archer sample (B) with tourist species removed.

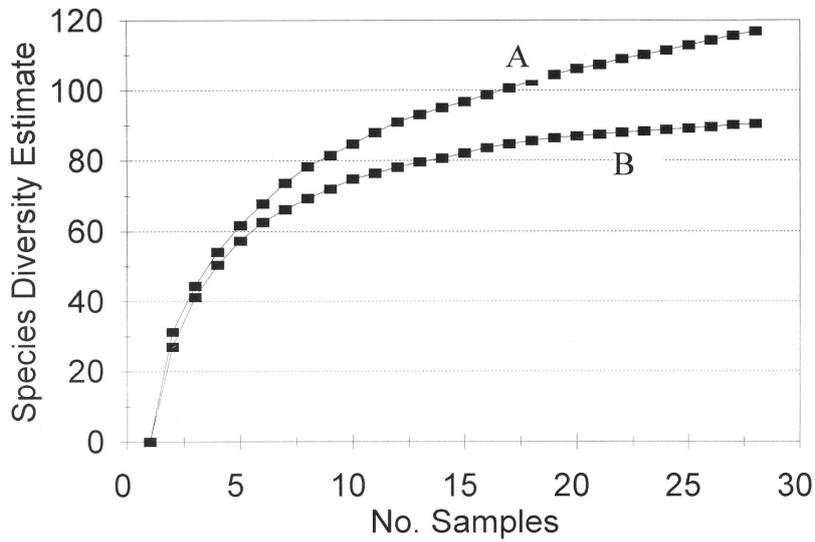


FIGURE 3.

The Bootstrap estimate of species richness for Pollington Quarry based on the Archer sample (A) and the Archer sample (B) with tourist species removed.

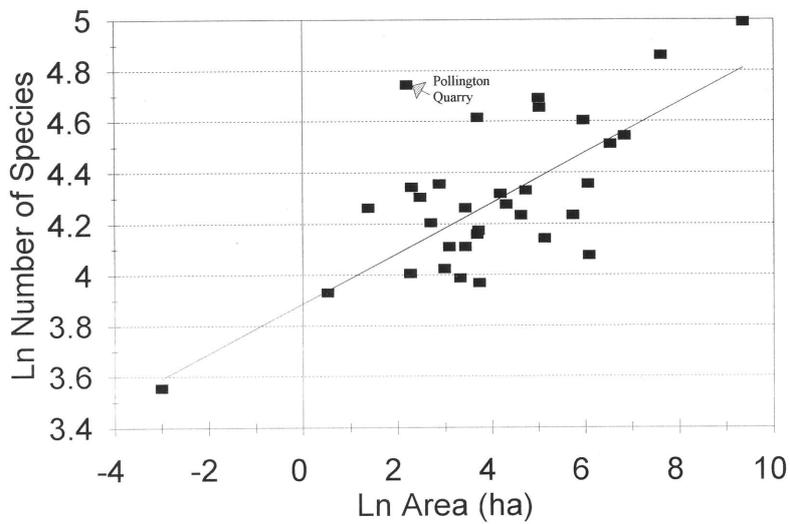


FIGURE 4.

A species-area relationship of 33 sites from the north and north Midlands of England.

are generally common and widespread would be expected to be found on several visits if they are resident species, e.g. *Mellinus arvensis*, *Andrena clarkella* and *A. cineraria* and (2) Cleptoparasites whose host species are tourist species (from 1), e.g. *Nomada lathburiana* and *N. leucophthalma*. With these two criteria, 20 species can be considered tourist species. These species were removed and the three species richness procedures re-run. The new species estimates are given in Figs 1b, 2b and 3b, and the species estimates after all 28 samples were considered are given in Table 5. The three estimates now stabilize and the stabilized estimates are very close to each other. The confidence limits are also reduced. From this analysis it can be predicted that Pollington Quarry has a resident number of species of solitary wasps and bees of 90 to 97 species, of which 86 to 92% have been recorded, and an unknown number of in excess of 20 tourist species. This is a relatively high number of tourist species recorded from a site.

The 20 tourist species are, as expected, those with a Universal or Widespread status. When these 20 species are removed and the species quality exercise repeated the quality score is 216 and the species quality score 2.43 (216 divided by 89 species). The new SQS now indicates that if only the resident species are considered the site become a first class quality Yorkshire site.

#### SPECIES-AREA RELATIONSHIPS

The number of solitary species can be related to site area. The species-area relationship can be found by plotting the number of solitary species recorded at a site against the area of the site, with both the number and area expressed as natural logarithms (ln). Fig. 4 shows a species-area plot of 33 sites from the north and north Midlands of England including Pollington Quarry, together with the regression line for 32 sites with Pollington Quarry excluded. The dot for Pollington Quarry falls well above the regression line and further from the regression line than any other site. Normally such a position for a dot would indicate that for Pollington Quarry is more favourable for species of solitary wasps and bees than the other sites. However, in this case, the dot's high position is a consequence of the large number of tourist species recorded from this site. If the tourist species are removed from the list for Pollington Quarry, then the dot becomes closely associated with the dots for the other sites.

TABLE 5  
Non-parametric estimates of species richness at Pollington Quarry  
based on the Archer sample

All species	Chao estimate	Jackknife estimate	Bootstrap estimate
No. species recorded	103	103	103
No. species estimated	140	134	117
95% confidence limits	112-168	124-144	—
% of estimated spp. found	73.6	76.9	88.0
Tourist removed	Chao estimate	Jackknife estimate	Bootstrap estimate
No. species recorded	83	83	83
No. species estimated	93	97	90
95% confidence limits	85-101	89-105	—
% of estimated spp. found	89.2	85.6	92.2

#### CLEPTOPARASITIC LOAD

The cleptoparasitic load (CL) is the percentage of aculeate species that are cleptoparasitic (or parasitoids) on other host aculeates. Weislo (1987) showed that parasite behaviour among aculeate Hymenoptera correlated with geographical latitude. Thus the 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 in Europe varied between 16% and 33%, a range of 17%.

For 27 Yorkshire sites, the author found that CLs for solitary bees vary from 25.6 to 40.0%, a range of 14.4%, which is close to that found by Wcislo. The CL value for the solitary bees with and without the tourist species (Table 6) falls within this range, and supports Wcislo's hypothesis.

Wcislo gave no CLs for solitary wasps, but from 27 Yorkshire sites CLs vary from 10.3 to 25.0%, a range of 14.7%. The CL value for the solitary wasps with the tourist species (Table 6) falls within this range, but without these species falls at a higher value outside this range. Since cleptoparasitic species tend to remain about or near their hosts' nesting sites it can be hypothesised that tourist species will be host rather than cleptoparasitic species. This hypothesis is supported by the solitary wasps species but less so by the solitary bee species (Table 6).

#### 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), crevices in old walls or exposed on the surface of rock or other hard material. Subterranean nesters nest in the soil, usually in burrows dug by themselves, but sometimes holes and crevices are used after being altered.

The AFs for the solitary species with or without tourist species are given in Table 7. The AFs for all the British species of solitary wasps is 46.2% and solitary bees is 17.9%. From

TABLE 6  
The relative frequency of the cleptoparasitic (or parasitoid) species among the solitary species recorded from Pollington Quarry based on the Composite sample

All species	No. hosts (H)	No. cleptoparasites (C)	Cleptoparasitic Load $CL = 100 \times C/(H+C)$
Solitary wasps	38	12	24.0
Solitary bees	40	19	32.2
Tourists removed	(H)	(C)	$CL = 100 \times C/(H+C)$
Solitary wasps	27	12	30.8
Solitary bees	33	17	34.0

TABLE 7  
The nesting habits of the solitary species from Pollington Quarry based on the Composite sample

All species	No. aerial Nesters (A)	No. subterranean Nesters (S)	Aerial nester frequency $AF = 100 \times A/(A+S)$
Solitary wasps	12	26	31.6
Solitary bees	7	33	17.5
Tourists removed	No. aerial Nesters (A)	No. subterranean Nesters (S)	Aerial nester frequency $AF = 100 \times A/(A+S)$
Solitary wasps	8	19	29.6
Solitary bees	5	28	15.2

29 Yorkshire sites, the AFs for solitary wasps varied from 0 to 90% and for solitary bees from 6.7 to 40.0%. The Pollington Quarry AFs for solitary wasps are just below the British AF and the solitary bee AFs are similar to the British AF. Removing the tourist species has little effect on the values of the AFs.

#### CONCLUSIONS ABOUT POLLINGTON QUARRY

1. It is an excellent site with more than 100 recorded species, including ten regionally rare species and eleven species of national importance.
2. Three estimates of potential species richness were stable and closely agreed with each other after 20 tourist species had been removed from the samples. It is estimated there is 90-97 resident species of solitary wasps and bees, of which 86-92% have been recorded.
3. After the removal of the tourist species, it is shown that it is a first class conservation site.
4. The species-area relationship indicates that for its area the expected number of solitary species has been recorded after removal of the tourist species.
5. The cleptoparasitic analysis indicates that, at least for the solitary wasp species, the tourist species are host rather than cleptoparasitic species.

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#### APPENDIX 1.

List of aculeate wasps and bees recorded from Pollington Quarry.

- Dryinidae: *Anteon flavicornis* (Dalman), *A. gaullei* Kieffer, *A. infectum* (Haliday), *A. pubicornis* (Dalman), *Lonchodryinus ruficornis* (Dalman).
- Bethylidae: *Bethylus fuscicornis* (Jurine).
- Chrysididae: *Hedychridium ardens* (Latreille in Coquebert), *Chrysis angustula* Schenck, *C. ignita* (L.), *C. ruddii* Shuckard, *C. rutiliventris* Abeille de Perrin, *C. viridula* L., *Trichrysis cyanea* (L.).
- Mutillidae: *Myrmosa atra* Panzer.
- Sapygidae: *Monosapyga clavicornis* (L.), *Sapyga quinquepunctata* (Fab.).
- Pompilidae: *Priocnemis exaltata* (Fab.), *P. parvula* Dahlbom, *P. perturbator* (Harris), *Dipogon variegatus* (L.), *Pompilus cinereus* (Fab.), *Episyron rufipes* (L.), *Arachnospila anceps* (Wesmael), *A. spissa* Schiødte, *Evagetes crassicornis* (Shuckard).

- Eumeninae: *Odynerus spinipes* (L.), *Ancistrocerus gazella* (Panzer), *A. oviventris* (Wesmael), *A. parietum* (L.), *A. scoticus* (Curtis), *A. trifasciatus* Müller, *Symmorphus bifasciatus* (L.).
- Vespiniae: *Dolichovespula sylvestris* (Scopoli), *Vespula rufa* (L.), *Paravespula germanica* (Fab.), *P. vulgaris* (L.).
- Sphecidae: *Dryudella pinguis* Spinola, *Tachysphex pompiliformis* (Panzer), *Trypoxylon attenuatum* Smith, *T. figulus* (L.), *Crossocerus elongatulus* (Vander Linden), *C. ovalis* Lepeletier & Brullé, *C. tarsatus* (Shuckard), *C. wesmaeli* (Vander Linden), *C. leucostomus* (L.), *C. podagricus* (Vander Linden), *C. quadrimaculatus* (Fab.), *Lindenius albilabris* (Fab.), *Entomognathus brevis* (Vander Linden), *Oxybelus uniglumis* (L.), *Stigmus solskyi* Morawitz, *Diodontus luperus* Shuckard, *D. minutus* (Fab.), *D. tristis* (Vander Linden), *Ammophila sabulosa* (L.), *Mellinus arvensis* (L.), *Nysson trimaculatus* (Rossi), *Gorytes quadrifasciatus* (Fab.), *Cerceris arenaria* (L.), *Philanthus triangulum* (Fab.).
- Colletinae: *Colletes daviesanus* Smith, *C. fodiens* (Geoffroy in Fourcroy), *Hylaeus signatus* (Panzer), *H. hyalinatus* Smith.
- Andreninae: *Andrena clarkella* (Kirby), *A. fucata* Smith, *A. fulva* Müller in Allioni, *A. scotica* Perkins, *A. bicolor* Fab., *A. cineraria* (L.), *A. nigroaenea* (Kirby), *A. denticulata* (Kirby), *A. nigriceps* (Kirby), *A. haemorrhoea* (Fab.), *A. tibialis* (Kirby), *A. barbilabris* (Kirby), *A. humilis* Imhoff, *A. minutula* (Kirby), *A. semilaevis* Pérez, *A. subopaca* Nylander, *A. ovatula* (Kirby), *A. wilkella* (Kirby).
- Halictinae: *Halictus rubicundus* (Christ), *H. tumulorum* (L.), *Lasioglossum leucozonium* (Schrank), *L. calceatum* (Scopoli), *L. fulvicorne* (Kirby), *L. nitidiusculum* (Kirby), *L. rufitarse* (Zetterstedt), *L. villosulum* (Kirby), *L. cupromicans* (Pérez), *L. leucopus* (Kirby), *L. morio* (Fab.), *L. smeathmanellum* (Kirby), *Sphecodes ephippius* (L.), *S. geoffrellus* (Kirby), *S. gibbus* (L.), *S. monilicornis* (Kirby), *S. pellucidus* Smith, *S. puncticeps* Thomson, *S. reticulatus* Thomson.
- Megachilinae: *Osmia rufa* (L.), *O. caerulea* (L.), *O. leaiana* (Kirby), *Megachile versicolor* Smith, *M. willughbiella* (Kirby), *Coelioxys elongata* Lepeletier.
- Anthophorinae: *Nomada fabriciana* (L.), *N. flavoguttata* (Kirby), *N. fulvicornis* Fab., *N. goodeniana* (Kirby), *N. integra* Brullé, *N. lathburiana* (Kirby), *N. leucophthalma* (Kirby), *N. marshamella* (Kirby), *N. panzeri* Lepeletier, *N. rufipes* Fab., *Epeolus variegatus* (L.), *Anthophora plumipes* (Pallas).
- Apinae: *Bombus lucorum* (L.), *B. terrestris* (L.), *B. hortorum* (L.), *B. lapidarius* (L.), *B. pratorum* (L.), *B. pascuorum* (Scopoli), *B. bohemicus* (Seidl), *B. vestalis* (Geoffroy in Fourcroy), *Apis mellifera* L.

## BOOK REVIEW

**Linnaeus' *Philosophia Botanica***, translated by **Stephen Freer**. Pp. xxvi + 402, incl. several illus. Oxford University Press. 2005. £35.00 paperback.

This is the first full English translation of *Philosophia Botanica*, a major work of Carl Linnaeus who laid the foundation of modern biological systematics and nomenclature. First published in hardback in 2003, this paperback retains the same format and beautiful presentation. As well as providing sample pages from the original Latin text alongside the English translation, the book contains reproductions of all the original plates. The complete translation is supported by Appendices of abbreviations and bibliographies, and two comprehensive indexes of contents and terms and of genera. The translator's meticulous attention to detail and the publisher's lavish production cannot be praised too highly. A valuable resource for taxonomists and of great interest to botanists in general and historians of science.

MRDS