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Editor **M. R. D. Seaward** MSc, PhD, DSc, FLS, The University, Bradford BD7 1DP

THE WASPS AND BEES (HYMENOPTERA: ACULEATA) OF MESSINGHAM SAND QUARRY IN WATSONIAN LINCOLNSHIRE WITH SPECIAL REFERENCE TO RESIDENT AND TOURIST SPECIES

MICHAEL. E. ARCHER
17 Elmfield Terrace, Malton Road, York, YO31 1EH

Messingham Sand Quarry has been found to be a very good site for aculeate wasps and bees, having 117 recorded species, and eight species of national importance. The quarry is a nature reserve of The Lincolnshire Trust for Nature Conservation. It is situated just to the south of Scunthorpe (VC 54, SE9003) in the North Lincolnshire Coversands and Clay Vale Natural Area. With an area of 40.5 ha., the nature reserve is covered by post-glacial sand and consists of a series of lagoons (created by the excavation of sand), heathland remnants, acidic grassland, marsh and coniferous and deciduous woodland.

The nesting areas of the aculeate species are in the open sunny areas. Subterranean nesters are associated with bare ground or ground with thin short vegetation, often on slopes. Aerial nesters use dead wood and plant stems such as bramble. Trees and shrubs, e.g. sallow, hawthorn, gorse, broom, heather and bramble, and herbs, e.g. vetches and bird's foot trefoil, provide important food sources.

Methods

Between 1988 and 2001, the author made 28 visits distributed throughout the year as follows: April (3 visits), May (6), June (6), July (6), August (6) and September (1). The first 14 visits were made between 1988 and 1996, the next five visits during 1999, a further five visits during 2000, and four visits during 2001. During these approximately three hour visits all species of aculeate wasps and bees were recorded and usually collected with a hand net for identification. One additional record of a female *Nomada ruficornis* recorded on 14 May 1994 was supplied by A. Godfrey. In the following account the nomenclature can be related to Kloet & 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 the seasonal progression of species

A full list of recorded species is given in the Appendix. At the family and subfamily 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. There are slightly more solitary wasp species than solitary bee species but distinctly more solitary wasp records than solitary bee records (ratio of wasp 1.33:1.00 bees). Of the solitary wasp families, the Sphecidae is the dominant family both in terms of the number of species and the number of records, although the Pompilidae are well represented. Of the solitary bee subfamilies the Andreninae and Halictinae are the dominant subfamilies, although the Anthophorinae are well represented.

Table 2 shows the numbers of species recorded and when species were first recorded for each month. The most productive months for solitary wasp species were June, July and August with June the most productive month for the first recording of species. June, July and August are the summer months so most wasp species would seem to have to wait until the warmer summer months before the adults can become active. The subterranean nesting spider-hunting wasps (Pompilidae) are particularly noticeable as they fly very quickly just above the surface of the sandy soil in open situations. *Episyron rufipes* and *Pompilus cinereus* nest in aggregations around which swarm numerous males. *Evagetes crassicornis* is a cleptoparasitic pompilid wasp on other subterranean nesting pompilids. The female cleptoparasite enters the cell of its host, eats the host's egg and substitutes her own. Its main hosts are probably *Arachnospila anceps* and *Anoplius nigerrimus*. The commonest

TABLE 1
Number of species and records from Messingham Sand Quarry

	Species	Records
Solitary wasps		
Chrysididae	4	7
Mutillidae	1	2
Pompilidae	14	84
Eumeninae	3	8
Sphecidae	32	165
Total solitary wasps	54	266
Solitary bees		
Colletinae	4	20
Andreninae	14	61
Halictinae	19	78
Megachilinae	2	6
Anthophorinae	8	35
Total solitary bees	47	200
Total solitary species	101	466
Social wasps and bees		
Vespinae	5	
Apinae	11	
Total solitary wasps and bees	16	
Total wasps and bees	117	

sphecid species are the fly hunters *Crabro cribrarius*, *Ectemnius continuus*, *Crossocerus quadrimaculatus* and *Oxybelus uniglumis*; the caterpillar hunter *Ammophila sabulosa*; the beetle hunter *Entomognathus brevis*; and the small aphid hunter *Diodontus tristis*. All these sphecid species are subterranean nesters except for *E. continuus* which nests in decaying wood. *Oxybelus uniglumis* also nests in aggregations and carries its captured prey on its extended sting.

The most productive months for solitary bee species were May, June, July and August with April, May and June the most productive months for the first recording of species. The

TABLE 2
Number of solitary species and months when species were first recorded at Messingham Sand Quarry

	Apr	May	Jun	Jul	Aug	Sep
Number of species						
Wasps	0	5	37	37	31	9
Bees	14	25	20	17	17	4
Number of species first recorded						
Wasps	0	5	34	10	5	0
Bees	14	17	11	4	1	0

commonest species include the spring species *Andrena haemorrhoa* and *A. scotica*, the summer species *Colletes succinctus* and *A. denticulata* which are particularly dependent on heather as a pollen source, and *Andrena bicolor* which has a spring and summer generation. Fertilized females of *Halictus rubicundus*, *Lasioglossum leucozonium* and *L. villosulum* emerge in the spring and rear a summer generation of females and males. *Specodes monilicornis*, which is the cleptoparasite of *H. rubicundus*, was also particularly noticeable. All of above solitary bee species are subterranean nesters.

The mean of species of solitary wasps and bees found per visit for each month was: April (5.7 species, range 5-7 species), May (10.8, range 5-14), June (17.0, range 13-23), July (17.8, range 12- 21), August (15.7, range 11-20), September (1 visit, 14 species).

Estimating 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 (in Colwell & Coddington, 1994) and Heltshe and 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 (two-occasion species) samples. The Jackknife estimate of Heltshe and Forrester is based on the unique 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.

The statistical procedures were run after 14, 19, 24 and 28 samples (or visits) had been made. 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 dependent on the number of samples. With a small number of samples the estimates are erratic, but as more samples are selected these may stabilise, giving confidence in them. The estimates of species richness with their 95% confidence limits are given in Table 3. The estimates of species richness based upon Chao procedure after 14 and 28 visits are given in Figs 1 and 2. The estimates stabilise after 28 visits with an estimated species richness of about 127 species of which 101 species (about 80%) have been recorded.

Previous experience using non-parametric statistical procedures to determine estimates of species richness from sites in Watsonian Yorkshire and Lincolnshire produced stabilised estimates after 12 (Gibraltar Point, Archer 1998, 2000) to 18 (Gundale, Archer 2001) visits. As such, the number of visits (28) to Messingham Sand Quarry is much larger. Why should this be so?

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, do not normally obtain their resources from the site. Vagrant species, normally occurring away from the geographical area of the site, were not found at Messingham Sand Quarry.

It is often difficult to separate resident and tourist species. Probably tourist species will tend to be unique species, or found on few occasions, as only small numbers would be expected to be present on the site and hence unlikely to be found. Unfortunately unique species could also be rare resident species, which again have small numbers on site and are hence unlikely to be found.

Table 4 shows the number of visits on which each species was recorded. There are 28 unique species, which represents more than a quarter (27.7%) of all the recorded species. Clearly there are many species that could be rare resident or tourist species. It is therefore necessary to generate more specific arguments to begin to separate the rare resident and tourist species. Three arguments can be forwarded to separate out, at least, some of the tourist species: 1. Parasitic species whose host(s) is (are) not present on the site – *Chrysis angustula*, *Trichrysis cyanea*, *Nomada striata*, *N. panzeri*. 2. Species which are not

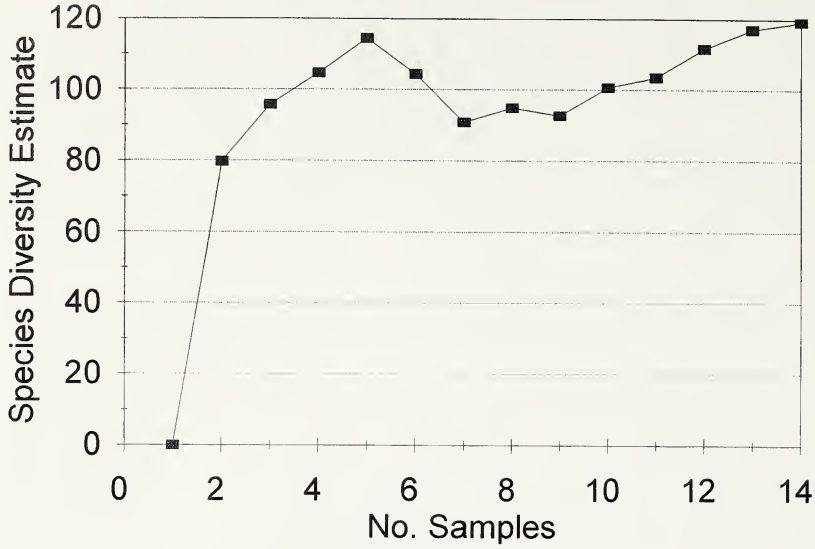

FIGURE 1.
The Chao presence/absence estimate of species richness for all records after 14 visits to Messingham Sand Quarry.

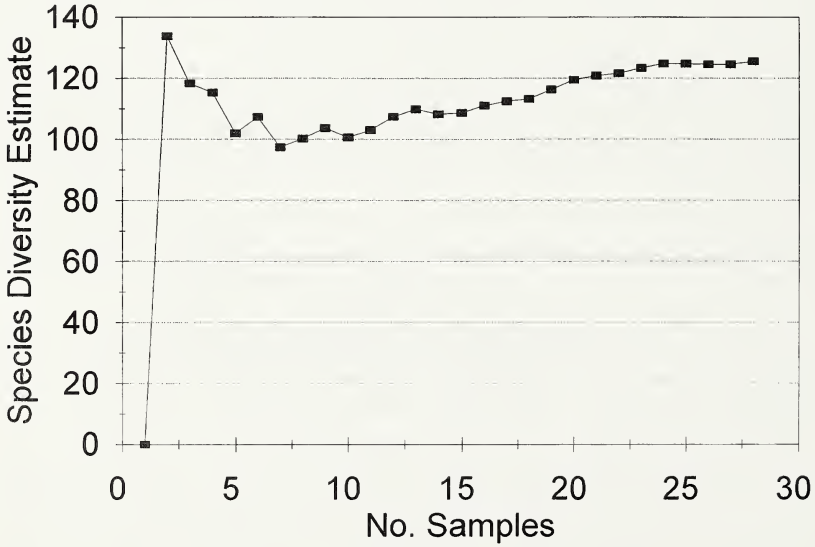

FIGURE 2.
The Chao presence/absence estimate of species richness for all records after 28 visits to Messingham Sand Quarry.

TABLE 3
Non-parametric estimates of species richness at Messingham Sand Quarry with the tourist species after 14, 19, 24 and 28 visits

	Chao estimate	Jackknife estimate
After 14 visits		
No. species recorded	78	78
No. species estimated	119	110
95% confidence limits	87-151	95-125
% of estimated species found	66	71
After 19 visits		
No. specis recrorded	90	90
No. species estimated	126	122
95% confidence limites	98-154	108-136
% of estimated species found	71	74
After 24 visits		
No. species recorded	98	98
No. species estimated	137	130
95% confidence limits	107-167	119-141
% of estimated species found	72	75
After 28 visits		
No. species recorded	101	101
No. species estimated	126	128
95% confidence limits	105-146	115-140
% of estimated species found	80	79

associated with the habitats present on the site because they lack the necessary resources – *Ectemnius sexcinctus*, *Philanthus triangulum*, *Andrena lapponica*, *A. wilkella*, *Halictus tumulorum*. *E. sexcinctus* and *P. triangulum* are two species which have recently undergone a national expansion in range and would have been expected to be found on several visits if their required resources were present on the site. 3. Species that are locally common and would have been expected to be found on several visits if they were resident species – *Priocnemis schioedtei*, *Andrena subopaca*, *A. chrysosceles*. These twelve tourist species were all unique species except for *Chrysis angustula*, *Andrena chrysosceles*, *Halictus tumulorum* and *Nomada panzeri* which was recorded on two visits.

With the twelve tourist species removed a stable estimate of species richness is obtained after 19 visits (Table 5, Fig. 3). This smaller number of visits corresponds with earlier

TABLE 4
Number of visits on which each species of solitary wasp and bee was found

No. visits	No. species	No. visits	No. species
1	28	9	3
2	16	10	1
3	11	11	1
4	6	12	1
5	14	13	0
6	7	14	1
7	7	15	1
8	4		

experience and indicates that Messingham Sand Quarry has about 100 resident solitary wasp and bee species of which 80 species (about 80%) have been recorded.

Two further problems now arise. Firstly, why are tourist species present on the site? Have the tourist species flown onto the site by accident or are there functional reasons for

TABLE 5
Non-parametric estimates of species richness at Messingham Sand Quarry without the tourist species after 14, 19, 24 and 28 visits

	Chao estimate	Jackknife estimate
After 14 visits		
No. species recorded	71	71
No. species estimated	97	96
95% confidence limits	74-120	84-108
% of estimated species found	73	74
After 19 visits		
No. specis recrorded	80	80
No. species estimated	98	103
95% confidence limites	81-115	92-114
% of estimated species found	82	78
After 24 visits		
No. species recorded	86	86
No. species estimated	108	108
95% confidence limits	88-128	100-116
% of estimated species found	80	80
After 28 visits		
No. species recorded	89	89
No. species estimated	106	108
95% confidence limits	89-122	100-117
% of estimated species found	84	82

their presence? Although it not possible to rule out completely their accidental presence it is possible that many tourist species are in dispersal phase, looking for new habitat for range expansion. As examples, from among the suggested tourist species, *Philanthus triangulum* requires as a nesting site a large sloping, bare sandy areas facing south. Such sandy areas are absent at Messingham Sand Quarry. There are also tourist parasites present which would be unable to find their hosts. Furthermore, *Halictus tumulorum* is usually associated with calcareous open sites while Messingham Sand Quarry is a sandy site.

The second problem relates to the observation that even with the tourist species removed, after the 24th and 28th samples, the species richness estimates, although still stable, have increased to about 108 species. It might be expected that once a stabilised estimate had been obtained, after the 19th sample the estimate would continue to have a similar value for a few years. Certainly the estimates after the 24th and 28th samples are similar, so that perhaps stopping after the 19th sample was premature. The advice would then be that a few more samples should be taken even after the estimates have stabilised.

Alternatively, it is possible that because of management changes at Messingham Sand Quarry some rare resident species have increased their population sizes and so become more visible to the recorder. Certainly management was actively creating new habitats during the period of this study. These management changes could also have allowed new immigrant species to find the resources they need to complete their life-histories on site.

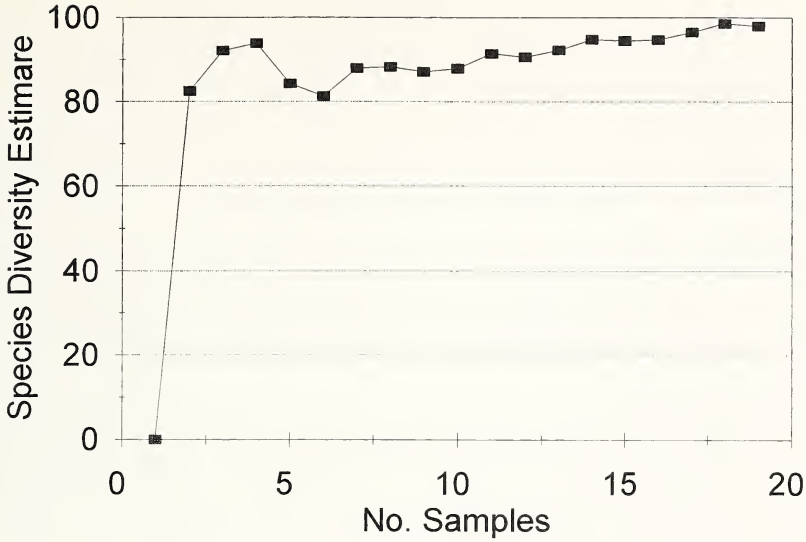

FIGURE 3.
The Chao presence/absence estimate of species richness for all records, less the tourist species, after 19 visits.

SPECIES-AREA RELATIONSHIP

Another problem in the study of any site, particularly when the estimate of the number of species is greater than the number recorded, is the difficulty of knowing when the recorded species list is sufficiently complete to enable reasonable comparisons with other sites to be carried out. One way to resolve this question is to make use of the species-area relationship (Usher, 1986), where the number of recorded solitary species and the area of each site, both expressed as natural logarithm (ln), are plotted against each other. Archer (1999) found that for north Midland and northern English sites the resulting correlation coefficient was statistically highly significant, indicating a positive linear relationship. Thus, if the number of species in relation to the area of the site falls within the range of these sites, then the site may reasonably be compared with other sites. The data for Messingham Sand Quarry fall within this range (95% confidence limits of the regression coefficient) so can be compared with other sites from the north Midlands and northern England.

QUALITY ASSESSMENT OF THE SOLITARY SPECIES

According to Shirt (1987), *Andrena tibialis* and *Sphecodes reticulatus* are nationally rare or 'Red Data Species' (RDB3). Falk (1991) suggested these two species be downgraded to nationally scarce status (Na). In addition, according to Falk (1991), *Cleptes semiauratus*, *Arachnospila minutula* and *Sphecodes crassus* should be given nationally scarce status (Nb). Recent work by the Bees, Wasps and Ants Recording Society would indicate that a further three species should be given a national scarce status (Archer 1999, 2002): *Anoplius concinnus*, *A. viaticus* and *Diodontus tristis*. These eight species are all at or near the northern edge of their national distribution.

By giving each of the 101 species of solitary wasps and bees an Archer national status (Archer 1999, 2002), a national quality score of 187 (Table 6) can be calculated for Messingham Sand Quarry and a national species quality score (SQS) of 1.9 (187/101).

TABLE 6
The Archer national quality scores of the solitary species recorded at Messingham Sand Quarry

National Status	Status value (A)	No. species (B)	Quality scores (A x B)
Universal	1	63	63
Widespread	2	30	60
Restricted	4	0	0
Scarce	8	8	64
Total		101	187

National SQSs for other Lincolnshire sites have similar values: Gibraltar Point (1.7), Kirkby Moor (1.9), Risby Warren (1.8) and Saltfleetby-Theddlesthorpe dunes (1.8).

Cleptoparasitic Load

The cleptoparasitic load (CL) is the percentage of aculeate species that are cleptoparasites (or parasitoids) on other host aculeates. Wcislo (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, except hot deserts where the occurrence of rainfall would tend to synchronise life-history characteristics. From a review of the literature Wcislo (1987) found that the CLs for bees in Europe varied between 16% and 33%, a range of 17%. As such, CLs for sites in Britain should have similar values. For the north Midlands and north England, the CLs for species of solitary bees varies from 21.7%-36.6% (range 14.9%) (Archer 1999). The CL for Messingham Sand Quarry (Table 7) falls within this range and therefore supports the Wcislo's hypothesis.

Wcislo (1987) gives no CLs for wasps, but Archer (1999) found that CLs of solitary wasps for sites from north Midlands and north England varied from 10.3%-22.2%. The CL for Messingham Sand Quarry (Table 7) falls within this range.

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 plant stem cavities (e.g. bramble), old snail shells, or crevices in old mortar 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 wasp and bee species are given in Table 8. The AFs for all the British species of solitary wasps is 46.2% and solitary bees is 17.9%. Thus the AFs for Messingham Sand Quarry are lower than the national values, probably indicating the lack of dead wood in sunny situations.

TABLE 7
The relative frequency of the cleptoparasitic (or parasitoid) species among the solitary species recorded from Messingham Sand Quarry

	No. hosts (H)	No. cleptoparasites (C)	Cleptoparasitic load CL = 100 x C/(H+C)
Solitary wasps	7*	46	13.2%
Solitary bees	16	31	34.0%

**Cleptes semiauratus* not included

TABLE 8
The nesting habits of the solitary species from Messingham Sand Quarry

	No. aerial nesters (A)	No. suberranean nesters (S)	Aerial nester frequency AF = 100 x A/(A+S)
Solitary wasps	13	33	28.3%
Solitary bees	3	28	9.7%

SUMMARY

Messingham Sand Quarry:

1) is a very good site for aculeate wasps and bees with 117 recorded species and eight species of national importance;
2) is predicted to have a species diversity of 126-128 species, of which probably about 20 are tourist species;
3) has the expected number of solitary species for its area, and so can be properly be compared with other sites;
4) has a species quality score expected for the best Lincolnshire sites;
5) has solitary wasp and bee cleptoparasitic loads similar to those from other sites as predicted by Wcislo (1987); and
6) has a low aerial nester frequency compared with British data indicating relatively fewer aerial nesters compared with subterranean nesters.

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APPENDIX

Chrysididae. *Cleptes semiauratus* (L.), *Hedychridium ardens* (Latreille *in* Coquerbert), *Chrysis angustula* Schenck, *Trichrysis cyanea* (L.).

Mutillidae. *Myrmosa atra* Panzer.

Pompilidae. *Priocnemis exaltata* (Fab.), *P. parvula* Dahlbom, *P. perturbator* (Harris), *P. schioedtei* Haupt, *Pompilus cinereus* (Fab.), *Arachnospila anceps* (Wesmael), *A. minutula* (Dahlbom), *A. trivialis* (Dahlbom), *Evagetes crassicornis* (Shuckard), *Anoplius concinnus* (Dahlbom), *A. infuscatus* (Vander Linden), *A. nigerrimus* (Scopoli), *A. viaticus* (L.), *Episyron rufipes* (L.).

Eumeninae. *Ancistrocerus parietinus* (L.), *A. trifasciatus* (Müller), *Symmorphus bifasciatus* (Panzer).

Vespinae. *Dolichovespula media* (Retzius), *D. sylvestris* (Scopoli), *Paravespula germanica* (Fab.), *P. vulgaris* (L.), *Vespula rufa* (L.).

Sphecidae. *Dryudella pinguis* (Dahlbom), *Tachysphex pompiliformis* (Panzer), *Trypoxylon attenuatum* Smith, *T. figulus* (L.), *Crabro cribrarius* (L.), *C. peltarius* (Schreber), *Crossocerus ovalis* Lepeletier & Brullé, *C. pusillus* Lepeletier & Brullé, *C. tarsatus* (Shuckard), *C. wesmaeli* (Vander Linden), *C. annulipes* (Lepeletier & Brullé), *C. quadrimaculatus* (Fab.), *Ectemnius continuus* (Fab.), *E. sexcinctus* (Fab.), *Lindenius albilabris* (Fab.), *Entomognathus brevis* (Vander Linden), *Rhopalum coarctatum* (Scopoli), *Oxybelus uniglumis* (L.), *Mimesa equestris* (Fab.), *M. lutaria* (Fab.), *Pemphredon inornata* Say, *P. lethifera* (Shuckard), *Diodontus luperus* Shuckard, *D. tristis* (Vander Linden), *Passaloecus gracilis* (Curtis), *Ammophila sabulosa* (L.), *Mellinus arvensis* (L.), *Nysson spinosus* (Forster), *N.trimaculatus* (Rossius), *Gorytes quadrifasciatus* (Fab.), *Argogorytes mystaceus* (L.), *Philanthus triangulum* (Fab.).

Colletinae. *Hylaeus communis* Nylander, *Colletes daviesanus* Smith, *C. fodiens* (Geoffroy *in* Fourcroy), *C. succinctus* (L.).

Andreninae. *Andrena clarkella* (Kirby), *A. fucata* Smith, *A. lapponica* Zetterstedt, *A. praecox* (Scopoli), *A. scotica* Perkins, *A. bicolor* Fab., *A. nigroaenea* (Kirby), *A. denticulata* (Kirby), *A. haemorrhoa* (Fab.), *A. tibialis* (Kirby), *A. barbilabris* (Kirby), *A. chrysosceles* (Kirby), *A. subopaca* Nylander, *A. wilkella* (Kirby).

Halictinae. *Halictus rubicundus* (Christ), *H. tumulorum* (L.), *Lasioglossum latriventre* (Schenck), *L. leucozonium* (Schranck), *L. albipes* (Fab.), *L. calceatum* (Scopoli), *L. nitidiusculum* (Kirby), *L. punctatissimum* (Schenck), *L. rufitarse* (Zetterstedt), *L. villosulum* (Kirby), *L. leucopus* (Kirby), *Sphecodes crassus* Thomson, *S. ephippius* (L.), *S. geoffrellus* (Kirby), *S. gibbus* (L.), *S. monilicornis* (Kirby), *S. pellucidus* Smith, *S. puncticeps* Thomson, *S. reticulatus* Thomson.

Megachilinae. *Megachile versicolor* Smith, *M. willughbiella* (Kirby).

Anthophorinae. *Nomada fabriciana* (L.), *N. goodeniana* (Kirby), *N. leucophthalma* (Kirby), *N. marshamella* (Kirby), *N. panzeri* Lepeletier, *N. ruficornis* (L.), *N. striata* Fab., *Epeolus variegatus* (L.).

Apinae. *Bombus lucorum* (L.), *B. terrestris* (L.), *B. lapidarius* (L.), *B. jonellus* (Kirby), *B. pratorum* (L.), *B. hortorum* (L.), *B. pascuorum* (Scopoli), *B. bohemicus* (Seidl), *B. sylvestris* (Lepeletier), *B. vestalis* (Geoffroy *in Fourcroy), Apis mellifera* L.