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# The aculeate wasps and bees (Hymenoptera: Aculeata) of Saltfleetby-Theddlethorpe NNR in Watsonian Lincolnshire, including statistical procedures for estimating species richness

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The aims of this paper are to describe the aculeate wasp and bee fauna of Saltfleetby-Theddlethorpe NNR, compare this fauna with that of near-by Gibraltar Point NNR (a coastal locality of about 437 hectares consisting of sand dunes, and salt and freshwater marshes) (Archer, 1998*a*), and then use non-parametric statistical procedures to estimate potential species diversity.

Saltfleetby-Theddlethorpe NNR is a good locality for aculeate wasps and bees, having 77 recorded species, including four of national importance. The area, about 440 hectares, is situated on the Lincolnshire coast between Saltfleet Haven in the north and Mablethorpe North End in the south (V.C. 54, TF49, TF48). The locality consists of sand dunes, salt and freshwater marshes as well as tidal sand and mudflats. The tidal sand and mudflats occupy a large part of the NNR and are not used by the aculeate wasps and bees. The non-tidal area is about 313 hectares.

The open grassy areas are rich in shrubs, e.g. bramble and hawthorn, and herbs, e.g. bird's foot trefoil, hogweed and white deadnettle, which provide food sources for the aculeates. The nesting areas of the aculeates are in the open sunny parts of the sand dunes and the edges of the shrub areas. The subterranean nesters mainly nest in the bare ground or ground with a short vegetation cover, often on slopes. The aerial nesters use the dead wood, such as elder, and dead plant stems, such as bramble.

## Methods

Between 1984 and 1998, I made 13 visits distributed throughout the year as follows: May (4 visits), June (3), July (3) and August (3). One of the visits during May was unsuitable for recording aculeate wasps and bees because of poor weather conditions. During these approximately four-hour visits, all species of aculeate wasps and bees were recorded (Archer sample) and usually collected with a hand net for identification. In addition, one record was made by J. P. Flynn (July 1991) and two records by A. S. Lazenby (16 July 1995).

In the following account, the nomenclature follows that of Fitton *et al.* (1978).

## Species present at Saltfleetby-Theddlethorpe NNR

A full list of recorded species is given in the Appendix with the names of the recorders.

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 Archer sample of the species of solitary wasps and bees consists of 62 species and 196 records. The solitary wasp family, Sphecidae, and the solitary bee family, Halictidae, are the dominant families in terms of the number of species and number of records.

## A comparison of species found at Saltfleetby-Theddlethorpe NNR and Gibraltar Point NNR

Using the Archer samples of solitary wasps and bees, 44 species are common to Saltfleetby-Theddlethorpe NNR and Gibraltar Point NNR (Archer, 1998*a*), 18 are only recorded from Saltfleetby-Theddlethorpe NNR and 29 species only from Gibraltar Point NNR. From the two locations together 91 species were recorded in the Archer samples.

These data can be compared by calculating similarity indices. Using the simple Jaccard index (Ludwig & Reynolds, 1988), which depends upon the presence or absence of species, gives an index of 48.4% of species common to both locations. The Morisita-Horn index, which uses quantitative information on the relative abundance of species, is relatively independent of sample size, but gives more importance to the more abundantly occurring species (Magurran, 1988). Abundance was determined from the number of records of each species. The Morisita-Horn index is 61.9%, which is higher than the Jaccard index, indicating that the Archer samples from the two localities are more similar to one another in terms of the more abundant species.

The differences between the two localities could be a consequence of either the species list not being complete for either locality, or, because of habitat and resource differences, some species will be unique to either locality. Recording by other people produced one species, not in the Archer sample, from Saltfleetby-Theddlethorpe NNR, but also found at Gibraltar Point NNR, and a further five species from Gibraltar Point NNR, also found at Saltfleetby-Theddlethorpe NNR. Thus further recording could reduce the differences between the two localities.

In qualitative terms the two localities have a similar range of habitats, although there are, perhaps, more dead trees in sunny sheltered situations at Gibraltar Point NNR, particularly at Syke's Farm. Thus aerial-nesting species requiring more sheltered conditions could be present at Gibraltar Point NNR, but not at Saltfleetby-Theddlethorpe NNR.

## Seasonal progression of species

June, July and August were the best months for recording species of solitary wasps, with July the most productive month for newly recorded species (Table 2). The species most evident were the pompilids *Pompilus cinereus* and *Episyron rufipes* and the sphecids *Mellinus arvensis* and *Gorytes quadrifasciatus*. These species are all subterranean nesters. The pompilids hunt spider prey, *M. arvensis* mainly muscid flies and *G. quadrifasciatus* cercopid (*Philaenus*) bugs. The mating flights of these solitary wasp species can be particularly noticeable.

**Table 1.** The number of species and records of aculeate wasps and bees from Saltfleetby-Theddlethorpe NNR.

| | No. species | No. records |
|---|---|---|
| Solitary Wasps | | |
| Chrysididae | 3 | 6 |
| Pompilidae | 6 | 28 |
| Eumenidae | 1 | 1 |
| Sphecidae | 19 | 60 |
| Solitary Wasps (total) | 29 | 95 |
| Solitary Bees | | |
| Colletidae | 7 | 19 |
| Andrenidae | 4 | 27 |
| Halictidae | 13 | 39 |
| Megachilidae | 4 | 6 |
| Anthophoridae | 6 | 13 |
| Solitary Bees (total) | 34 | 104 |
| Total Solitary Wasps & Bees | 63 | 199 |
| Social Species | | |
| Vespidae | 3 | |
| Apidae | 11 | |
| Total Social Species | 14 | |
| Total Aculeate Wasps & Bees | 77 | |

**Table 2.** The number of species and newly recorded species of solitary wasps and bees recorded per month at Saltfleetby-Theddlethorpe NNR.

| | May | June | July | August |
|---|---|---|---|---|
| No. species | | | | |
| Solitary Wasps | 4 | 13 | 24 | 12 |
| Solitary Bees | 18 | 18 | 13 | 9 |
| No. new species | | | | |
| Solitary Wasps | 4 | 9 | 15 | 1 |
| Solitary Bees | 18 | 7 | 7 | 2 |

**Table 3.** The Archer national quality scores of the 63 species of solitary wasps and bees recorded from Saltfleetby-Theddlethorpe NNR.

| Status | Status Value (A) | No. species (B) | Quality Scores (A*B) |
|---|---|---|---|
| Universal | 1 | 44 | 44 |
| Widespread | 2 | 15 | 30 |
| Restricted | 4 | 0 | 0 |
| Scarce | 8 | 3 | 24 |
| Rare | 16 | 1 | 16 |

May, June and July were the best months for recording species of solitary bees, with May the most productive month for newly recorded species (Table 2). The species most evident were the aerial-nesting *Hylaeus confusus* (associated with dead elder), the subterranean-nesting *Lasioglossum calceatum*, and the aggregated subterranean nests of *Andrena barbilabris*.

## Justification for comparing Saltfleetby-Theddlethorpe NNR with other localities

Is the species list from Saltfleetby-Theddlethorpe NNR sufficiently complete so that comparisons with other localities may reasonably 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 species and the area of each locality, both expressed as natural logarithm (ln), are plotted against each other. Archer & Burn (1995) (Archer, updated in press), found for some north Midlands and northern England localities that 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 a locality falls within the range of these localities which show a statistically significant species-area relationship, then the locality may reasonably be compared with other localities. The data for Saltfleetby-Theddlethorpe NNR fall within this range (95% confidence limits of the regression coefficient) so can be compared with other localities.

## Quality assessment of the solitary species

According to Shirt (1987) and Falk (1991), *Podalonia affinis* is a nationally rare or 'Red Data Book' species (RDB3) and is probably on the northern edge of its range in Lincolnshire. Three species are nationally scarce species (Falk, 1991): *Nysson trimaculatus, Colletes halophilus* and *Sphecodes crassus*. These three species extend their range further northwards in Yorkshire (Archer, 1998*b*). Recent work carried out by members of the Bees, Wasps and Ants Recording Society (Archer, 1998*c*) indicate that the status of *Podalonia affinis* will need to be changed.

By giving each of the 63 species of solitary wasps and bees a national status (Archer, 1998*d*), Saltfleetby-Theddlethorpe NNR has a national quality score of 114 (Table 3) and a national species quality score (SQS) of 1.8 (114/63). National SQSs for other Lincolnshire localities are 1.8 for Risby Warren (Archer, 1994) and 1.7 for Gibraltar Point NNR (Archer, 1998*a*). These national SQSs are the same or similar to that for Saltfleetby-Theddlethorpe NNR and may indicate the national SQS that might be expected from the best Lincolnshire localities.

National SQSs vary from 1.2–3.0 (with one locality 3.8) from 19 localities in the north and north Midlands of England (Archer, in press). The Lincolnshire localities are in the lower half of this range.

National quality and species quality scores also have been calculated for the twelve good-weather Archer visits from May until September (Table 4). Table 4 also shows the overall quality and species quality scores of the Archer sample.

**Table 4.** The national daily quality scores of the Archer sample of solitary wasps and bees recorded from Saltfleetby-Theddlethorpe NNR.

| Date | No. species | Quality Score | Species Quality Score |
|---|---|---|---|
| 3 May 1995 | 9 | 9 | 1.00 |
| 23 May 1995 | 12 | 16 | 1.33 |
| 30 May 1996 | 12 | 29 | 2.42 |
| 1 June 1985 | 11 | 11 | 1.00 |
| 9 June 1984 | 10 | 11 | 1.10 |
| 25 June 1998 | 17 | 43 | 2.53 |
| 7 July 1984 | 19 | 31 | 1.63 |
| 29 July 1984 | 20 | 27 | 1.35 |
| 30 July 1995 | 17 | 28 | 1.65 |
| 6 August 1989 | 8 | 17 | 2.13 |
| 9 August 1986 | 9 | 11 | 1.22 |
| 26 August 1984 | 14 | 25 | 1.79 |
| Overall | 62 | 113 | 1.82 |

**Table 5.** Nonparametric estimates of species richness of solitary wasps and bees at Saltfleetby-Theddlethorpe NNR and Gibraltar Point NNR based on the Archer sample.

| | Saltfleetby-Theddlethorpe NNR | | Gibraltar Point NNR | |
|---|---|---|---|---|
| | H & F[1] | C[2] | H & F | C |
| No. species | | | | |
| Recorded | 62 | 62 | 72 | 72 |
| Estimated | 84 | 83 | 89 | 81 |
| 95% confid. limits | 69–99 | 63–102 | 76–102 | 70–92 |

[1] Heltshe & Forrester (1983)
[2] Chao *in* Colwell & Coddington (1994)

**Table 6.** The relative frequency of the cleptoparasitic species among the solitary wasps and bees at Saltfleetby-Theddlethorpe NNR.

| | No. hosts (H) | No. cleptoparasites (C) | Cleptoparasitic Load CL = 100*C/(H+C) |
|---|---|---|---|
| Solitary Wasps | 24 | 5 | 17.2 |
| Solitary Bees | 22 | 12 | 35.3 |

**Table 7.** The nesting habits of the host species of solitary wasps and bees recorded at Saltfleetby-Theddlethorpe NNR.

| | No. aerial nesters (A) | No. subterranean nesters (S) | Aerial Nester Frequency AF = 100*A/(A+S) |
|---|---|---|---|
| Solitary Wasps | 7 | 17 | 29.2 |
| Solitary Bees | 6 | 16 | 27.3 |

Quality scores are likely to be greatly influenced by recording effort, but SQSs should help correct for variation in recording effort (Ball, 1992; Foster, 1996). Although recording effort was more or less constant for each Archer visit, the percentage variation of daily quality scores (478%) is greater than the SQSs (253%). Thus SQSs can help correct for both variation in recording effort and in quality scores. The greater percentage variation of the quality scores is a consequence of the variation in the number of species recorded on each visit (varied between 9–20 species, % variation 222%).

Can the SQSs from one or two visits to a locality be used to give a relatively good prediction of the overall SQS for the locality? Only four of the daily SQSs (Table 4) fall within the 25% range (1.00–2.53) of the overall SQS. The daily SQSs with higher than the 25% range values contained the rare species, *Podalonia affinis*. The five daily SQSs with lower than the 25% range values did not contain rare or scarce species. The four daily SQSs, which are within the 25% range values, all contain scarce species. The high quality species (i.e. rare and scarce species), because of their high numerical coding, exert a large influence on the daily SQS so that it is difficult to predict overall SQS from any one or two visits.

### Estimating the potential number of solitary wasp and bee species

Heltshe & Forrester (1983) and Chao (*in* Colwell & Coddington, 1994) describe statistical procedures to estimate species richness after a number of samples have been taken from a locality. The Jackknife estimate of Heltshe & Forrester is based on the observed number of species that are only observed on one occasion during sampling (= unique species), while the quantitative estimate of Chao is based on the unique species and the species observed in two samples (two occasion species). Because of the discovery of newly recorded species during the months of adult activity (Table 4) it is advisable that the samples be distributed throughout the months of adult activity.

The estimates of species richness at Saltfleetby-Theddlethorpe NNR and Gibraltar Point NNR with their 95% confidence limits are given in Table 5. A possible complication in making these estimates may be that some of the unique species were accidentally present, being outside their normal range or habitat (vagrant species). Vagrant species would artificially increase the estimate of species richness. The unique and two-occasion species of Saltfleetby-Theddlethorpe NNR are indicated in the appendix. None of the unique species of Saltfleetby-Theddlethorpe NNR would appear to be vagrant species – all the unique species, except for *Sphecodes ephippius*, are also found on the near-by sand dunes of Gibraltar Point NNR (Archer, 1998*a*) or Spurn Point (Archer, unpublished). Also, the hosts of *S. ephippius* (*Lasioglossum calceatum* and *L. leucozonium*), are both found at Saltfleetby-Theddlethorpe NNR.

These estimates of species richness indicate the following. Firstly, the potential species diversity at both localities is probably numerically similar. Secondly, the increased difficulty of finding species at Saltfleetby-Theddlethorpe NNR compared with Gibraltar Point NNR (Archer made a similar number of visits to each locality, finding fewer species at Saltfleetby-

Theddlethorpe NNR than Gibraltar Point NNR) is reflected in the relatively wider confidence limits for Saltfleetby-Theddlethorpe NNR. Thirdly, that a further 21–22 species could be found at Saltfleetby-Theddlethorpe NNR and a further 9–17 species at Gibraltar Point NNR. Already a further 11 species have been found at Gibraltar Point NNR by other recorders (Archer, 1998*a*).

The nonparametric methods for estimating species richness used above are relatively new. Caution must be exercised in their use until they have been fully tested. Palmer (1990) found that the Jackknife estimate gave a slight underestimate and Colwell & Coddington (1994) that the Chao estimator gave the more accurate estimate, but indicated that all non-parametric methods must give underestimates if too few samples are taken. As such, it is possible that slightly more species could be found at both localities than the estimates indicate.

## Cleptoparasitic load

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

For the north and north Midlands of England, the CL for species of solitary wasps varies from 10.3–22.2 (range 11.9) (Archer, in press). The CL for Saltfleetby-Theddlethorpe NNR is near the middle of this range.

For the north and north Midlands of England, the CL for species of solitary bees varies from 21.7–36.6 (range 14.9) (Archer, in press). The CL for Saltfleetby-Theddlethorpe NNR falls within this range, but is near the upper border. As such, more host species may await discovery. Speculation based on the species list from Gibraltar Point NNR suggests these species will probably be from the genera *Andrena, Osmia* and *Anthophora*.

## Aerial nest frequency

The aerial-nester frequency (AF) is the percentage of host aculeate species that have aerial nest sites. Compared with Gibraltar Point NNR, the AF for solitary bees is similar, but the AF for solitary wasps is low, perhaps indicating that further aerial-nesting species of solitary wasps await discovery. Dead wood and stems in sunny situations are present at Saltfleetby-Theddlethorpe NNR, but, as indicated earlier in this paper, perhaps not in such sheltered situations as those at Gibraltar Point NNR. Hence, these aerial-nesting species of solitary wasps, if they require more sheltered situations, may not be present at Saltfleetby-Theddlethorpe NNR. If further species of aerial-nesting solitary wasps are present at Saltfleetby-Theddlethorpe NNR, then speculation based on the species list from Gibraltar Point NNR list suggests these species will probably be from the genera *Ancistrocerus, Trypoxylon, Crossocerus, Pemphredon* and *Passaloecus*.

## Conclusion

In summary Saltfleetby-Theddlethorpe NNR:

1, is a good locality for aculeate wasps and bees;
2, has a species quality score expected for the best Lincolnshire localities;
3, is predicted to have a species diversity of 83–84 species of solitary wasps and bees, which is similar to the predicted value for Gibraltar Point NNR;
4, has solitary wasp and bee cleptoparasitic loads similar to those from other localities as predicted by Wcislo (1987);
5, on the basis of the Gibraltar Point NNR list further host species of solitary bees and, may be, aerial-nesting species of solitary wasps could be present.

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## Appendix

### Aculeate wasps and bees recorded from Saltfleetby-Theddlethorpe NNR

Collectors: F = Flynn, L = Lazenby, Archer recorded all species except *Crossocerus megacephalus*. U = Unique species, 2 = two-occasion species.

**Chrysididae**: *Hedychridium ardens* (Latreille), *Chrysis ignita* (L.) (U), *C. impressa* Schenck (U).

**Pompilidae**: *Priocnemis perburbator* (Harris) (2), *Pompilus cinereus* (F.), *Arachnospila anceps* (Wesmael) (2), *Evagetes crassicornis* (Shuchard) (2), *Anoplius infuscatus* (Vander Linden) (U), *Episyron rufipes* (L.).

**Eumenidae**: *Ancistrocerus trifasciatus* (Müller) (U).

**Vespidae**: *Dolichovespula norwegica* (F.), *Vespula rufa* (L.), *Vespula germanica* (F.).

**Sphecidae**: *Astata pinguis* (Dalhbom) (U), *Tachysphex pompiliformis* (Panzer), *Trypoxylon attenuatum* Smith (U), *Crabro cribrarius* (L.) (2), *C. peltarius* (Schreber) (U), *Crossocerus tarsatus* (Shuchard), *C. wesmaeli* (Vander Linden), *C. megacephalus* (Rossius) (F), *C. quadrimaculatus* (F.) (U), *Ectemnius cavifrons* (Thomson) (2), *E. lapidarius* (Panzer), *Oxybelus uniglumis* (L.), *Penulus pallipes* (Panzer) (U), *Pemphredon lethifer* (Shuchard) (U), *Ammophila sabulosa* (L.), *Podalonia affinis* (Kirby) (2), *Mellinus arvensis* (L.) (L), *Nysson trimaculatus* (Rossius) (2), *Gorytes quadrifasciatus* (F.) (L).

**Colletidae**: *Colletes fodiens* (Geoffroy) (U), *C. halophius* (Verhoeff) (2), *C. succinctus* (L.) (U), *Hylaeus communis* Nylander, *H. confusus* Nylander, *H. brevicornis* Nylander (U), *H. hyalinatus* Smith (2).

**Andrenidae**: *Andrena scotica* Perkins, *A. nigroaenea* (Kirby), *A. haemorrhoa* (F.), *A. barbilabris* (Kirby).

**Halictidae**: *Halictus rubicundus* (Christ), *H. tumulorum* (L.), *Lasioglossum leucozonium* (Schrank) (U), *L. calceatum* (Scopoli), *L. nitidiusculum* (Kirby) (U), *L. villosulum* (Kirby), *L. cupromicans* (Perez) (2), *L. leucopum* (Kirby), *Sphecodes crassus* Thomson (U), *S. ephippius* (L.) (U), *S. geoffrellus* (Kirby) (= *fasciatus* von Hagens) (2), *S. gibbus* (L.) (U), *S. monilicornis* (Kirby).

**Megachilidae**: *Megachile centuncularis* (L.) (U), *M. versicolor* Smith (U), *M. circumcincta* (Kirby) (U), *Coelioxys inermis* (Kirby) (2).

**Anthophoridae**: *Nomada fabriciana* (L.) (U), *N. goodeniana* (Kirby), *N. marshamella* (Kirby) (2), *N. ruficornis* (L.) (U), *N. rufipes* F. (U), *Epeolus variegatus* (L.) (2).

**Apidae**: *Bombus lucorum* (L.), *B. terrestris* (L.), *B. lapidarius* (L.), *B. pratorum* (L.), *B. hortorum* (L.), *B. pascuorum* (Scopoli), *B. muscorum* (L.), *Psithyrus bohemicus* (Seidl), *P. sylvestris* Lepeletier, *P. vestalis* (Geoffroy), *Apis mellifera* L.