THE FORAGING PREFERENCES OF THE HAIRY-FOOTED FLOWER BEE (ANTHOPHORA PLUMIPES (PALLAS 1772) IN A SURBURBAN GARDEN

Maggie Frankum, 3 Chapel Lane, Knighton, Leicester LE2 3WF

PREAMBLE

This paper is based on a project carried out as a requirement of a three-year Diploma in Applied Ecology at the University of Leicester (1997). The original report is extensively illustrated and stretches to 85 pages. This paper attempts to distill the main findings of the research. It is hoped that it will stimulate other entomologists in the county to carry out basic research literally on their own doorstep.

INTRODUCTION

In springtime, with the onset of warmer weather, the foraging activities of social bumblebees such as *Bombus pratorum, B pascuorum, B hortorum, B terrestris* and *B lapidarius,* are fairly commonplace in suburban gardens. The first big queens emerge from hibernation to establish their nests and produce new worker bees. However, there are other species of bees that are less noticeable until some particular behaviour pattern draws attention to them.

One such early species is the hairy-footed flower bee, *Anthophora plumipes* (Pallas, 1772; Figure 1), striking in its sexual dimorphism. The golden-brown male has a distinct yellow face and fans of long bristles on the middle legs (hence its common name). The jet black female has orange pollen brushes on the hind legs.

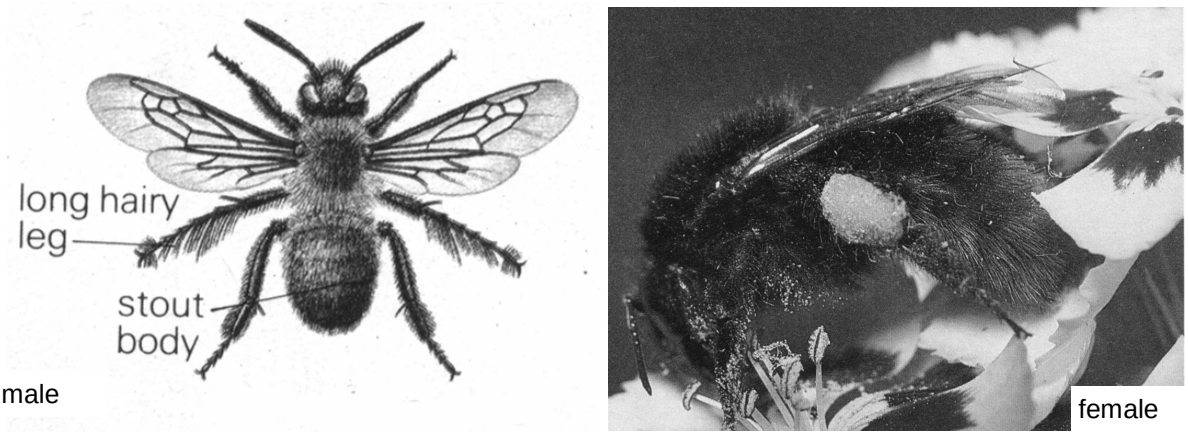

Figure 1: *Anthophora plumipes*

They are hairy and look like small bumble bees with a body length of about 14mm (Proctor *et al*, 1996). However, they do differ as the eyes extend to the jaw without the usual cheek patches found in bumblebees (Chinery, 1972). They have a long slender tongue (about 13mm) giving them access to nectar in flowers with long

corollas (Proctor *et al*, 1996). They are fairly easy to identify in the field especially early in their flight period as *Bombus* queens are much larger. However, as the season progresses, care must be taken because, at first glance, the females could be confused with small faded *B pratorum* workers. The males may be confused with *B pascuorum* workers or *Eristalis intricarius* and *Merodon equestris* var *narcissi* (the brown colour form) hoverflies.

Anthophora plumipes has a fast darting flight, emitting a high pitched buzz and are very easy to disturb, reacting quickly to any movement or shadows. As a consequence, they are often difficult to observe. They have the ability to hover almost stationary at flowers when foraging for nectar and pollen and also as part of the male territorial and sexual behaviour.

Although resembling bumblebees, *A plumipes* is a solitary, not social, bee and there are no workers. Each female makes her own individual nest burrow with no male help and independent of other females. A cell a day is stocked with food for the future offspring. Nesting places are chosen with a sunny aspect e.g. wattle and daub walls, between the brickwork of the flue-lined chimney of a house (Owen, 1994), or even in the old cob wall of a village car park burrowing into the softer material (John Mousley, personal communication). They also nest in soil and when an aggregate of nests are found together, it is probably because of the lack of other suitable sites in the vicinity (Archer, 1990).

There was little recent information on the species in the literature at the start of the project. Flower bees were briefly mentioned in "*Humble Bee*" (Sladen, 1912) with four species (*A pilipes, A retusa, A furcata* and *A quadrimaculata*) being described by Saunders (1896). No mention was made of *A plumipes*. Three of the four species were described by Step (1932) - *A retusa* (the Potter Flower bee), *A furcata* (the Forked-tail Flower bee) and *A pilipes* (the Hairy-footed Flower bee). It would seem that the latter species was renamed as *A plumipes* sometime after. No further reference to the species was apparent until the 1970s when two general keys to the British aculeates were published (Chinery, 1972; Willmer, 1985).

Apart from Archer (1990), who referred to records of *Anthophora plumipes* during this century, and Stace (1994) noting their feeding habits at *Pulmonaria* and other members of the Boraginaceae, very little was known about the bee in Leicestershire until this project commenced.

Whilst this project was underway in a Leicester suburban garden, parallel studies were being undertaken elsewhere during 1993-6. These studies included thermoregulation, the costs of warm-up and body size (Stone, 1993), female activity patterns relating to temperature, nectar supplies and body size (Stone, 1994). Male foraging and courtship behaviour was examined (Stone *et al* ,1995) as was female response to sexual harassment (Stone, 1995).

AIMS OF THE STUDY

Casual observations of *Anthophora plumipes* made during recent years seemed to indicate a preference for the pink and blue bell-like flowers of lungwort (*Pulmonaria*

officinalis, Boraginaceae). The initial aim was to establish whether there was indeed this relationship. Poor plants, because of weather conditions, required a modification of the study plan. Elsewhere in Leicestershire, *Anthophora* bees had been observed foraging around other members of the Boraginaceae (Stace, 1994). Accordingly, the study was altered to examine the preference of the bees for members of the Boraginaceae including the role of flower colour and shape, nectar availability, temperature, time of day etc.

THE STUDY SITE

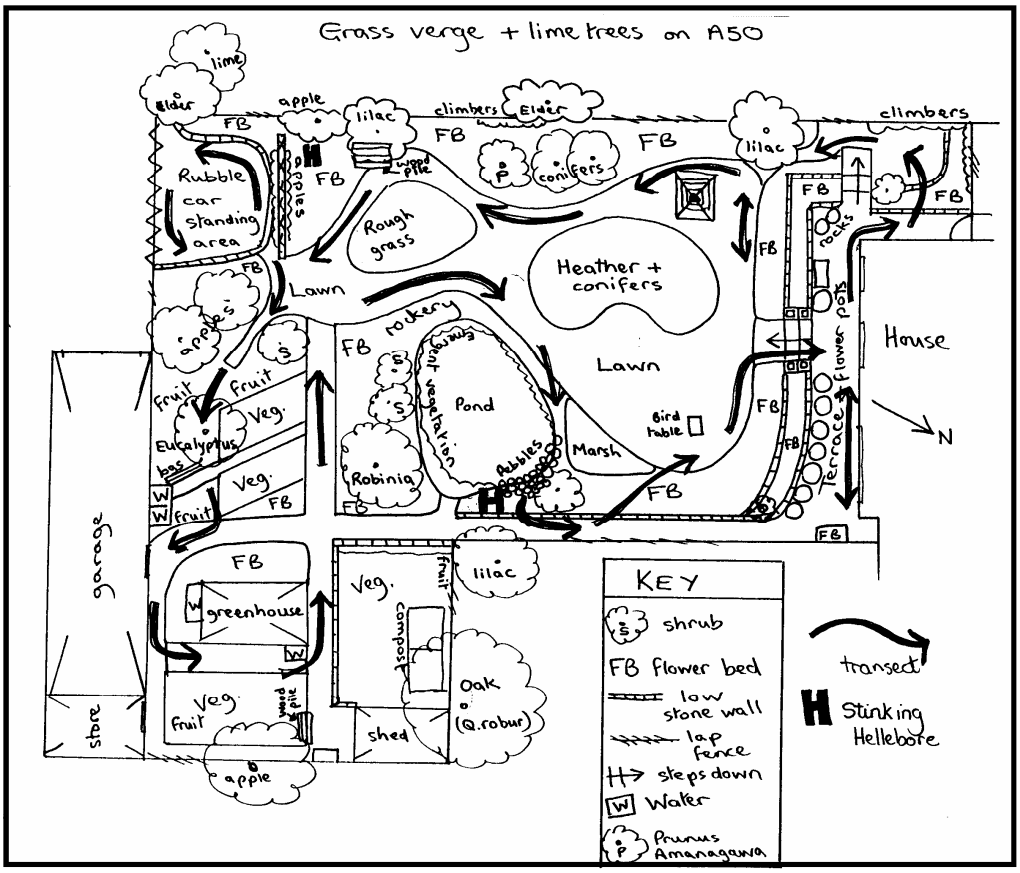

Figure 2 : Layout of study site

The study site (Figure 2) is an L-shaped garden in suburban Knighton (Leicester SK596014) of approximately 800m^2 area (altitude 75m). It is adjacent to a major road junction and, apart from traffic pollution, has been a chemical-free area for more than 20 years. It is managed as a wildlife garden, with a mosaic of habitats including low stone walls, wooden fences, trees and shrubs, wood piles, rockery, heather bed, lawn and rough grass, pond and marshy area, vegetable garden and compost heap. In addition there are informal herbaceous flower borders providing a continuous range of nectar and pollen sources throughout the spring and summer. The site slopes gently to the SSE and has a sunny aspect in the main.

METHODS

Recording the behaviour of *Anthophora plumipes* at the study site was by walking the transect (Figure 2) whenever possible during each 2-hour period, from the beginning of March. This was carried out throughout the flight period until no further bee sightings were made. The ambient temperature was recorded by positioning a thermometer out of direct sunlight in the garden and general weather conditions noted. The plant species in the garden were recorded (including colour of flower, length of corolla tube, whether single or multiple inflorescences etc) and the availability of nectar sources noted as they flowered. In 1995 male bees were often seen chasing and patrolling. In order to investigate this behaviour further, the first male bee to appear in 1996 was marked with white Tippex, which allowed easy recognition of the bee when in flight (Figure 3).

Figure 3: Marked male bee on *Pulmonaria*

WEATHER DURING THE STUDY PERIODS 1995-6

1995 - March was mainly dry but overcast with cold winds keeping temperatures low. This was especially so early in the morning with temperatures only rising during sunny periods (6-14℃). There was snow at the end of the month. Although April started slightly warmer (up to 18℃) in bright sunshine, again, prevailing cold winds kept the temperature down throughout much of the month with overcast skies, rain and sleet. The maximum was 20℃. May started off hot and dry (up to 23℃) but later cold, northerly winds once more reduced temperatures. This unsettled weather continued throughout the remainder of the month.and into June.

1996 - March started cold with frost, rain and snow, these conditions spilling over into April although temperatures started to climb somewhat. Early May weather was still changeable, due to strong cold easterly winds, but towards the end of the month temperatures started to rise (up to 25℃) with rain giving humid conditions. June started hot (up to 30℃) and still humid.

TIME OF EMERGENCE AND FLIGHT PERIOD

In 1994-5, available information suggested that *A plumipes* was an “early” species with a flight period of March-June.

Table 1: Flight periods of *Anthophora plumipes* 1995-6

As the over-wintering nest sites were not found in the garden (and thus unable to be

monitored directly), the arrival of the first bees was pinpointed by walking the trnsect (Figure 2) every day from the beginning of March. The flight period extended until no more bees were seen.

The weekly records of both sexes for 1995-6 are shown in Table 1. During 1995, the flight period of the males lasted about seven weeks; in contrast the females had a much longer flight time, almost double that of the males. The following year, the flight periods for both sexes was similar but started about a month later than in 1995 and extending, at least for the males, later into the summer.

FLOWERS AVAILABLE FOR FORAGING

A weekly record was made during each year of any plants in flower, in order to establish their flowering period and possible availability for foraging by the bees. A total of 81 species from 24 families were in flower during the flight period of *Anthophora plumipes* during 1995 with 13-46 species available in any one week.

In 1996, 72 species listed in 1995 were available with the addition of a further 28 (from 26 families) introduced into the garden in 1996. During the second study year, plants flowered 2-3 weeks later than in 1995 because of poor weather conditions.

Observations were made of the flower species that the male and female bees preferred to visit in any one week. Only a third (32 from various families) of the available flower species were seen to be visited by *Anthophora plumipes.* Tables 2a and 2b detail the number of visits to each flower type during each survey week in both years, with Table 3 summarising the total number of visits to each plant family during the same period.

Table 3: Visits of *Anthophora plumipes* to flower families in 1995 and 1996

Table 2a: Visits of *Anthophora plumipes* to flowering species 1995

Survey week number	1	2	3	4	5	6	7	8	9	10	11	12	13
Commencing date	13.iii	20.iii	27.iii	3.iv	10.iv	17.iv	24.iv	1.v	8.v	15.v	22.v	29.v	5.vi
	M/F*	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F
Daffodil (multi-headed)													
Primrose hybrid (purple)													
Primrose hybrid (yellow)													
Primrose hybrid (white)													
Anemone blanda													
Daffodil (standard)													
Primrose hybrid (pink)													
Primrose													
Primrose hybrid (gold)													
Pulmonaria													
Stinking hellebore													
Primrose hybrid (violet)													
Lithospermum													
Violet													
Yellow archangel													
Rosemary													
Honesty													
Aubretia													
Daffodil (twin rockery)					0/2	0/14	0/10						
White deadnettle													
Ground ivy													
Ajuga													
Comfrey (purple)													
Comfrey (pink)													

*M/F = male/female bee visits; shaded area = in flower

Table 2b: Visits of *Anthophora plumipes* to flowering species 1996

Survey week	2	3	4	5	6	7	8	9	10	11	12	13	14
Commencing date	20.iii	27.iii	3.iv	10.iv	17.iv	24.iv	1.v	8.v	15.v	22.v	29.v	5.vi	12.vi
	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F	M/F
Iris (purple rockery)													
Stinking hellebore													
Erica sp													
Rosemary													
Aubretia													
Pulmonaria													
Forget-me-not													
Honesty													
Red deadnettle													
White deadnettle													
Comfrey (white)													
Yellow archangel													
Lithospermum													
Prunus amanagawa													
Ajuga reptans													
Solomon's seal													
Sprouting broccoli													
Comfrey (purple)													

*M/F = male/female bee visits; shaded area = in flower

The first bees seen in 1995 (March) were foraging amongst the daffodils, primulas,

Lithospermum and also stinking hellebore. When snow fell at the end of the month only the females were active. Foraging activity increased in April with the males seeming to favour *Lithospermum.* In contrast, females also visited yellow archangel and white deadnetlle, as well as occasional visits to rosemary, ground ivy, aubretia, daffodils, primroses, violets and *Pulmonaria*. As in March, when temperatures were lower, only the females continued to forage. By May, only females were seen foraging on the same range of plants, with comfrey being visited towards the end of the flight period.

The cold weather in March 1996, resulting in the late flowering of plants, meant that no bees were seen until April. Males briefly visited purple rockery iris and stinking hellebore whilst females preferred the latter and heather. A little later, both sexes also visited *Pulmonaria* whilst females also chose honesty and males chose red deadnettle. As the season progressed, a wide range of flowers were visited by the females with the males mainly being seen at aubretia and white deadnettle. By June, only females were observed, foraging the comfrey, sprouting broccoli and Solomon's seal.

FORAGING RELATED TO TIME OF DAY AND AMBIENT TEMPERATURE

The observation process allowed analysis of the data to determine the foraging behaviour related to time of day and ambient temperature. During the 1995 investigation period, males seemed to show two peaks of activity (1000-1200; 1600-1800) whereas the female activity was spread over a much wider time range (0800-2000) (Figure 4a). Females showed a similar pattern in the following year and this was reflected in the male activity (Figure 4b).

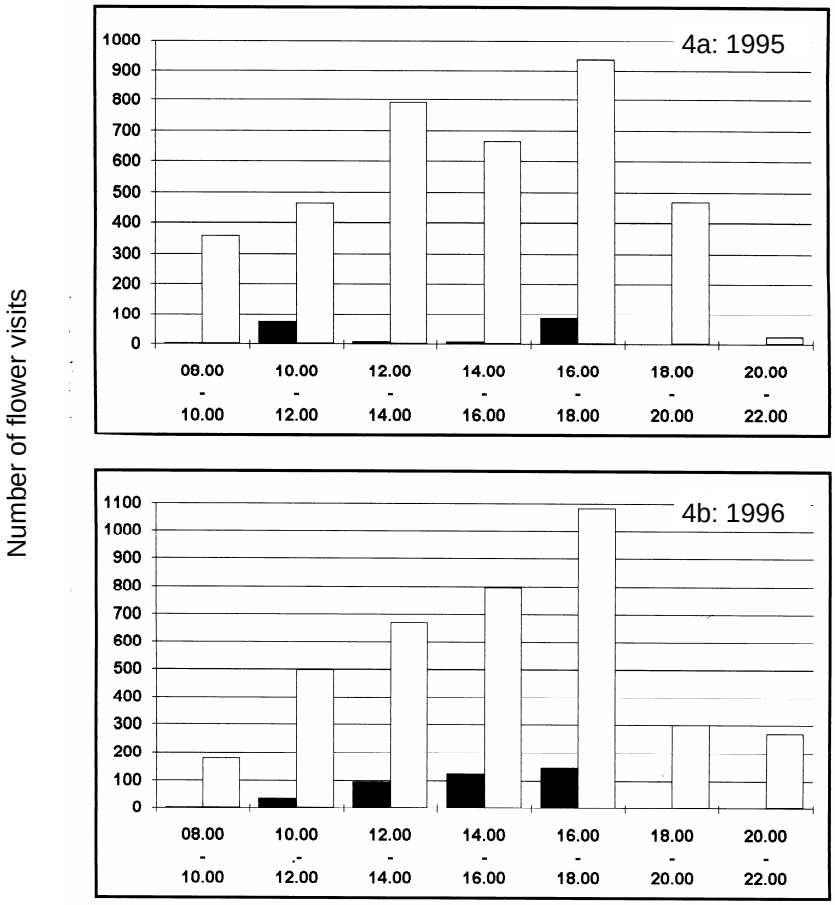

Figure 4: Foraging by *Anthophora plumipes* related to time of day

■ male □ female

Peak activity of female bees in both years occurred within the ambient temperature range of 14-20℃ although they were observed between 8℃ to 27℃. Male activity was seen between 8-20℃ with no obvious peak foraging temperature (Figures 5a, 5b).

FORAGING OF BORAGINACEAE IN PREFERENCE TO OTHER FAMILIES

Visits made by male and female bees to flowers of the Boraginaceae family were noted during 1995 and 1996 and compared to visits to all other plants considered as a group. The duration of each visit was timed and the total time spent visiting different flower families noted. In 1995, apart from a few early visits to daffodils (Liliaceae) and primroses (Primulaceae), males foraged *Lithospermum* (Boraginaceae) when it commenced flowering. Most of the flower visits were of 1-7 seconds duration (Figure 6a). Females started off in a similar way and, even though they also foraged *Lithospermum* in weeks 5-8, they were also more likely to visit other families especially the deadnettles (Lamiaceae).

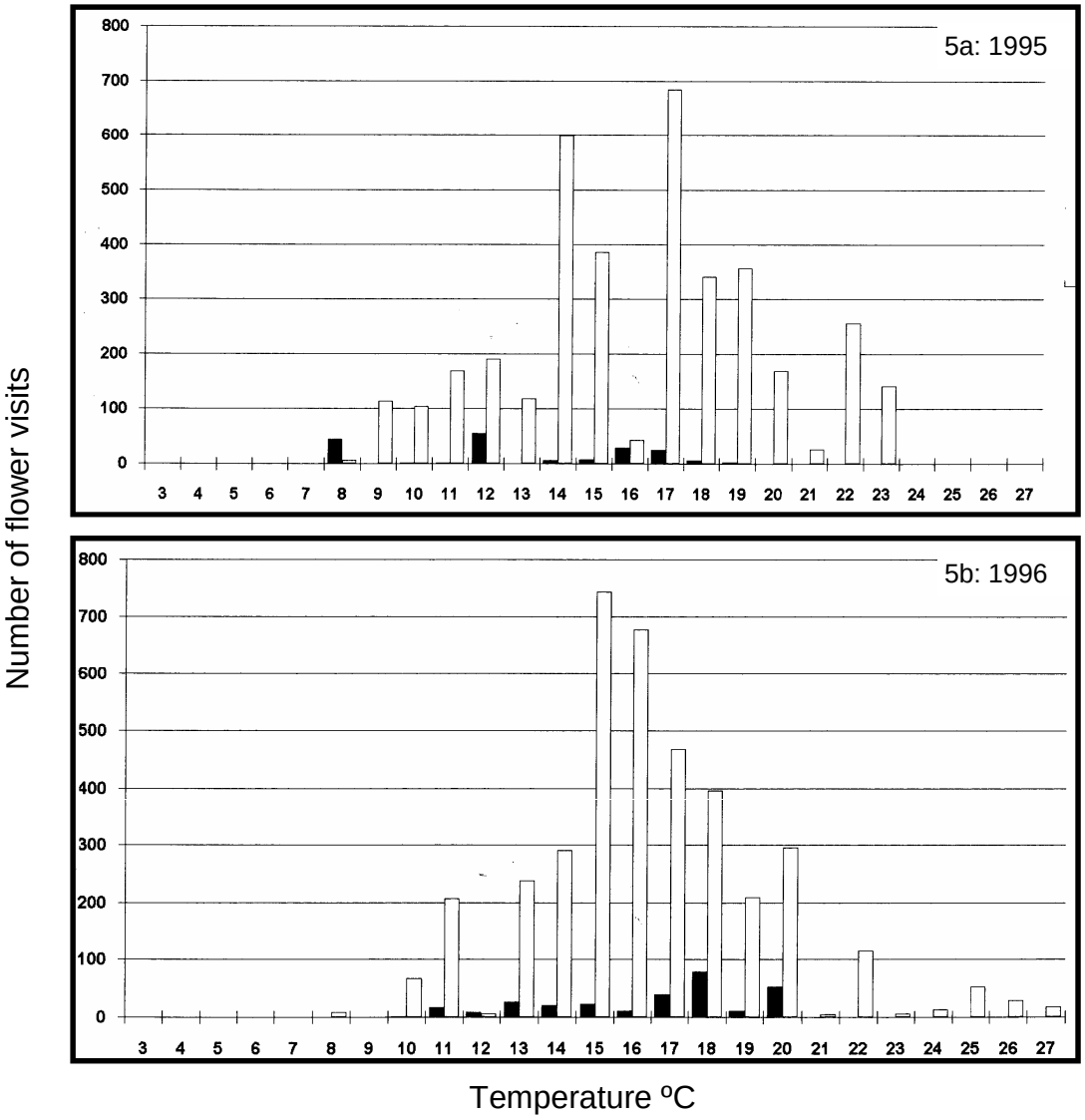

Figure 5: Foraging by *Anthophora plumipes* related to temperature

■ male □ female

However, as the comfrey came into flower (weeks 10-13) the Boraginaceae became the favoured family. Again flower visits were of 1-7 seconds duration (Figure 7a). During 1996 the start of flowering of most plants was as much as three weeks later than in 1995 and *Anthophora* were also late emerging (week 4). The males initially visited stinking hellebore (Ranunculaceae) until week 7 when they also foraged on the limited amount of *Pulmonaria* (Boraginaceae) that was available. As they died back the bees moved to white deadnettle. Visits to the Boraginaceae were brief - about 2 seconds but visits to the hellebore and deadnettles were of 2-7 seconds duration, with visits to others sometimes much longer (Figure 6b).

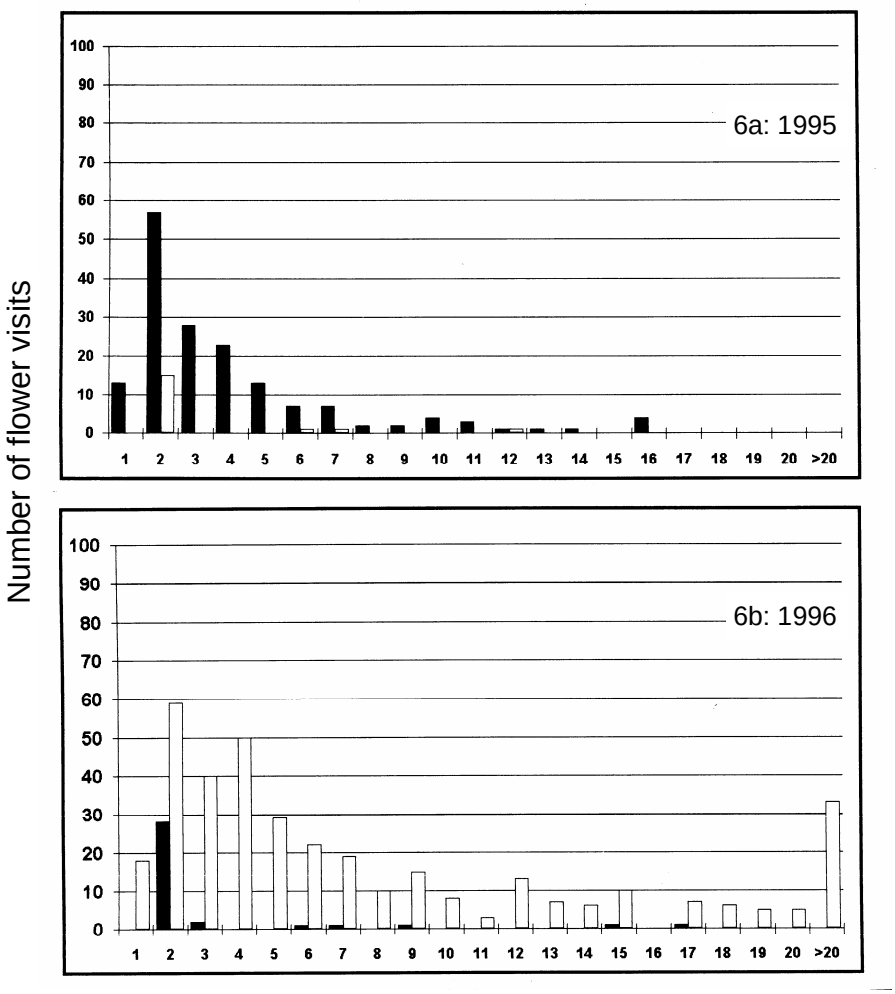

Figure 6: Duration of visits by male *A plumipes* to Boraginaceae

(■ = Boraginaceae □ = Other families)

Table 4: Total visits by both sexes of *A plumipes* to each plant family

Table 4 compares the total number of visits by both sexes to preferred flower

families during 1995 and 1996. The females were not very active in weeks 4-6 only visiting stinking hellebore. They then started to forage the Boraginaceae (*Pulmonaria* and white comfrey) (weeks 7 & 8) but were still more likely to forage other families. During weeks 11-13 they were foraging various members of the Boraginaceae (*Lithospermum,* white and purple comfrey, forget-me-not). In contrast to the previous year, the females spent less time foraging at the Boraginaceae with visits of 1-3 seconds duration compared to 1-9 seconds for other flowering families (Figure 7b).

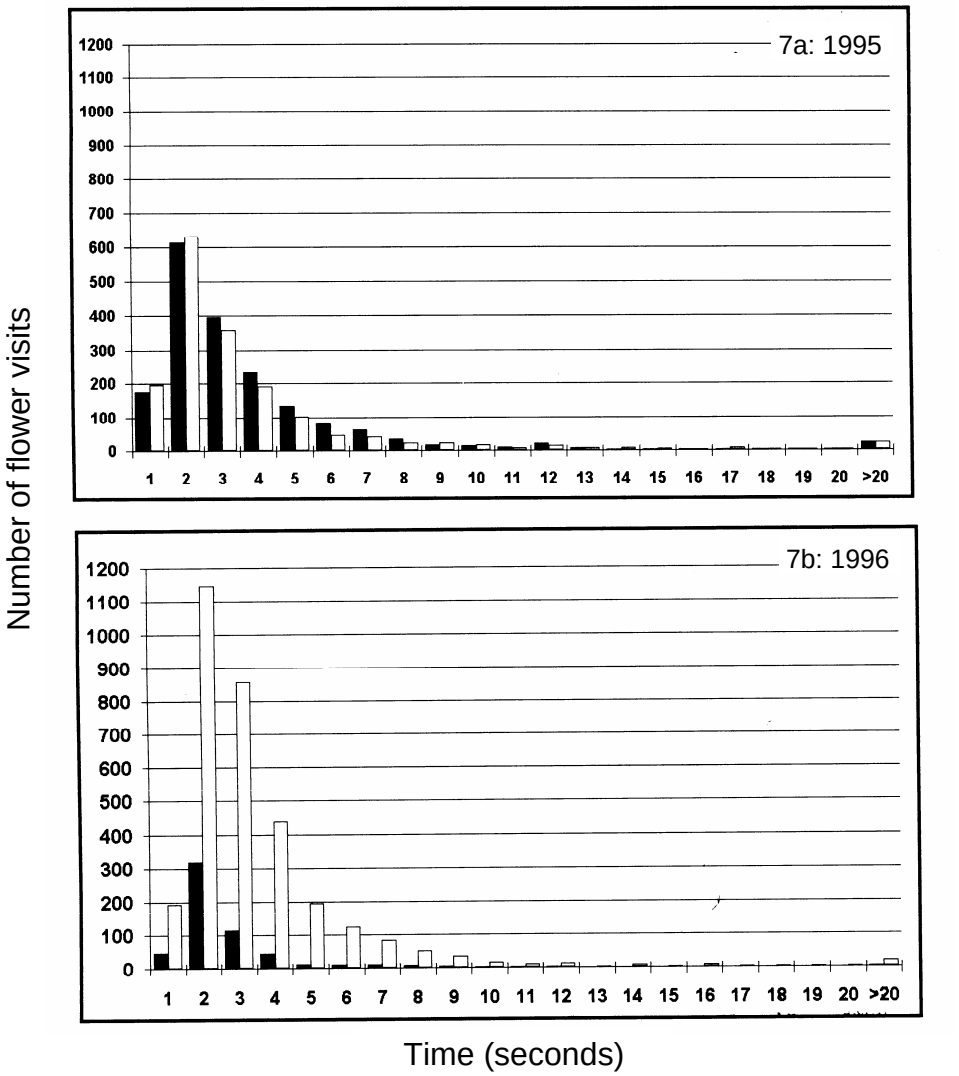

Figure 7: Duration of visits by female *A plumipes* to Boraginaceae
(■ = Boraginaceae □ = Other families)

INFLUENCE OF COLOUR ON FORAGING

Previous observations had noted that *Anthophora plumipes* were seen to frequently visit *Pulmonaria* flowers. During the present study, when *Pulmonaria* were not available, observations were made to determine if there was a preference for other

flowers with a similar blue/pink colour as compared to other colours. Visits by both sexes to flowers were divided into two colour groups (PPB - purple/pink/ blue; YWG - yellow/white/green). It is appreciated that these colours are as seen through human eyes and not as seen by the insect. In 1995, both sexes initially visited YWG flowers but later switched to the PPB group. In 1996 the males foraged at YWG flowers throughout the observation period but only at the PPB group in weeks 7-10. Females, however, used YWG flowers initially but from week 7 they foraged PPB as well. Over the two year period, both sexes spent more time visiting the PPB group than the YWG group in 1995 and the reverse in 1996 (Figure 8).

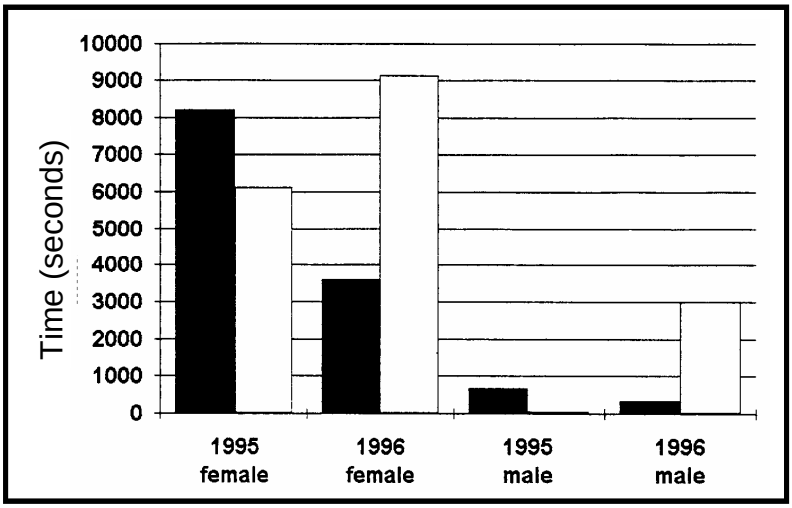

Figure 8: Total time spent visiting flowers related to colour
(■ = Purple/Blue/Pink □ = Yellow/White/Green)

INFLUENCE OF FLOWER SHAPE ON FORAGING

Despite a wide variety of flower families available to the bees to forage, only those flowers especially adapted to long-tongued pollinators such as *Anthophora plumipes* were utilised. Boraginaceae, with long fused corolla tubes and "limbs" to cling to, were important but the insects also visited the zygomorphic flowers of the Lamiaceae which are even more closely adapted to their pollinators by providing a platform for settling upon whilst probing for nectar at the base of the corolla tube. Other flower families were foraged to a lesser degree.

A comparison of the number of flower visits made by both sexes of *Anthophora plumipes* to Boraginaceae and Lamiaceae, found that in 1995 males only visited the former group and the females also made more visits to this group than to the Lamiaceae (Figure 9a). In 1996 both sexes made more visits to Lamiaceae than to Boraginaceae (Figure 9b).

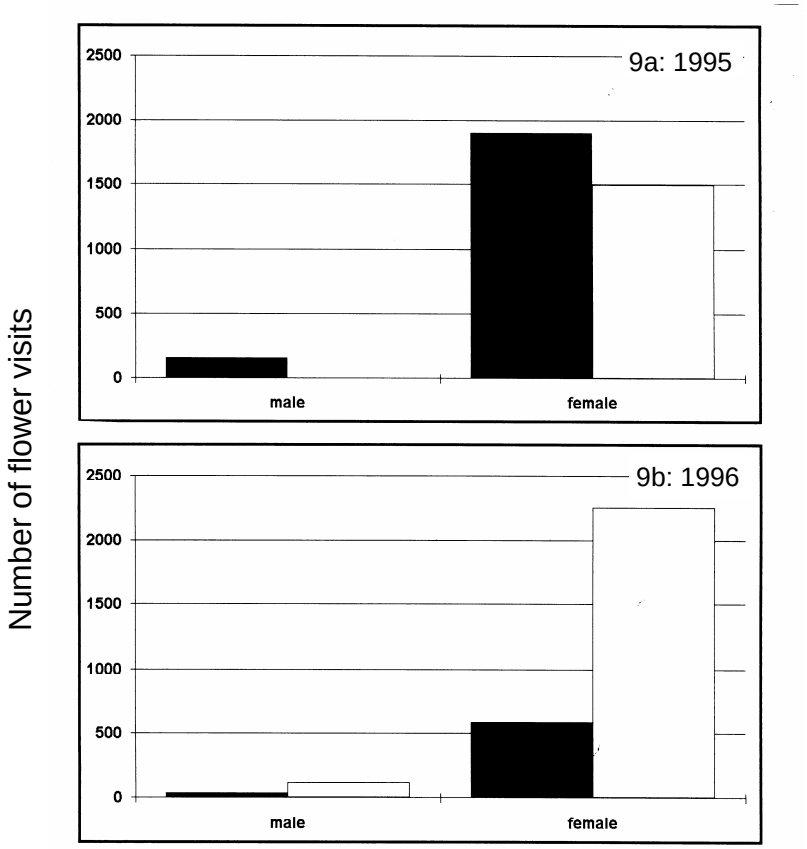

Figure 9: **Foraging related to flower shape**
(■ = Boraginaceae □ = Lamiaceae)

MALE SEXUAL AND TERRITORIAL BEHAVIOUR

During the 1995 season it had been observed that male *Anthophora plumipes* engaged in chasing and patrolling activities (Figure 10).

In order to study this further, the first male detected in the spring of 1996 was caught and marked with Tippex (Figure 3) on its thorax and released. Aided by this highly visible white spot, the activities of the marked male bee were seen to always centre on the Stinking Hellebore flowers, the main available nectar sources at that time (examples are given in Figure 11).

The bee basked on the leaves and occasionally foraged around the flowers for nectar. However, the main aim seemed to be a check for the presence of females and to court/mate with them if possible. If no females were around, the male patrolled briefly up the border and quickly returned again to the hellebore, checking once again for females. Sometimes the male flew to other hellebore plants but quickly returned to the favoured plant in the sun. The male responded very quickly to any movement, including shadows of passing birds, bumblebee queens, falling petals or, if lucky, managed to mate with a foraging female.

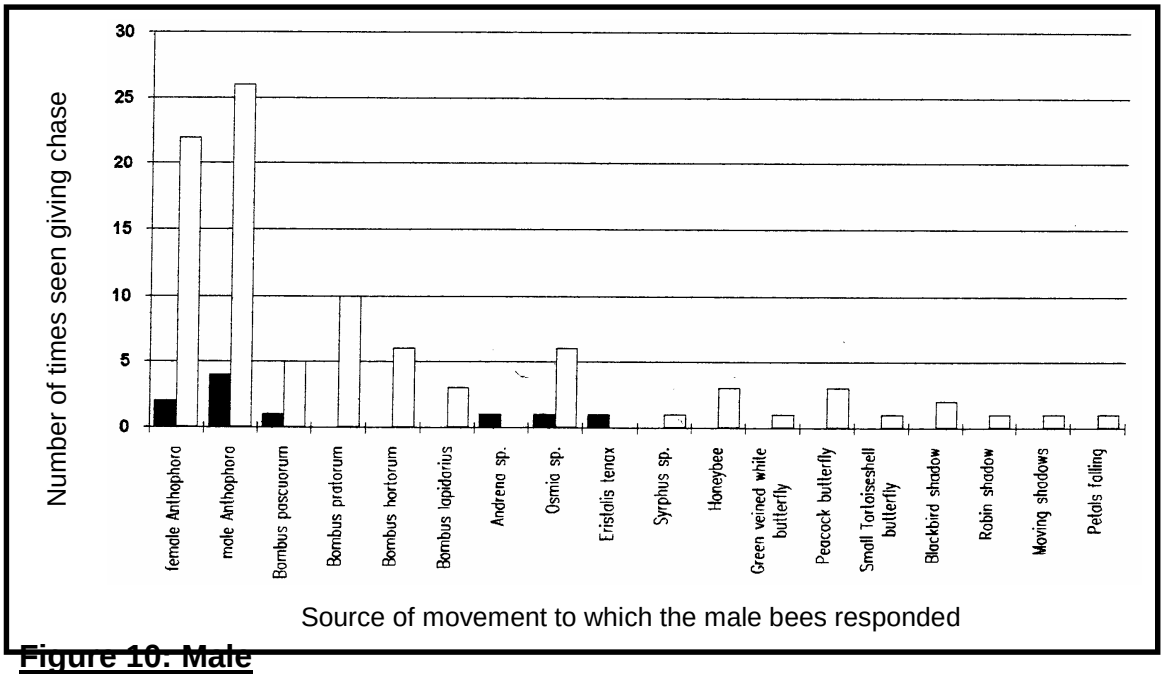

Figure 10: Male *Anthophora plumipes* sexual/territorial behaviour

■ 1995 □ 1996

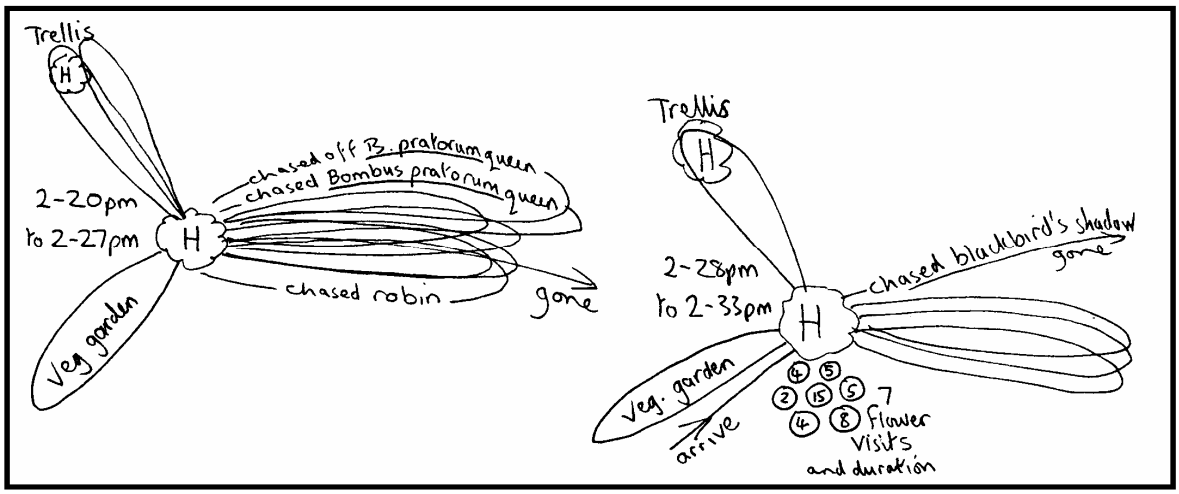

Figure 11: Examples of marked male behaviour centred on Stinking Hellebore 13.iv.96

This would seem to confirm recent research demonstrating resource-based polygyny ("many wives") at floral food sources in spring, when there is a low density of males and also exclusive territoriality at these nectar sites (Stone *et al*, 1995).

By May the flowering period of the hellebore was over and the main nectar sources were more varied and well-distributed around the garden. The activities of the marked male had changed and it was observed to patrol much further afield in search of the more widely scattered females (Figure 12). It has been

reported that as male density increases, exclusive territoriality is abandoned in favour of patrolling with considerable spatial overlap of males. The strategy becomes one of opportunistic polygyny (Stone *et al*, 1995), as seen in the present observations.

Occasionally, as the marked male hovered behind a foraging female, another male was seen to join the queue, ready to pounce given the opportunity. The females were often knocked to the ground but some were seen to take avoiding action and hide between the flowers until the males had moved away. Frequent sexual harassment such as this is reported to significantly reduce rates of foraging from the more profitable outer flowers and prolongs the time required to stock nest cells (Stone, 1995).

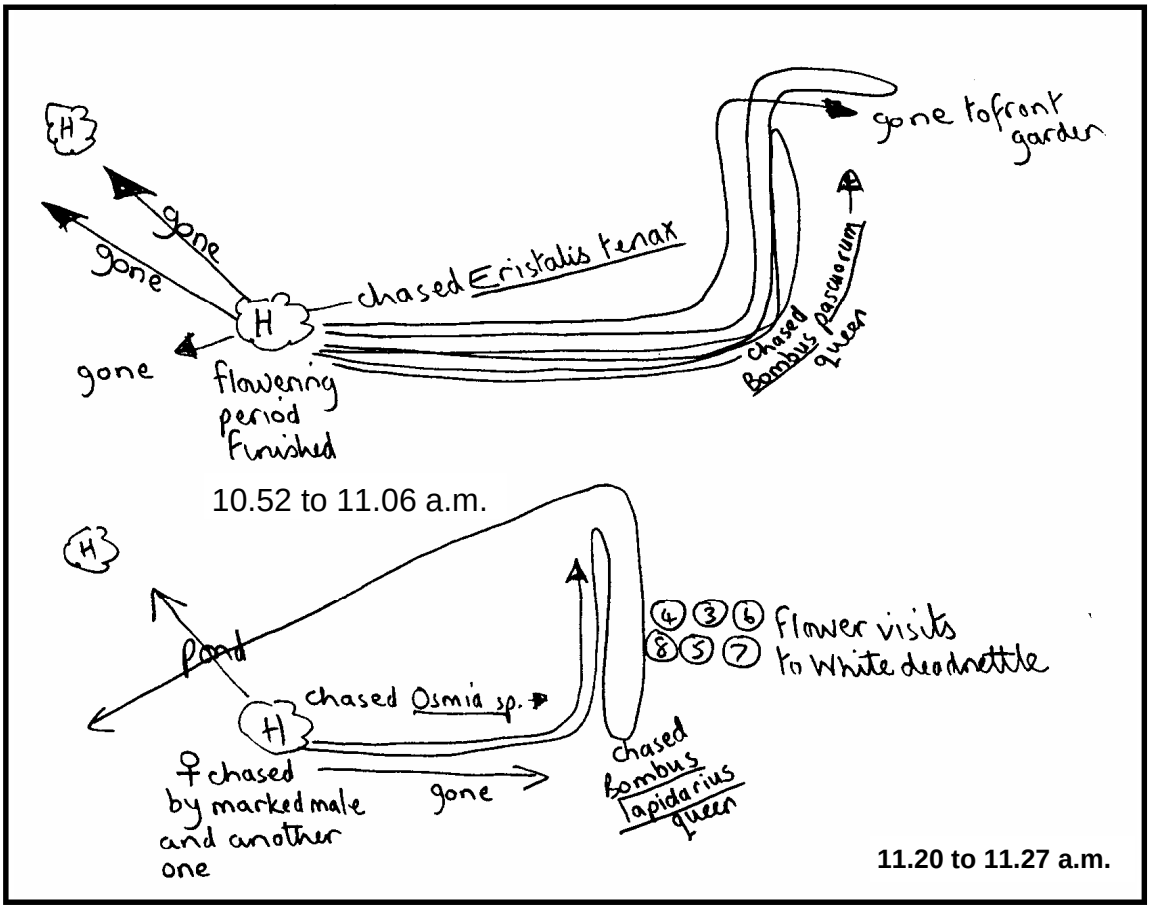

Figure 12: Examples of behaviour by marked male bee 29.v.96

DISCUSSION

Weather conditions in early spring strongly influence the activities of early emerging *A plumipes* bees directly affecting their ability to fly, forage and seek a mate. The weather also determines when the first flowers open to become available as food sources for the bees. Females are also affected by weather conditions, with larger females emerging earlier in the day from nesting tunnels than smaller ones, thus being able to collect nectar and pollen at lower ambient

temperatures. As only one cell is completed each day, the body size of the offspring emerging the next season will depend on interactions between the weather and the body size of the mother and hence the quality and quantity of food that she is able to provide (Stone, 1994). Ongoing cold conditions in early 1996, delayed the start of the flowering period in the garden by up to three weeks compared with the previous year. Also bees emerged around mid-March 1995 but were not seen until early April in 1996. The flight period of the males was longer/later in 1996, yet that of the females was slightly shorter (10 weeks) in 1996 than in 1995. It may be that this was affected by the variations in flowering periods, with possible competition with other foraging species (e.g. other long-tongued bumblebees) also being a factor, as they utilise the same nectar and pollen sources. Two crucial requirements in the flower/insect visitor relationship making it beneficial to both parties are (1) the attraction of pollinators to the flowers and (2) the availability of food for the insect, for daily survival of individuals and also for females to stock brood cells. Consequently flowers offer pollen and nectar as a reward to the bees for the pollination service. To achieve this the flower needs to attract the bees by either colour and/or scent. Many flower petals have guidemarks some of which are visible to humans but almost as many again being visible to insects in the ultra violet range. The spectrum of bee-visible light differs from man such that they perceive blue-green and ultra violet as distinct colours (e.g. Daumer 1958) and some species (including *Anthophora plumipes* and bumblebees) are red blind (Menzel, 1990).

At the start of the project in 1995, when *Pulmonaria* was a scattered one or two barely open florets, it was expected that the first bees would visit them or similar PPB coloured flowers. However, this was not the case with bees preferring to visit the YWG coloured group of flowers. Initially the males were seen to forage violet coloured primrose hybrids, *Aubretia,* honesty and especially *Lithospermum,* whereas females seemed to prefer YWG flowers. Later, as more flowers became available, the females were seen to forage both groups of flowers. In 1996 there seemed to be no different foraging preferences between the sexes. The situation is probably complex as bees have different perceptions of colours to man (Daumer, 1958). It seems that, although colour is important in attracting bees, there is not a colour preference and other factors are probably involved as well. The shape of the flower is also relevant when considering its suitability for foraging by *Anthophora plumipes*. Only those flowers with the correct length corolla tube for the tongue (13mm long) of the bee will be used. This eliminates short-tongued bumblebees, unless they are resourceful enough to bite holes at the base of the corolla tube and obtain the nectar without pollinating the flower. Once the holes are cut, many insects take advantage of this easy access to the nectar (Proctor *et al*, 1996) but *A plumipes* was always seen to visit tubular flowers in the correct manner even if a hole had been cut. In 1995 both sexes of the bee made more visits to Boraginaceae than Lamiaceae but the reverse was true in 1996, indicating that foraging choice varies from year to year with available flowers always being dependent upon weather conditions and temperature. The availability of nectar varies with time throughout the day and may depend upon the rate of removal by insects. During 1995 female bees foraged earlier in the morning than the males and would have taken advantage of any large standing crops of nectar that had accumulated overnight. Apart from a

midday foraging lull by the males in 1995, the number of flower visits increased throughout the day until 18.00h after which there were no flower visits by the males and reduced foraging by the females until dusk (22.00h). In both years there were more flower visits by females than males. Competition with other bees for the same nectar possibly caused the standing crop to diminish faster than it could be replenished and shorter visits to more flowers were needed to obtain sufficient food for stocking brood cells.

Large, mature suburban gardens are a gradually declining habitat because of increasing urban development. They are valuable sanctuaries for many species and they may play an important role in aculeate conservation by providing suitable nesting sites for solitary bees, offering a chemical-free habitat and a range of nectar and pollen sources throughout the flight period. It is important to note that 2/4 *Anthophora* species mentioned a century ago by Saunders (1896) are threatened by habitat loss (*A retusa* is RDB1, *A quadrimaculata* is Nb; Falk, 1991). It would be unfortunate if *A plumipes* was to follow the same path.

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