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Foraging behaviour of anthracine flies (Diptera: Bombyliidae) in Southern Sinai, Egypt.

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ABSTRACT

We describe the seasonal and diurnal activity patterns, and the influence of temperature on the activity of members of a bee-fly community in the St Katherine Protectorate in southern Sinai. Ten species were present, including three new to science. All species appeared to forage exclusively on flowers of *Alkanna orientalis* (Boraginaceae), and activity patterns are probably dependent upon the thermal balance each individual achieves during the daily ambient conditions.

KEYWORDS: foraging, pollination, thermoregulation, Bombyliidae, anthracine

INTRODUCTION

Members of the dipteran family Bombyliidae (bee-flies) are virtually cosmopolitan in distribution, and are found primarily in warm arid to semi-arid habitats (Greathead & Evenhuis 1997), where they form a conspicuous part of the flower-visiting insect fauna (Toft 1984a). In Egypt, the Bombyliidae are very well represented, and the diversity of their appearance together with their varied parasitic mode of life can scarcely fail to excite interest (Efflatoun 1945). Very little is known about the biology and especially the ecology of bee-flies, except for fragmentary information reported in taxonomic works, and a few studies of bee-flies as components of larger systems (e.g. Motten *et al.* 1981).

It is commonly argued that two or more species utilizing the same set of limiting food resources will partition them, thereby avoiding competition (Ginsberg 1983). Toft (1983 & 1984b) found patterns in the ecology of bee-fly communities that suggested that competition among adult bee flies for nectar and pollen was occasionally a significant factor. These resources therefore can be potentially limiting for bee flies, at least in some species, despite bee flies gaining much of their total nutrition during the larval stage. If

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competition is severe enough to cause resource partitioning, then coexisting foragers may partition flower resources by flying at different times of the season, or at different times of the day, by foraging on different flower species, or by visiting flower patches of different sizes (Ginsberg 1983).

Climatic factors play an important role in determining the occurrence and timing of activities, and hence the frequency of insect visits to flowers. High levels of activity and high visitation rates are usually associated with warm conditions and high light levels (McCall & Primack 1992). The interaction between thermal balance and diel rhythmicity is responsible for many of the patterns of the insect activity seen in nature. Insect body size strongly influences thermal balance, and temporal patterns in the appearance of difference species at flowers are often simply explained by body size acting via thermal balance (see Willmer 1983; Gilbert 1985; Stone *et al.* 1999). For example, in a study on bees, Willmer & Unwin (1981) concluded that inter-specific differences in activity patterns were readily related to variation in body size. Therefore smaller insects, having lower temperature excesses (difference between body and ambient temperatures) and high cooling rates, are expected to be most active at greater radiation levels, such as those occurring in the middle of the day. Larger insects attain and maintain high temperature excesses fairly easily, and may readily reach a temperature conductive to activity even under conditions of low solar radiation. Thus larger insects are active earlier and later in the day than smaller insects, but may risk overheating during the middle of the day.

Little is known of diurnal activity patterns in bombyliid flies, and sometimes foraging plays a relatively small part in their activity budget. For example, adults of the genus *Anthrax* apparently spend very little time feeding and a great deal of time is given to searching for the nest of their hosts (Hull 1973). Despite this, bee-flies can be major pollinators of flowers.

The present study looks at the anthracines of a bee-fly community in the wadis near the town of St Katherine in southern Sinai, Egypt. As we show, these flies only visit the flowers of *Alkanna orientalis*, and the main pollinators of this plant in the St Katherine area are *Anthophora* bees and bombyliid flies (Willmer *et al.* 1994; Semida *et al.* 1998). These two taxa may share the floral resources, since they vary in their pattern of foraging activity during the day and season. The activity of bee-flies occurs at different times from those of *Anthophora*, with a maximum around midday when the bees' activity is very low (Semida *et al.* 1998).

MATERIALS AND METHODS

The mountainous area around the town of St Katherine is an isolated area of high biodiversity in the middle of southern Sinai, at an altitude of 1650 m. It contains the highest mountains in Egypt (Gebel Katherine at 2642 m; Gebel Mousa at 2285 m), forming a rugged set of mountains with acid plutonic and volcanic rocks. The area has an unusual climate as compared to the rest of Egypt, being relatively cool in summer (mean August temperature = 26°C) and cold in winter (mean January temperature = 7.7°C). It is the wettest region of Egypt, with up to 100 mm of rain per year.

Wadi El-Arbaein runs from the town of St Katherine south-east to the foot of G. Katherine, bounded by G. El-Sarwo (alt. 2150 m) to the east, an extension of G. Safsafa

(2168 m), and G. El-Rabba at the northern boundary (see map in Willmer *et al.* 1994). In Wadi El-Arbaein, the vegetation is made up of numerous species of plants, but each is represented by only few individuals. The most common plants in Wadi El-Arbaein are: *Alkanna orientalis* (L.) Boiss. (Boraginaceae), *Fagonia mollis* Del. (Zygophyllaceae), *Peganum harmala* L. (Zygophyllaceae), *Origanum syriacum* L. (Labiatae), *Stachys aegyptiaca* Pers. (Labiatae), *Phlomis aurea* Decne. (Labiatae), *Tanacetum santolinoides* Dc. (Compositae), *Artemisia inculta* Del. (Compositae), and *Echinops glaberrimus* Dc. (Compositae). These plants are found in different patches of habitat isolated or semi-isolated from each other in different localities of the wadi. Some plants are restricted to areas up on the mountain-tops, while others grow in the wadi bed or on the rocky slopes of the mountains.

From preliminary studies in Wadi El Arbaein in 1997, it was noticed that anthracine bee-flies were frequent only at certain sites in the wadi, foraging only on *Alkanna orientalis*, in spite of the presence of many other types of flower. This was observed many times through the activity period of these flies from the beginning of May until the beginning of August. Consequently, it was hypothesized that there might be a relationship between the diversity and abundance of these anthracine flies and the plant cover of *Alkanna orientalis*. This plant is visited by only a few insect species, but abundantly by *Anthophora* bees (see Willmer *et al.* 1994; Gilbert *et al.* 1996; Stone *et al.* 1999; Gilbert *et al.* 1999). A perennial with a shrubby base, it has yellow green foliage covered with glandular hairs exuding a sticky irritant liquid, and yellow flowers containing very large amounts of nectar. The plant starts to flower during the second half of March, and increases gradually to reach a maximum during the last week of April; by June there are only a few flowers to be seen.

Three sites were chosen for studying the patterns of diversity and seasonal abundance of bee-flies. Site A was at the mouth of El-Arbaein, and contained only a moderate number of *Alkanna* plants; site B at the middle of the wadi contained more *Alkanna* plants than site 1; site C was in the adjacent Wadi El-Talaa, and contains no *Alkanna* plants. Each site measured 10 x 10 m, and was studied during 1998 approximately every two weeks (at the beginning and at the middle of each month) during the activity period of the bee-flies, from the beginning of May to the beginning of August. For three periods of 30 mins (in the morning, around midday, and in the afternoon), as many flies as possible were collected with an insect net at each site. The flies were killed using ethyl acetate and taken to the laboratory and pinned. The Shannon-Wiener diversity index (H') was calculated from these data, using the formula H = - (pi (ln pi) where pi = proportion of the I'th species in the site.

A standard line transect was chosen to estimate the daily abundance patterns of species in the middle of Wadi El-Arbaein, deliberately chosen to contain many *Alkanna orientalis* plants. The transect was 200 m x 5 m, and was also visited at the beginning and middle of each month. At each visit, observations started at 9 am and ended at 6 pm, and during this time the transect was censused at a constant very slow pace each hour. All times are cited in local Egyptian time (GMT +2).

Besides the transect there was also a standard quadrate measuring 5 x 5 m for observing the diurnal activity and foraging behavior of each species. The quadrate was watched for 30 minutes in each hour to record the following activities: flying, feeding, resting in shade, basking in the sun, fighting with other insects or hovering on *Alkanna* plants.

Unless a specimen was collected, it was impossible to distinguish the sex of each species in the field, and therefore sex is ignored in the analysis. Temperature was recorded every hour using a digital thermometer, and the simple correlation test was applied to investigate the effect of this climatic factor on the activity of observed species as measured by the duration of activities in each hour during the day.

RESULTS

One hundred and fifty specimens representing ten species belonging to the bombyliid tribe Anthracini were collected during the study, and all were foraging only on *Alkanna orientalis*. Eight of the collected species belong to the genus Anthrax, while two species belong to the genus *Spogostylum* (Table 1). All ten species were collected at site B, but only seven of them were collected from site A, where they were much less frequent. At site C in Wadi El-Talaa, no specimens were collected. Diversity as measured by the Shannon-Wiener index was higher for site B than for site A, and the two sites differed significantly in abundance, as measured by the number of collected individuals of each species (sign test, $Z = 2.85$, $p < 0.01$). The average percentage cover of *Alkanna orientalis* followed these site variations in diversity (Table 1). Using the detailed data of site B, there was a correlation between *Alkanna* cover and both diversity ($r = 1.0$, $n = 7$, $p<0.01$) and species richness ($r = 0.93$, $n = 7$, $p<0.01$); these data are, however, confounded by seasonal changes.

In site B, diversity as measured by H was moderate (1.697) in early May, increased to a maximum of 2.01 in early June, and thereafter declined gradually to a minimum of 1.193 in mid-July. Likewise species richness increased gradually from May to the maximum of 9 species in June, and then declined gradually again during July and early August. Abundance was at a maximum in mid-June (a total of 30 specimens collected), but on most days the number caught was between 10 and 21; only one specimen was collected in early August.

Three species of *Anthrax* (*fuscipennis*, *lucidus* and *trifasciatus*) and the two *Spogostylum* species have reasonable sample sizes from site B, and hence their seasonal appearance and diurnal activity patterns can be tentatively assessed. All three Anthrax species appear to have extended emergence periods (possibly multiple generations) with a peak in mid-June. Only one rare species, *A. moursyi*, may be a spring species with a peak in early May. *S. candidum* also had a long emergence period, and possibly two generations; it peaked later, in early July. In contrast, the other species of *Spogostylum*, *isis*, was clearly a spring-emerging species, with virtually all individuals being caught in May or early June.

Most bee-flies showed diurnal activity patterns that shifted seasonally, demonstrating their susceptibility to environmental conditions, probably temperature. For example, the large spring species *S. isis* had its maximal activity at 1300 h in early May, but this had shifted one hour earlier by early June. In early June at the start of the main emergence period of the medium-sized *A. trifasciatus*, activity was unimodal and maximal at 1400 h, but during most of the summer in mid-June and July it became bimodal, with activity peaking at 1100 h and 1500-1600 h. Similar changes occured in the activity patterns of *A. fuscipennis* and *A. lucidus*. In contrast, the large *S. candidum* had a bimodal pattern of diurnal activity throughout its phenology. Most species spent a lot of their time basking during the morning, but were seen hovering during the afternoon: feeding was usually observed during the morning.

The common medium-sized species of *Anthrax* showed significant negative correlations between the total duration of all their activities and ambient temperature (r = -0.82, p<0.05 for *A. lucidus*; r = -0.87, p<0.05 for *trifasciatus*), and for the duration of basking (r = -0.82, p<0.05 for *lucidus*; r = -0.90, p<0.01 for *trifasciatus*). The two large species of *Spogostylum*, *S. candidum* and *S. isis* showed no evidence for these correlations.

Table 1: Species and total number of individuals collected from three sites near St Katherine in southern Sinai during May-August 1998

	Total numbers collected throughout the year				
Species	**Site I**	**P**	**Site II**	**P**	**Site III**
Anthrax fuscipennis (Ricardo)	2	0.0488	18	0.165	0
Anthrax lucidus (Becker)	6	0.146	11	0.101	0
Anthrax melanista (Bezzi)	0	0.000	2	0.048	0
Anthrax sticticus Klug	3	0.073	8	0.073	0
Anthrax trifasciatus Meigen	12	0.293	25	0.229	0
Anthrax greatheadi sp. nov.	0	0.000	6	0.055	0
Anthrax moursyi sp. nov.	2	0.049	4	0.037	0
Anthrax sp. (undescribed)	0	0.000	1	0.009	0
Spogostylum candidum (Sack)	8	0.195	19	0.174	0
Spogostylum isis (Meigen)	8	0.195	15	0.138	0
Total (10 species)	41		109		0
Diversity index[1]	1.76		2.032		0
Cover[2] of *Alkanna orientalis*	4.73%		8.73%		0

1. Shannon-Wiener diversity index (see Methods)
2. Estimated plant cover

DISCUSSION

Only five species were collected regularly at Wadi El-Arbaein, while the others were rare. These findings are consistent with many other community and specifically pollination studies which show that a small number of species dominate the community, whilst the majority of species are relatively rare (e.g. Cane & Payne 1988). Overall, a fairly diverse fauna consisting of ten anthracine species from two genera were collected foraging on *Alkanna orientalis* at sites in Wadi El-Arbaein. This sub-community of flower visiting insects is apparently completely dependent upon *Alkanna* flowers, since in Wadi El-Talaa where no *Alkanna* plants were present, no specimens were collected at all, and the abundance and species richness increased with increasing cover of *Alkanna*. Furthermore, even though the main flowering season of *Alkanna* finishes in June, bee-flies still appear only to forage on its flowers well into July and even August. Of course, it may be that the absence of anthracine flies from Wadi El-Talaa may be due to site differences rather than the absence of *Alkanna*. Against this interpretation is the fact that three different anthracine species were collected opportunistically from Wadi El-Talaa, and these were indeed foraging on *Alkanna orientalis* flowers near the sampled site. Our tentative conclusion is that anthracine diversity is tied to the presence of particular floral resources, and in the mountains of southern Sinai this is specifically the flowers of *Alkanna orientalis*.

Semida *et al.* (1998) recorded *Anthophora* bees and bombyliid flies as the main pollinators of *Alkanna orientalis* in Wadi El-Arbaein. He found that the two groups of insects vary in their patterns of foraging activity during the day and season. *Anthophora* bees appear early in the flowering season, reaching their peak of abundance in the first half of the season (around mid-April). On the other hand, bee-flies appear in the second half of the season, reaching their peak of abundance around early June. They also seem to have different activity patterns during the day. Other occasional visitors to *Alkanna* flowers [*Eupeodes* (*Metasyrphus*) *corollae*, *Eristalinus aeneus*, *Delta dimidiatipenne*, *Oxythyrea* sp., *Coccinella* sp. and various butterflies] seem to visit the flowers uncommonly or rarely, and they cannot be considered as important pollinators.

We assume that resources for adult anthracine flies, from *Alkanna* flowers, are not limiting at Wadi El-Arbaein, but are superabundant; this may underlie the occurrence of more than one anthracine species synchronously, without competing. Anthracine flies were noticed taking refuge on *Alkanna* plants: over and above their foraging requirements and the nesting behaviour of their insect hosts, this may contribute to the relationship between abundance and diversity of anthracine flies and plant cover of *Alkanna* in Wadi El-Arbaein.

Species-specific environmental tolerances set by these intrinsic factors, such as thermoregulatory ability, in relation to the daily course of extrinsic factors such as temperature determine definite "daily activity windows" for different pollinators. Interspecific differences in timing of insect activity windows, which represent a compromise between the constraint imposed by resource availability, daily fluctuation in temperature and thermoregulation costs, and risk of predation, lead to succession of insect species ordinarily foraging on a given plant species in the course of the day (Kevan & Baker 1983; Willmer 1983; Gilbert 1985; Semida 1994). The interaction between thermal balance and diel rhythmicity is responsible for many of the patterns of the insect activity seen in nature. Insect body size strongly influences thermal balance and interspecific differences in activity patterns are readily related to variation in body size. Smaller insects, having lower temperature excess (difference between body and ambient temperatures) and high cooling rates, are expected to be most active at greater radiation levels, such as those occurring in the middle of the day. Larger insects attain and maintain high temperature excess fairly easily, and may readily reach a temperature conducive to activity even under conditions of low solar radiation (Semida 1994).

Herrera (1990) found that small anthophorid bees tend to display a unimodal activity pattern, with maximum abundance occurring around midday. Medium- to large-sized *Anthophora* species have bimodal activity patterns, with peaks in early mid-morning and mid-late afternoon, with a minimum around midday. Diel patterns of activity of the main insect pollinators in Wadi El-Arbaein are also strongly affected by the insect body size and the ambient temperature (Semida 1994; Semida *et al.* 1998). The medium-sized *Anthophora pauperata* bees exhibit a bimodal pattern of activity when temperatures are between 18-25°C, but small bombyliid flies start their activity later in the morning and have a peak of activity around midday, coinciding with the highest air temperatures (about 30°C). This may be due to their need to obtain enough heat to warm up their bodies, and yet not to lose this heat via their high cooling rates because of their small body size.

Anthracine flies are medium- to large-sized insects and most species were found to exhibit a bimodal activity. The medium-sized species of the genus *Anthrax* (except for *Anthrax fuscipennis*) were active when the temperature was in the range of 25°C-30°C and their activities, as measured by duration, were significantly correlated with ambient temperatures, while the larger species of genus *Spogostylum* were active in the range of 25°C-33°C and their activities including basking were not correlated with ambient temperatures. These differences between the two genera may be due to the lower cooling rates of the larger *Spogostylum* species. Generally we may conclude that the smaller the anthracine bee-fly, the more sensitive it is to ambient temperature.

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الملخص العربى

سلوك البحث عن الغذاء فى ذباب آنثراسينى (رتبة ثنائية الأجنحة – فصيلة بومبيلييدى) فى منطقة جنوب سيناء – مصر

على على المرسى[١]، فرانسيس جلبرت[٢]، سامى زلط[٣] و مجدى الحواجرى[١]

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تم خلال هذه الدراسة بيان النشاط الموسمى واليومى وتأثير الظروف المناخية وخصوصا درجة الحرارة على تواجد أنواع ذباب آنثراسينى (فصيلة بومبيلييدى) أو كما يسمى "بذباب النحل" وذلك فى محمية سانت كاترين بمنطقة جنوب سيناء. تم رصد عشرة أنواع من هذا الذباب فى منطقة الدراسة شاملة ثلاثة أنواع جديدة إلى الفونة العالمية.

أوضحت الدراسة أن جميع الأنواع تنشط باحثة عن الغذاء وذلك على أزهار نبات اللوبيد (*الكانا أورينتاليس*) والذى يعتبر المصدر الرئيسى للذباب للحصول على المصادر الغذائية، أيضا كان النشاط اليومى والموسمى يعتمد على توازن درجات الحرارة داخل جسم الحشرة والذى يعتمد بشكل كبير على الظروف المناخية المحيطة وبالتالى كان نشاط الأنواع يختلف بشكل كبير إعتمادا على التغير فى درجات الحرارة فى منطقة الدراسة.