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COMPARISON OF FLIGHT PERIODS OF SOLITARY AND PRIMITIVELY EUSOCIAL BEES IN URBAN ENVIRONMENTS AND NATURE CONSERVATION AREAS: A PRELIMINARY REPORT

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Comparison of Flight Periods of Solitary and Primitively Eusocial Bees in Urban Environments and Nature Conservation Areas: a Preliminary Report. Sirohi, M. H., Jackson, J. & Ollerton, J. —

Solitary and primitively eusocial bees, an important group of pollinators, have declined in the past few decades. In view of the recent focus on safeguarding pollinating insects, it is vital to understand the basic ecology of species for their conservation, for example their phenologies. We observed the flight periods of solitary and primitively eusocial bees in both the urban core of a large British town and nearby nature conservation areas. The bee surveys were conducted with standardised methods, on warm sunny days from the first appearance of bees in March 2012 and continued until October 2012. This study confirmed that a high number of species are active in the spring season. The emergence dates of species in urban areas and nature sites varied; about 26 of the 35 species were recorded at least one week earlier in urban areas; in contrast, only four species were seen earlier in nature conservation sites. When comparing this with the expected flight periods recorded (largely in nature sites) in the literature, many species were recorded at their expected time. However, a few individuals were recorded after their usual flight activity time, suggesting that the populations were possibly affected by the microclimate in urban areas. More urban phenological data are needed to understand the phenological trends in bees in urban habitats.

Key words: Hymenoptera, phenology, pollinator conservation, urban habitats, Apoidea.

Introduction

The phenologies of living organisms have gathered enormous attention as a vital element of ecosystems because organisms respond to changes in their environments (Rosenzweig et al., 2008; Lehmann et al., 2020). Understanding of the phenology of pollinating insects such as flight periods and peak abundance is important because around 90 % of plant species depend on pollinating insects for their survival (Ollerton et al., 2011; Tong et al., 2023). The phenological events of pollinators and their host plant are synchronized to some extent but the effects of environment on the developmental stages and subsequent phenology of bees are largely unknown. In contrast to that, a wide range of research has reported shifts in phenological events in many flowering plant species (Yu et al., 2016; Wolf et al., 2017; Petruski et al., 2019; Suonan et al., 2019; Kudo, 2020). The response of species to the changed environment may vary. The shifts in emergence dates of species may not only produce harsh conditions for the species itself, but also result in a cascade of negative effects on other species of the community in the form of ecological mismatch of plant-pollinator relations (Gillespie et al., 2016; Byers, 2017; Morton & Rafferty, 2017; Shrestha et al., 2018).

Solitary and primitively eusocial bees are important pollinators of wild and agricultural plants (Ollerton, 2017). Apart from rural populations, a huge diversity of such insects inhabit urban areas and deliver ecosystem functions and services, i.e. pollination (Lowenstein et al., 2014; Baldock et al., 2015; Sirohi et al., 2015, 2022; Threlfall et al., 2015; Langellotto et al., 2018; Theodorou et al., 2020). Urban areas are thus thought to be a substantial sanctuary for the declining populations of some pollinators (Hall et al., 2017; New, 2018; Ollerton, 2021). The effects of various environmental factors, such as temperature (Bosch & Kemp, 2003), scarcity of food resources (Kim, 1999; Peterson et al., 2006), and nesting conditions (Stephen & Osgood, 1965; Klostermeyer et al., 1973) on the phenology of solitary and primitively eusocial bees have already been reported (Eickwort et al., 1996; Richards 2000; Soucy, 2002; Wyman & Richards, 2003). However the phenology of these taxa in urban areas is hardly known. Urban areas tend to be warmer due to human activities, a phenomenon called the 'urban heat island effect' (Santamouris, 2006; Mohajerani et al., 2017). A difference of 1–4 °C is common between urban and rural areas, however, urban areas have been recorded as being up to 10 °C warmer than the surrounding environment (Santamouris, 2006). Therefore, we hypothesize that pollinators emerge earlier in urban environments due to this warmer microclimate. To understand the ecology of solitary and primitively eusocial bees in urban settings, this research focuses on their phenology and examines the differences in their emergence and activity times in both the urban environment of a large British town and nearby nature reserves, meadows, and orchards, collectively termed 'nature sites'.

Methods

Bee phenology was observed in and around Northampton, a large British town in the East Midlands (52°14'14" N, 0°53'50" W). The area has a moderate temperature, rising to an average maximum temperature about 22 °C in the warmest months of July and August. The coldest month recorded in Northampton is January with average minimum temperature 0.5 °C (Spellman, 2012). In the months of May and June, generally days remain sunny with a north-easterly wind, which can be followed by cold nights. The weather recorded during the time of the study (March–October, 2012) was not very different to what is usually recorded, except a slightly warmer March and more days with precipitation in April and June (fig. 1).

The data were collected from eighteen urban sites including churchyards, gardens, roadside verges, traffic islands and green open spaces within a 500 m radius of the centre of town. To compare the pollinators' phenology in urban areas, six nature sites were selected within a range of up to 5000 metres from the centre of town, which is close enough to share a similar regional climate and species pool. Details of the field sites, size and methods are given in the supplementary material (see also Sirohi et al., 2015). Bee surveys were conducted on sunny and warm days between 10 am and 5 pm (Cane et al., 2000) using two methods, pan traps (for 7 hours, 3 traps/survey/site) and hand netting for 30 minutes each site during surveys. The sampling sites were divided into two groups; each group of sites was surveyed every week with one or the other method from 1st March 2012 and continued until the 28th of October 2012.

We compared the observed phenologies of solitary and primitively eusocial bees with species accounts in the published volumes of the *Provisional Atlas of Aculeate Hymenoptera of Britain and Ireland* (Edwards 1997; Edwards, 1998; Edwards & Telefer, 2001, Edwards & Telefer, 2002; Edwards & Broad, 2005; 2006; Edwards & Roy, 2009). However, not all species have been addressed in those volumes. Therefore, the species' phenologies were compared with the studies of other organizations that record solitary and primitively eusocial bees nationally or locally. Principally, we considered the Bees Wasps and Ants Recording Society (BWARS) which is a national society for recording Hymenoptera in the United Kingdom (BWARS, 2013). If BWARS had no data for a particular species, the phenology was compared with the observations of other organizations, such as

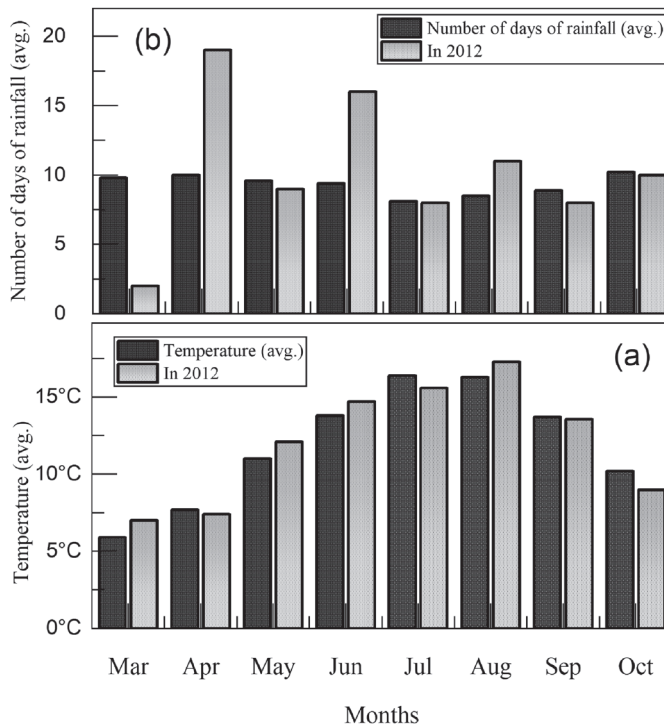


Fig. 1. Average maximum temperature and days of rainfall higher than 1 mm in Northampton. The monthly averages were calculated from the data recorded at Northampton weather station from 1981 to 2010 (Met Office, 2015).

Nature Spot (Nature Spot, 2013) which records the wildlife of Leicestershire and Rutland, and The Essex Field Club (The Essex Field Club, 2013) which is a wildlife society for Essex, England. Most of these phenologies are based on observations in natural areas. We also consulted Falk & Lewington (2015), the most recent field guide to bees of Britain and Ireland.

The emergence dates of species may vary slightly between years due to variation in environmental conditions. Therefore, we divided each month into four quarters (roughly equal to a week) and pooled pan traps and hand netting observations into the relevant week. Due to such variation, the published data also mentioned the flight periods in approximate time; for example, the Provisional Atlas used the words as 'early', 'mid', and 'late' of certain months (Edwards & Broad, 2005; Edwards & Broad, 2006). This study assumed early as the first week, late as last week and mid-month as the two middle weeks of the month.

Results

Bee species started emerging from the second week of March and continued until summer (fig. 2). Ten bee species of families Andrenidae: *Andrena bicolor* (Fabricius, 1775), *A. dorsata* (Kirby, 1802), *A. minutula* (Kirby, 1802), Apidae: *Anthophora plumipes* (Pallas 1772), *Melecta albifrons* (Förster, 1771) and Halictidae: *Lasioglossum malachurum* (Kirby, 1802), *L. morio* (Fabricius, 1793), *L. smeathmanellum* (Kirby, 1802), *L. calceatum* (Scopoli, 1763), *L. lativentre* (Schenck, 1853) appeared in the second week of March (see supplementary data). A high abundance of bees was recorded in the months of April and May, with between 30–39 bee species in flight each week (fig. 2).

The species of family Andrenidae were seen in flight from spring to summer seasons, though about 90 % of individuals were observed in spring (fig. 1). All species of Andrenidae emerged in the month of March except *Andrena cineraria* (Linnaeus, 1758) which was observed from the first week of April (Supplementary data).

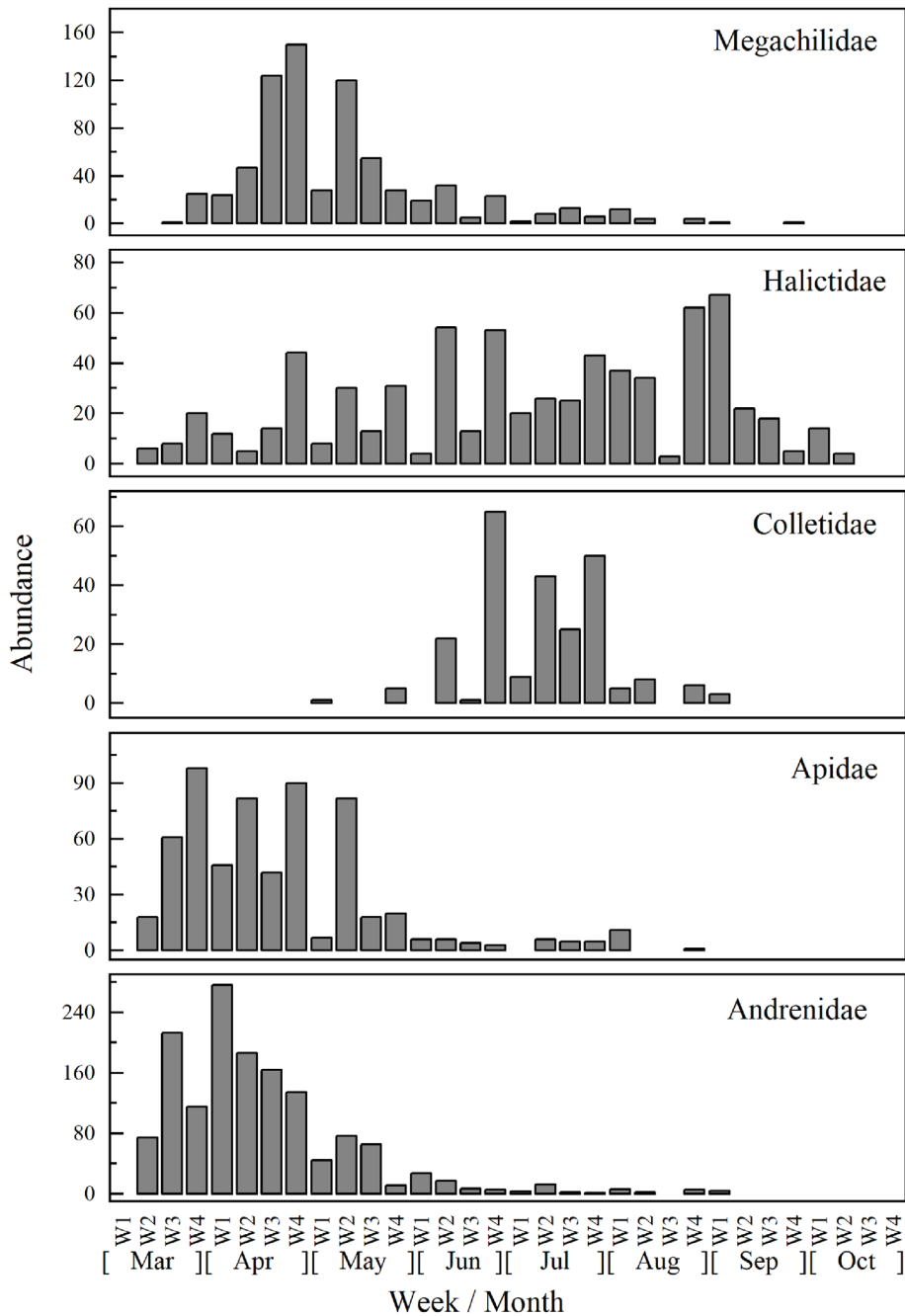


Fig. 2. Flight period and abundance of bee species of five families observed in various urban and nature sites in Northampton, England.

The family Apidae was dominated by kleptoparasitic species. The species of the genus *Nomada* are generally kleptoparasites of species of Andrenidae, therefore, their presence was expected. The members of the latter family started their flights in the second week of March, emerging sporadically in spring except *Anthophora quadrimaculata* (Panzer, 1798) which emerged later in the summer. We recorded *Nomada rufipes* (Fabricius, 1793) (total 10 individuals) from the last week of April to the end of May (fig. 3), which is well ahead

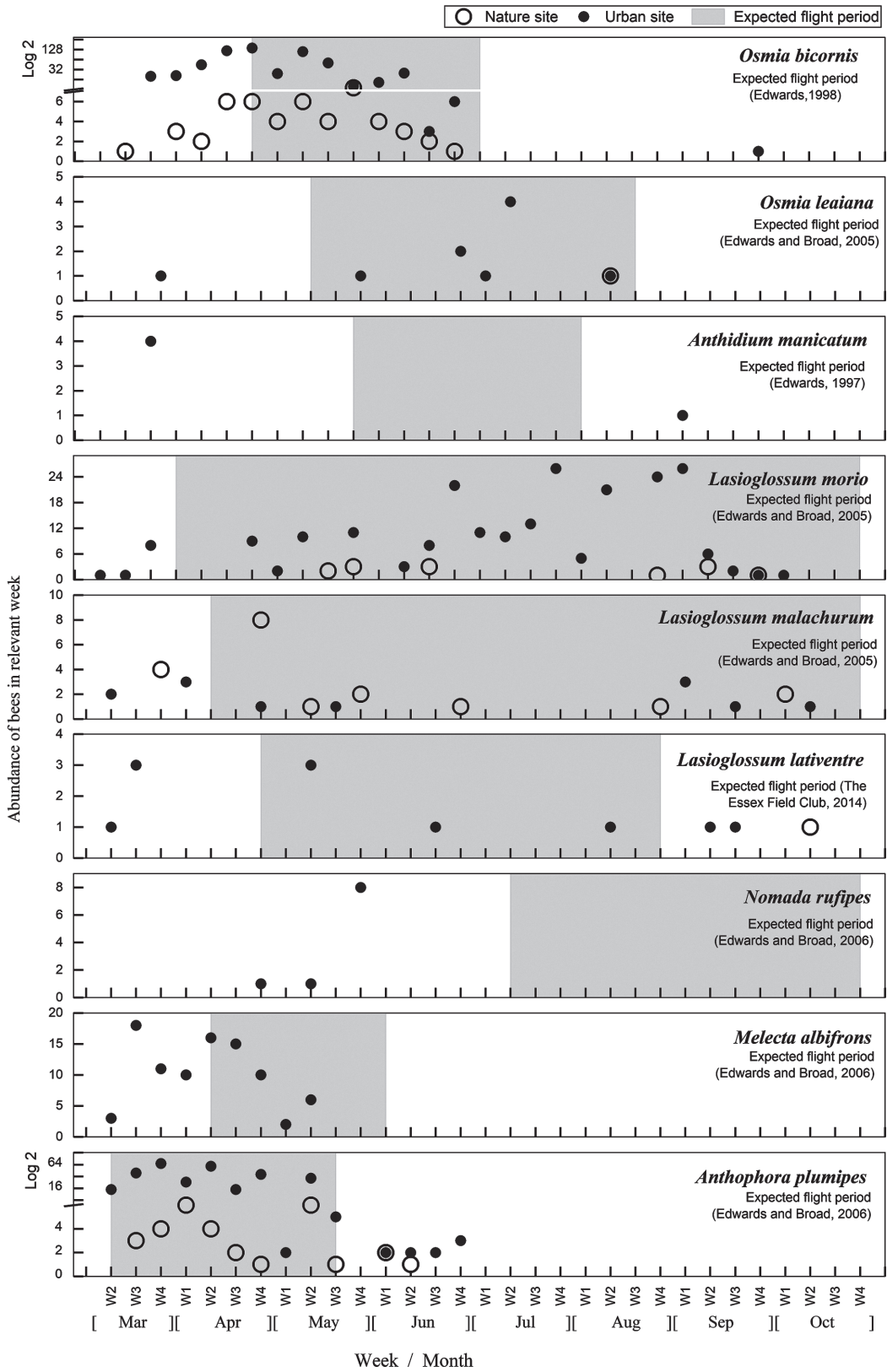


Fig. 3. Bee species observed in the field before and after their expected flight periods. The shaded region shows the expected flight period in England.

of its expected emergence time in England from the first week of July (Edwards & Broad, 2006). Overall, species of Family Apidae were highly abundant in the spring season but also present in summer (fig. 2). None of the members of this family was observed in autumn. *A. plumipes* was seen in flight until June, four weeks beyond its expected flight time (fig. 3). The kleptoparasite *M. albifrons* was only present in urban sites and emerged in advance of their expected flight time (fig. 3). The species emerged early at the same time as its host *A. plumipes*.

The members of family Colletidae were confined to and abundant in the summer season except seven individuals of *Hylaeus hyalinatus* (Smith, 1842) seen flying in the last week of spring and the first week of autumn (supplementary data). The members of family Halictidae emerged from the second week of March to May and species were observed in flight sporadically throughout the year until the second week of October. The family was represented by three genera. The genus *Lasioglossum* dominated, being species rich and highly abundant. The genus was present among all seasons with peak abundance in summer. *L. morio* and *L. malachurum* emerged two and three weeks ahead of expected time, respectively (fig. 3). *L. lativentre* was the only species which was seen in flight before and after the expected flight times (fig. 3).

The members of family Megachilidae emerged from the third week of March. The species were in low abundance except *Osmia bicornis* (Linnaeus, 1758). The species were observed intermittently throughout the seasons until September (fig. 3). *O. bicornis* was the dominant species in the family which was observed from the third week of March to the end of June. However, after a long disappearance of about 11 weeks a single male of *O. bicornis* was observed in autumn on 29th of September (fig. 3). *Osmia leaiana* (Kirby, 1802) was seen in its expected flight time except one individual which was spotted about four weeks before its expected flight season (fig. 3). Similarly, *Anthidium manicatum* (Linnaeus, 1758) was observed in March and then in September. No individuals of *Anthidium* were found from April to August (fig. 3).

We observed a substantial effect of urban microclimate on bee flight periods. A total of 153 individuals of nine bee species were recorded one to nine weeks before or after their expected flight periods (fig. 2). In contrast, only 14 individuals of four species were seen at unusual flight periods in nature sites (fig. 3).

Comparing the first flight records of species in urban areas and nature sites, most species (26 of 35 spp. having ≥ 10 individuals in total) were found one or more weeks earlier in urban areas before being recorded in nature sites (fig. 4). Six of the Andrenidae species were in flight about one to four weeks before being caught in nature sites. Only two species of *Andrena* were seen in nature sites before they were seen in urban sites, while others appeared in the same week in urban and nature sites. *Andrena flavipes* (Panzer, 1799), a bivoltine species, was seen with two broods in urban sites but the second brood was not recorded in nature sites. *Hylaeus signatus* (Panzer, 1798) and *H. hyalinatus* were seen in flight at urban sites about four weeks before being observed in nature sites (fig. 4). Species of Colletidae were rare in nature sites, and therefore might be present but not observed due to very low detectability.

There was 2–17 weeks' advancement in emergence of *Lasioglossum* species in urban areas except in *L. villosulum* (Kirby, 1802) which was observed in urban areas four weeks later than in nature sites. However, this advancement could be related to the higher abundance (and therefore detectability) of members of this family in urban areas. Only five species, *Andrena cineraria*, *A. nitida* Müller, 1776, *A. tibialis*, *Halictus rubicundus*, and *Lasioglossum albipes*, were recorded in the same week in urban and nature sites. On the

other hand, three ground nesting species, *Andrena flavipes*, *A. nigroaenea*, *Lasioglossum villosulum*, and a cavity nester, *Osmia bicolor*, were seen one to four weeks earlier in nature sites (fig. 4).

Discussion

The flight periods of pollinating insects are crucial as these must be synchronized with the plants that provide nectar and pollen resources. This study recorded flight periods of all species encountered in the field season and some species were clearly more abundant than others, with abundant species encountered more frequently. As a result, their flight periods were much clearer. For example, *O. bicornis* was observed more often and showed a clear appearance from the third week of March. The species was encountered every week until the end of June, with a peak abundance in late April to early May (fig. 3). In contrast, many species were less abundant and observed very sporadically, such as *Lasioglossum leucozonium* which was encountered intermittently in all seasons. Due to lower detectability and subsequently low number of observations of such species, it was difficult to establish their exact flight period and peak abundance. *L. leucozonium* was expected from March (Edwards & Roy, 2009; Falk & Lewington, 2015) but encountered for the first time in early May. It was quite possible that the spe-

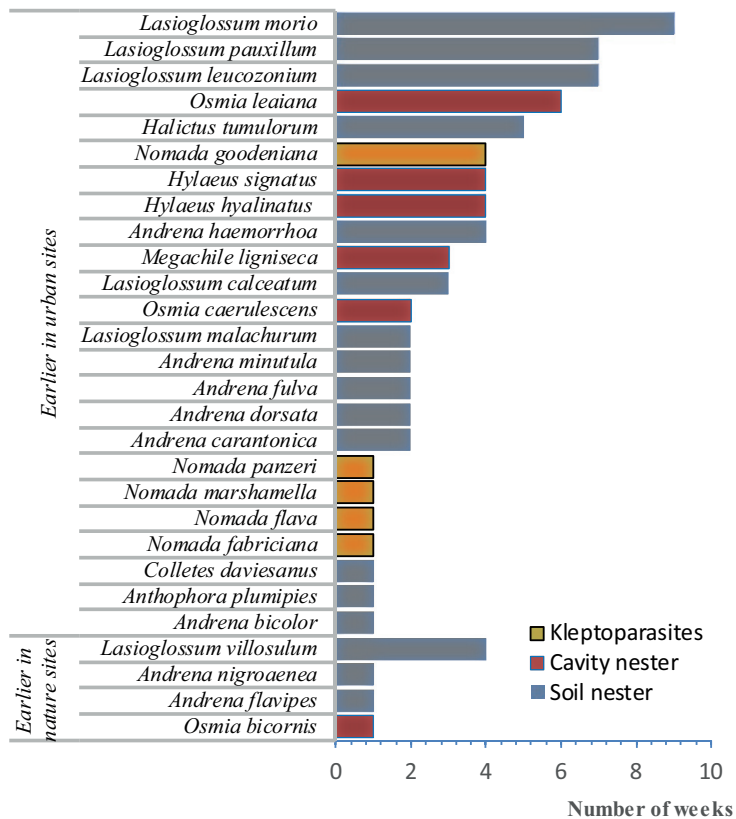


Fig. 4. Emergence of species recorded earlier in urban and nature sites. Five soil nesting bees, *Andrena cineraria*, *Andrena nitida*, *Andrena tibialis*, *Halictus rubicundus* and *Lasioglossum albipes*, and one kleptoparasite *Nomada flava* were recorded in the same week in urban and nature sites. Two soil nesting species *Lasioglossum lativentre* and *Lasioglossum smeathmanellum* were very rare in nature sites (represented by one and two individuals, respectively) therefore not included in the figure.

cies was in flight earlier but was not observed due to low detectability. However, their presence at the observed times was comparable to their expected time of flight period as per published information (Edwards & Roy, 2009).

When comparing the flight periods of species with the published data in England, many species (about 80 %) were seen in flight at their expected time. However, a few species were seen foraging some weeks earlier than expected. For example, *A. nitida*, *M. albifrons* (Edwards & Broad, 2006), *O. bicornis* (Edwards, 1998) and *Osmia caerulescens* (Edwards & Broad, 2005) were expected to be in flight from April but these species were seen in flight 1–3 weeks before in the second and third weeks of March. This may be due to the slightly warmer weather recorded in March which could have triggered their emergence, which is often controlled by the local weather (Roy & Sparks, 2000; Kreamer & Favi, 2010). Changes in emergence dates of bees of up to three weeks in some years have already been reported. For example, in a five year study of the phenology of *Osmia lignaria*, Kreamer and Favi (2010) found that the emergence date of this species varied from the beginning until the end of March depending on the weather. Similar changes of emergence dates from year to year due to their environment have also been reported in other insects, for example butterfly emergence dates advance 2–10 days for 1 °C increase in temperature (Roy & Sparks, 2000). Likewise, plants can also vary significantly between years in their flowering dates (Ollerton & Lack, 1998; Ollerton & Diaz, 1999). Therefore, a few weeks' early emergence in some species in this study may be related to local weather conditions.

Insects usually have one or more generations per year. However, it is under genetic or environmental control whether to develop into an adult or rest in diapause (Scoble, 1995). The expression of one or more broods is generally controlled by photoperiod and temperature (Scoble, 1995; Altermatt, 2010). Many bivoltine (having two generations per year) populations turn to univoltine (one generation per year) when moved to higher altitude (Välimäki et al., 2008). In a study of European butterflies and moths, Altermatt (2010) found a significant effect of warm temperature after 1980 in a large proportion of butterfly species, and 44 species had been recorded with an increased number of generations. In our study, most univoltine species were seen at their usual flight periods but individuals were also found far before or after their usual flight times. For example, *O. leaiana*, was found in its expected flight period from late May to August, with peak abundance in mid-July (Edwards & Broad, 2005; Falk & Lewington, 2015), but a single individual of this species was also spotted on 27th of March, which was too early and isolated from the main population (fig. 2). In another case, *O. bicornis* was expected to be seen in flight from April to June (Edwards, 1998) but the species emerged two weeks earlier in mid-March and continued until the end of June. The study did not record any individuals of *O. bicornis* after June until the end of September when a male individual of this species was spotted on 29th of September (fig. 3). This was an unexpected sighting of a species three months after disappearing earlier in that year. These isolated individuals from the population in *O. bicornis* and *O. leaiana* may belong to the partial second brood of the species or may be related to the unusual occurrences related to the urban microclimate.

Another example was *A. manicatum* which is also a univoltine species. This species can be seen foraging from May to late August with a peak abundance in June and July (Edwards, 1997). But in this study all individuals of the species were found either far before or long after its expected flight period (fig. 3). Though a species' phenology can change geographically (Välimäki et al., 2008), *A. manicatum* had already been spotted visiting *Linaria*

purpurean in its expected flight period (May–August) by the first author during in 2011 on 21st July. For this reason, therefore, this cannot be an example of geographical change in phenology. Edwards (1997) also mentioned the sighting of few freshly emerged individuals of *A. manicatum* in late July in 1995 but he was not sure whether those individuals belonged to the second brood of the species. The average flight season of *A. manicatum* is 80 days (Wirtz et al., 1992). In this study the species was first spotted in March and then in September, which is too long to be expected for a single brood species in flight, so this population might have produced a second brood in August/September. The second broods of *O. bicornis*, *O. leaiana*, and *A. manicatum* have not been formally described in England. This needs more case studies to establish whether these species have produced partial second broods or individuals found far away from the flight periods were actually a small fraction that was affected by the local climate.

It is also pertinent to mention that most of such individuals of the species found in unusual flight times were observed in urban sites (fig. 3). This raises a question as to why all such phenological variations appeared in urban areas. The phenology in urban sites reported in this study may slightly vary from the published phenology of bees in England due to microclimatic differences and resource availability. Each urban area may provide a different environment depending on the resources, climate and geography, consequently the phenological response of solitary and primitively eusocial bees is changeable accordingly. Furthermore, there is a lack of phenological data for urban areas so that the existing published data might be biased towards the rural sites. This underlines the necessity for more detailed research about the urban habitats for solitary and primitively eusocial bees to understand phenological trends.

Data statement

All data generated or analysed during this study are included in this published article and its supplementary information files.

Conflict of interest

The authors declare no conflict of interest.

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Supplement. Data 1. List of the urban and nature sites surveyed for bees in and around Northampton town, England with their descriptions, size and survey methods

Site name	Size, m ²	Site description	Bee surveys
Urban site 1	1287	A garden with lawn and flowers at All Saint Church.	<p>The surveys were conducted from the first week of March 2012 and continued until October 2012</p> <p>Each month was divided into four quarters (referred to as week).</p> <p>W1 = First quarter 1–7 dates of the month (7days) W2 = Second quarter 8–15 dates of the month (8 days) W3 = Third quarter 16–23 dates of the month (8 days) W4 = Fourth quarter 24–30/31 dated of the month (7/8 days)</p> <p>Two methods hand netting and pan traps were used in surveys to avoid the biases in catching bee species.</p> <p>Hand netting for 30 minutes each survey each site, twice a month, on alternate weeks.</p> <p>Three yellow pan traps were placed on the ground at each sites twice a month on alternate weeks, on sunny days between 9 am to 5 pm.</p> <p>The sites were divided in two groups, each group containing nine urban and three nature sites. Each group of sites were surveyed every week with one or the other method (either hand netting or pan traps).</p> <p>The details are the bee species, diversity and abundance are published in Sirohi et al. (2015).</p>
Urban site 2	7556	A garden with land and flowers at St Giles Church.	
Urban site 3	8217	A garden with lawn and flowers at Church of Holy Sepulchre.	
Urban site 4	5383	A garden with lawn and flowers at New Testament Church.	
Urban site 5	1669	A garden with flowers at St Peter's Church.	
Urban site 6	330	A small garden at County Club.	
Urban site 7	662	A small garden at County Hall.	
Urban site 8	6380	County car park having unpaved surface with patches of flowers.	
Urban site 9	2911	A wild flower island surrounded by roads, next to bus stand.	
Urban site 10	90	A wild flower roadside patch.	
Urban site 11	517	Roadside wild flower patches.	
Urban site 12	964	Roadside wild flower patches.	
Urban site 13	754	Roadside wild flower patches.	
Urban site 14	314	Roadside wild flower patches.	
Urban site 15	1303	Open wild flowers patch with tress.	
Urban site 16	990	A road verge with wild flowers.	
Urban site 17	400	A road verge with wild flowers.	
Urban site 18	711	A traffic roundabout at St Peter's way.	
Nature site 1	82124	Bradlaugh Fields Nature reserve. Wild flower meadow	
Nature site 2	41856	The Barnes Meadow Nature Reserve. Wild flower meadow	
Nature site 3	96591	Kingsthorpe Meadow Nature Reserve. Wild flower meadow	
Nature site 4	20220	Wilson's Orchard (apple trees and wild flowers).	
Nature site 5	21043	Abington Meadow. A wild flower meadow	
Nature site 6	8827	Child First Orchard, a combination of orchard, garden and small forest patch.	

Supplement. Data 2. The emergence and flight duration of species of family Andrenidae observed during 2012 at urban and nature sites. Number in each column represents the total individuals observed that week. (U = Urban sites, N = Nature sites, E = Expected as per literature)

Species	Mar			Apr			May			Jun			Jul			Aug			Sep			Oct	
	2-W	4-W	1-W	2-W	4-W	1-W	2-W	4-W	1-W	2-W	4-W	1-W	2-W	4-W	1-W	2-W	4-W	1-W	2-W	4-W	1-W	2-W	
<i>Andrena bicolor</i>	U	2	163	3	4	7	1	2	1	1	1	2	2	2	6	1							
	N		6	1	2	3	1	1	1	1	1	1	1	1	1	1							
	E																						
<i>Andrena carantonica</i>	U	1	8	1	1	1	2	3	1	1	1	1	1	1									
	N		2	1				3	1	1													
	E																						
<i>Andrena chrysoseceles</i>	U																						
	N																						
	E																						
<i>Andrena cineraria</i>	U	1	6	6	3	5	1	2	3	1	1	1	1	1									
	N		1	4	1	4	4	4	4	1	1	1	1	1									
	E																						
<i>Andrena dorsata</i>	U	4	8	3	1	1	4	1	2	1	1	1	1	1	1	1	2	2	2	1	1	1	
	N		1	9																			
	E																						
<i>Andrena flavipes</i>	U	1	4	5	2	1	2	4	1	1	1	1	1	3	3	1	1	1	1	1	1	1	
	N		2	1	6																		
	E																						
<i>Andrena fulva</i>	U	1	5	1	6	3	4	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	N		7	4																			
	E																						
<i>Andrena haemorrhhoa</i>	U	1	4	1	3	2	6	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	
	N																						
	E																						
<i>Andrena minutula</i>	U	1	9	5	5	8	4	2	3	4	2	1	1	1	1	1	2	2	2	5	2	2	
	N		3	4	4	2	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	E																						
<i>Andrena nigroaenea</i>	U	1	1	1	1	1	4	6	5	1	2	1	1	1	1	1	1	1	1	1	1	1	
	N																						
	E																						
<i>Andrena nitida</i>	U	1	5	2	4	3	1	3	4	1	1	4	1	1	1	1	1	1	1	1	1	1	
	N		3	1	4	5	3	2	5	1	2	1	1	1	1	1	1	1	1	1	1	1	
	E																						
<i>Andrena tibialis</i>	U	3	3	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
	N		3	3																			
	E																						

Species not detected but assumed to be present

Supplement. Data 3. The emergence and flight duration of species of family Apidae observed during 2012 at urban and nature sites. Number in each column represents the total individuals observed that week. (U = Urban sites, N = Nature sites, E = Expected as per literature)

Species	Mar			Apr				May				Jun				Jul				Aug				Sep		Oct					
	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2		
<i>Anthophora plumipes</i>	U 1	3	6	2	5	1	3	2	2	5	2	2	2	2	3																
	N 3	4	4	6	4	2	1			6	1	2	1																		
	E																														
<i>Anthophora quadrimaculata</i>	U																														
	N																														
	E																														
<i>Melecta albifrons</i>	U 3	1	1	1	1	1	1	1	2	6																					
	N																														
	E																														
<i>Nomada fabriciana</i>	U 1	1	4																												
	N 4																														
	E																														
<i>Nomada fulvoguttata</i>	U 1																														
	N																														
	E																														
<i>Nomada flava</i>	U																														
	N																														
	E																														
<i>Nomada goodeniana</i>	U 1	2	2	2	7	1	2	3																							
	N																														
	E																														
<i>Nomada marshamella</i>	U																														
	N																														
	E																														
<i>Nomada panzeri</i>	U																														
	N																														
	E																														
<i>Nomada ruficornis</i>	U																														
	N																														
	E																														

Species not detected but assumed to be present.

Supplement. Data 4. The emergence and flight duration of species of family Colletidae observed during 2012 at urban and nature sites. Number in each column represents the total individuals observed that week. (U = Urban sites, N = Nature sites, E = Expected as per literature)

	Mar			Apr			May			Jun			Jul			Aug			Sep			Oct				
	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	
<i>Colletes daviesanus</i>	U						1																			
	N																									
	E							3																		
<i>Hylaeus communis</i>	U																									
	N																									
	E																									
<i>Hylaeus hyalinatus</i>	U																									
	N																									
	E																									
<i>Hylaeus signatus</i>	U																									
	N																									
	E																									

Species not detected but assumed to be present

Supplement. Data 6. The emergence and flight duration of species of family Megachilidae observed during 2012 at urban and nature sites. Number in each column represents the total individuals observed that week. (U = Urban sites, N = Nature sites, E = Expected as per literature)

Species	Mar			Apr			May			Jun			Jul			Aug			Sep			Oct	
	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2	W-3	W-4	W-1	W-2		
<i>Anthidium manicatum</i>			4																				
	U																						
	N																						
	E																						
<i>Chelostoma campanularum</i>																							
	U																						
	N																						
	E																						
<i>Coelioxys quadridentata</i>																							
	U																						
	N																						
	E																						
<i>Megachilecentuncularis</i>																							
	U																						
	N																						
	E																						
<i>Megachile ligniseca</i>																							
	U																						
	N																						
	E																						
<i>Megachile willughbiella</i>																							
	U																						
	N																						
	E																						
<i>Osmia caerulea</i>																							
	U																						
	N																						
	E																						
<i>Osmia leatiana</i>																							
	U																						
	N																						
	E																						
<i>Osmia bicornis</i>																							
	U																						
	N																						
	E																						
<i>Osmia spimulosa</i>																							
	U																						
	N																						
	E																						

Species not detected but assumed to be present