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Spatiotemporal Variation in House Spider Phenology at a National Scale Using Citizen Science

Running Title: House Spider Phenology

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Abstract

The seasonal appearance of *Tegenaria* and *Eratigena* (the best known of the UK genera termed "house spiders") results in considerable public and media interest. Here, we present the largest dataset ever gathered on the occurrence of house spiders anywhere in the world. We collected almost 10,000 records from different locations within the UK (amounting to ca. 250X more locations and 25X more records than any previous study) over a 6-month period. Using this dataset, which contained details of sighting dates, times, location within UK, location within the home, location within rooms and sex, we were able to investigate a number of aspects of house spider ecology. Eighty-two percent of records were males, supporting previous studies that showed house spider surges in autumn are predominantly males seeking mates. Sightings peaked in mid-September with a significant northwest progression

across the UK as autumn progressed. Daily activity peaked at 19:35hrs and spiders were seen more-or-less uniformly throughout different rooms and we discuss why this is more likely to be because of spider ecology than human behaviour. Within rooms, there was a sex-based difference in ecology with females more common on ceilings and doors/windows and males more common on walls, possibly because of sex-specific differences in mobility.

Keywords: arachnids, citizen science

Introduction

Spiders are frequently associated with dwellings, presumably attracted by a favourable physical environment and potential prey availability. A recent study of spiders in houses in Belgium identified 19 species, with *Pholcus phalangioides* being the most common (Jocqué *et al*. 2016); many of these species were also found in houses studied in Kansas, USA (Guarisco, 1999) and the UK (Smithers, 1990). Despite the range of spiders found in dwellings, it is those belonging to the genera *Tegenaria* (*T. domestica*, *T. gigantea*, *T. parietina* and *T. savea*), and *Eratigena atrica* that are commonly called "house spiders" (Roberts, 1995). Their relatively large size makes them highly noticeable and the seemingly sudden appearance of house spiders during late summer and early autumn usually causes a surge in public interest in spiders (e.g. Molloy, 2016). This increase has been hypothesised to coincide with mating (Oxford, 2009). However reports of increases are generally ad-hoc, localised (e.g. to the county of Yorkshire, UK (Oxford and Smith, 1987)) or confined to relatively small numbers of observations (N=729 in the case of Oxford and Smith (1987)) and are not currently supported by any substantial published datasets at local or national level.

Indeed, despite public interest, relatively little scientific research has been conducted on the ecology of house spiders in general (Jocqué *et al*. 2016). The studies that have been undertaken to date have been largely descriptive and spatially localized (e.g. Oxford and Smith, 1987; Smithers, 1990; Guarisco, 1999; Jocqué *et al*., 2016) even, in one instance, being restricted to a single house (De Armas, 2003). According to Jocqué *et al*. (2016), who studied the spiders associated with 43 houses in Northern Belgium, the number of sightings increases substantially during late summer and autumn. The same study found that males are more likely to be seen than females, but this was based on a relatively low sample size of just 61 individuals of *Tegenaria* and *Eratigena*. The basic ecology of spiders within homes, including their use of different rooms and locations within those rooms, also remains largely unexplored.

Thus, there are a number of substantial gaps in our understanding of even basic ecology, especially at large spatial scales. Gaps include basic phenology, distribution within houses, and whether temporal and spatial patterns differ between males and females. In this study, we used citizen science to overcome the difficulties normally inherent in gathering sufficient data at large spatial scales (Hart *et al*., 2012). We use the resultant dataset of spider sightings at a national scale – the largest such dataset of house spider records anywhere in the world – to gain insight into spider ecology.

Material and Methods

In collaboration with the Royal Society of Biology, we launched a free application for mobile phones and tablets (running on Apple and Android) called *Spider in da House* in August 2013. This app comprised identification notes and images as well as a recording interface that allowed people to submit records of house spiders, specifically *Tegenaria* and *Eratigena* (henceforth collectively referred to as house spiders). Participants were also able to submit records via a simple SurveyMonkey form accessible from the Royal Society of Biology's website. The project attracted considerable publicity and was featured in every major UK newspaper, most local newspapers, and BBC Local and National Radio. Both survey

platforms were open for records from 1 August 2013 to 28 January 2014 with survey publicity starting 14-days prior to the start date.

Participants recorded: date; time; latitude/longitude (automatically derived for app users with location services enabled); room (e.g. bedroom, kitchen, bathroom); location within room (e.g. ceiling, wall, on furniture); and sex of spider (female, male or "not sure"). Although participants were asked to record only house spiders within the home, some records clearly referred to other locations or other species. Records from gardens and outdoor locations were excluded as were records containing terms such as "in web" and "hanging" since these are not characteristics of the focal species. Records recording other named species (such as "orb web garden spider") were also removed. It should be noted that although this study focussed on house spiders it is entirely likely that not all the records submitted were of *Tegenaria* or *Eratigena* and none of the records submitted were formally validated for species. Of the 10,268 records within the study period (app = 8,636; SurveyMonkey = 1,632), 363 were removed, giving 9,905 in total. Most records were complete but some had missing data for specific fields, hence sample sizes do not always equal the total number of records.

Results and Discussion

In terms of seasonal phenology, the number of records increased substantially from late August (survey week 4; 22-29 August) reaching a pronounced peak in mid-September (survey week 7; 12-19 September) (Figure 1a). Records decreased rapidly from the September peak, reaching just 8-12 per week January compared to a median (±IQR) of 1,028(±353) records per week in the 7 weeks between 22 August (the start of survey week 4)and 9 October (survey week 11), and an overall median of 271(±710) records per week across the study period.. Our study is of course vulnerable to anthropogenic effects masking underlying spider phenology. It is entirely possible that the initial media attention caused the pronounced peak and subsequent momentum, and the following "decay" represents a decline in public

interest. A similar momentum effect was noted in another spider phenology study requesting help from the public (in that case sending in specimens) (Oxford and Smith, 1987). However, another study that did not rely on public participation (Jocqué *et al*. 2016) identified a very similar September peak and subsequent decline in spider sightings in Belgium. This study also identified a build-up in August that was less abrupt than that found in this study, a fact probably explained by the inclusion of all house-associated spider species in the Belgium study.

Our data also allowed us to examine the daily phenology of house spiders. Sighting times were converted to GMT and were significantly unimodal with a pronounced peak in early evening (mean = 19:35 GMT (19:25-19:45 95% CI based on SE); Rayleigh's test: Z=981.6, N=9,807, p<0.001; Figure 1b). One issue with citizen science data can be that records can reflect human parameters rather than the phenomenon under observation, and in this case the mean time could simply reflect the behaviour of people sitting down in their living rooms at this time. This recording problem was also identified by Jocqé *et al*. (2016) in analysing the location of spider sightings within houses (see below). However, comparison of records through the day for living rooms versus bedrooms revealed only a slight increase in records from bedrooms in the late evening that was not significant (living rooms: mean=19:36 (19:21-19:51 95% CI based on SE); Bedrooms: mean=19:47 (19:18-2015 95% CI based on SE); Watson-Williams F-test: F=0.665; df=1, 3611; p=0.415 (Batschelet, 1981)). This finding indicates that the times of sightings probably reflect the ecology of spiders rather than people.

The dates of sightings were linked to location at a national scale. We found a statistically significant (but very weak) effect of latitude and longitude on sighting date with sightings moved northwards and westwards through the season (latitude: Spearman's Rank Correlation r_s=0.106, N=7,129, p<0.001, approx. r^2 derived from Pearson correlation= 0.076; longitude: Spearman's Rank Correlation r_s=-0.087, N=7,129, p<0.001, approx. r^2 derived from Pearson correlation=0.027). It is possible that this effect is

complicated by the distribution and phenology of individual species. For example, *T. parietina* has a mostly south-eastern distribution (Harvey et *al*. 2002) and if this species has an earlier peak (as appears might be the case, e.g. see srs.britishspiders.org.uk/portal.php/p/Summary/s/Tegenaria+parietina) then it could bias earlier observations to the south east. Without verification of species identification however it is not possible to confirm this potential bias. We decided against asking participants to submit photographs, partly because we felt it would reduce the number of people willing to take part but also because some studies have shown that photographs submitted by the public can be unsuitable for ID even within relatively straightforward taxa (e.g. *Bombus*) (Stafford *et al*. 2010).

Spiders were recorded from rooms throughout houses although most records were from living rooms (27.2%), and bathrooms (20.8%) in agreement with previous, far smaller, studies (e.g. Jocqué *et al*. 2016). Living rooms are one of the most commonly-used areas of the house, but the high percentage of bathroom observations suggests again that our records are not simply reflecting people's room use. However, a high incidence of spiders seen in baths and sinks, where spiders are easily trapped and therefore observed, coupled with a generally less-cluttered environment might be making spiders more apparent in bathrooms. In terms of location within rooms, almost half of all observations were of spiders on floors (Table 1).

The overall sex ratio was highly male biased confirming the finding of other studies (e.g. Oxford and Smith, 1987) that the peak in spider sightings is driven by males searching for mates. Of the 4,613 records of sex 3,795 (82.3%) were male and 818 (17.7%) were female (chi-square goodness of fit test against an expected 50:50 ratio: χ^2=1921.2, df = 1, p<0.0001). There was no significant association between sex of spiders and room (chi-square contingency test: χ^2=10.7, df=8, p=0.217) but there was a highly significant association between sex and location within a room (chi-square contingency test: χ^2=73.3, df=5, p<0.0001) (Table 1). This was driven by females being overrepresented on ceilings and

doors/windows and males being overrepresented on walls (Table 1). This is an initially puzzling result, since females have to climb walls in order to reach ceilings. However, since females are generally less mobile than males it may be that they spend far less time on their initial climb than they spend relatively immobile (and also, perhaps, less likely to be observed than mobile males) in a resting position.

For the first time, we have been able to investigate the seasonal and daily phenology of house spiders and their finer scale ecology at a national level using the largest dataset yet compiled. We have also been able to provide insights into the distribution of spiders around houses, confirm that most sightings of house spiders are males, and show that males and females frequent different locations within rooms.

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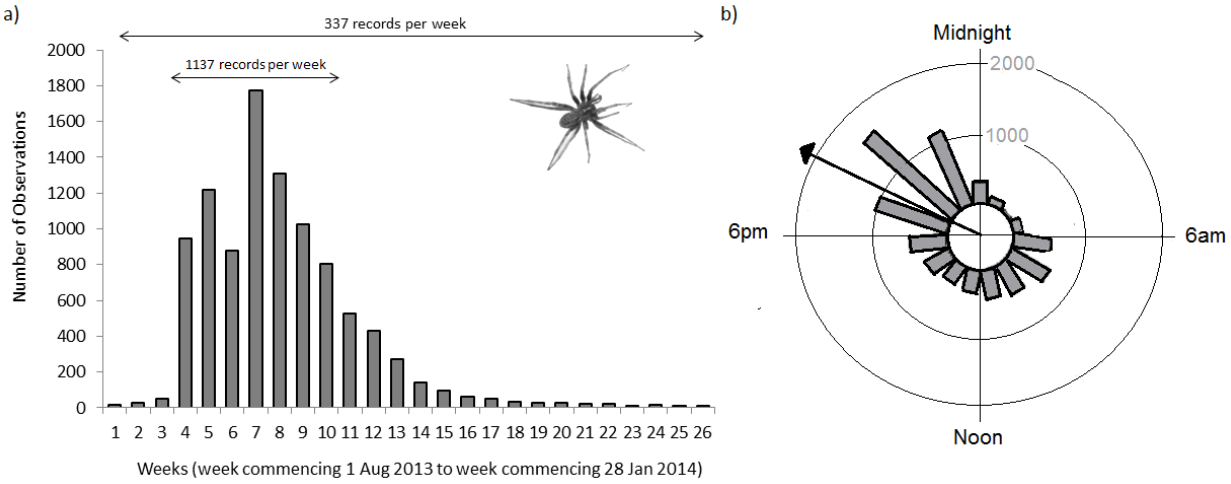
Table 1: Recorded sightings of spiders in 2013-2014 both between rooms (left) and within rooms (right). Because not all information was available for all records, data here do not always sum to the overall number of records submitted. Bold entries indicate where the sex ratio differed from the underlying distribution (see Chi square results).

Room	Sightings		Sex ratio		Location	Sightings		Sex ratio	
	n	%	Females	Males	within room	N	%	Females	Males
Living room	2247	27.3	202 (17.7%)	939 (82.3%)	Floor	3752	48.2	309 (14.8%)	1785 (85.2%)
Bathroom	1721	20.9	153 (17.4%)	726 (82.6%)	Wall	2001	25.7	**85 (10.5%)**	**727 (89.5%)**
Bedroom	1366	16.6	108 (16.1%)	561 (83.9%)	Ceiling	806	10.3	**82 (34.3%)**	**157 (65.7%)**
Hallway/stairs	1348	16.4	117 (18.0%)	533 (82.0%)	Sink	804	10.3	68 (14.4%)	404 (85.6%)
Kitchen	1304	15.8	134 (20.8%)	510 (79.2%)	Door/window	292	3.7	**30 (27.8%)**	**78 (72.2%)**
Conservatory	94	1.1	11 (22.4%)	38 (77.6%)	Furniture	134	1.7	10 (16.7%)	50 (83.3%)
Utility room	67	0.8	5 (20.0%)	20 (80.0%)					
Dining room	60	0.7	7 (24.1%)	22 (75.9%)			Overall sex ratio	818 (17.7%)	3795 (82.3%)
Attic/cellar	34	0.4	0 (0.0%)	10 (100%)					

Figure Legends

Figure 1: Phenology of house spider sightings with reference to: (a) date and (b) time of day. The arrow on the circular histogram shows the mean sighting time.

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