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Aerial dispersal of spiders in central east Germany: Modelling of meteorological and seasonal parameters

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Abstract
Spiders are abundant insect predators in farmland, but little is known on how weather parameters influence the composition and number of aerially dispersing spiders in central east Germany. During the year 2003 airborne spiders were collected with a Rothamsted insect survey trap in Aschersleben (Saxonia-Anhalt) in a height of 12.2 meters form April to October. Simultaneously meteorological conditions were continuously measured at the bottom of the trap. With a generalized linear model we try to calculate which meteorological aspects are significant for long distance flights by spiders dependent on family, sex, and seasonal changes. Dominant families are Linyphiidae (42%), Theridiidae (35%), Tetragnathidae (9%) and Araneidae (8%). These four families dominate the composition of the aeronautic spider fauna in central east Germany. The statistical analyse shows that ballooning is directly influenced by numerous meteorological parameters and their interactions.

INTRODUCTION

In the last years there has been a growing awareness of the role of spiders acting as natural enemies of insect pests in agro-ecosystems (Wetzel 2004). But often the spider density of a field is negatively influenced by crop management and pesticide expenditure (Volkmar et al. 1999). So in conventionally cultivated fields the migration from source areas plays an important role for the population dynamics of spiders (Schmidt et al. 2008). The methods of colonisation include short-distance walking in border areas, and potentially long-distance airborne migration behaviour. Different spider families have developed the ability for aerial dispersal by ballooning (Greenstone 1990). Ballooning is a special method of passively travelling on a silken thread carried by airflow and one special characteristic that permits spider populations to exist in agro-ecosystems (Weyman & Jepson 1994)

But little is known on how weather parameters influence the number of long-term flights and the composition of the aeronautic fauna (Bishop 1990, Drake & Farrow 1988).

MATERIALS AND METHODS

Data source and Sampling site

During the year 2003 airborne spiders were collected with a Rothamsted insect survey trap located in Aschersleben (11°27′E, 51°45′N, 136 m a.s.l.) 30 kilometres east of the Harz mountains in a height of 12.2 meters and an airflow of 40–50 cubic metres per minute from April to October. Aschersleben is surrounded by a relatively open cultivated area which is predominantly used for cereal and rapeseed production. The trap was emptied every day at 6 am. Afterwards, the adult

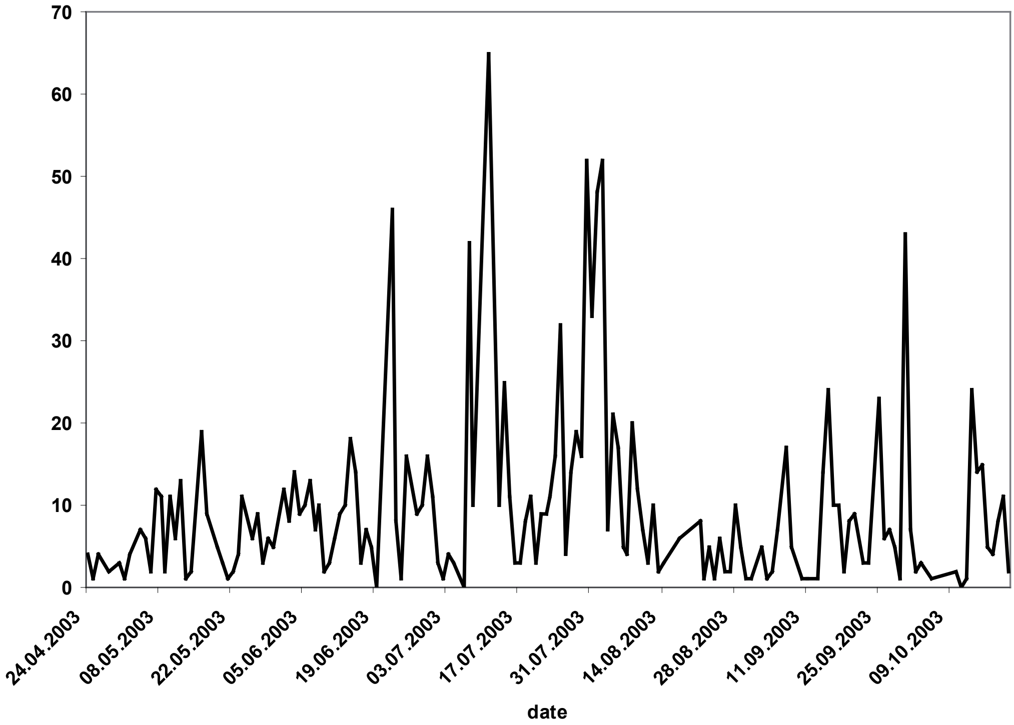

Fig. 1. Numbers of individuals caught per day over the sampling period.

spiders that were caught were categorized in family and species from the adult forms. Spiders were determined according to Heimer & Nentwig (1991) as well as Roberts (1985, 1987) and classified on the basis of the nomenclature by Platnick (1993). Meteorological conditions were continuously measured at the bottom of the trap simultaneously to the sampling.

Variables

Meteorological variables were chosen which show a direct connection to the production and maintenance of thermals that may influence flight conditions or the initiating of ballooning. Relevant variables are the daily mean temperature at 2 m, at the soil surface and 20 cm underground (indicative for spider activity and production of vertical wind), mean wind speed and wind maximum, humidity, air pressure and sun radiation. Also, the same variables of the previous day were taken into account. Daily spider catches were counted, sexed, and adults determined. To integrate agricultural management practices over the year which could influence the occurrence of ballooning spiders, the sampling time from April to October was divided into 3 parts. Period 1 was defined from April 24 to July 03 to represent the mean time of agricultural management practices during the growing season until harvest, period 2 from July 04 to August 27 as the harvesting time and period 3 from August 28 to the 20th of October as the pre-winter development phase.

Statistics

Using a „maximum likelihood"-approach with the criterion „smaller is better" (AIC, AICC), a generalized linear mixed model (GLIMMIX) (SAS 2006) was generated with the SAS program on family levels for the

Effect	F Value	Pr > F	Effect	F Value	Pr > F
sex	3.37	0.0346	ground temperature^{-1}	7.66	0.0057
air pressure	10.44	0.0012	wind direction^{-1}	21.34	<.0001
wind direction	19.81	<.0001	mean air temperature *family	15.25	<.0001
mean temperature 20 cm underground	57.12	<.0001	mean ground temperature*family	21.00	<.0001
sun radiation	12.95	0.0003	humidity*family	4.97	0.0020
rain sum	5.49	0.0192	humidity*sex	5.81	0.0031
mean temperature 20 cm underground^{-1}	57.12	<.0001	mean wind speed*maximum wind speed	17.90	<.0001
humidity^{-1}	51.81	<.0001	family*wind direction^{-1}	13.78	<.0001
mean wind^{-1}	81.66	<.0001	family*sex*season	8.04	<.0001

$^{-1}$ conditions of the previous day

Table 1. Meteorological covariables which show a significant F-test in the model (n=1470).

four most represented families in order to analyse the influence of weather parameters as well as interactions between them on the total amount of individuals caught. For analysis, the parameter "count" of individuals was estimated as a Poisson-distribution.

RESULTS

A total of 1435 spiders from 13 families were collected, of which 77.4% were immatures, 9.2% adult males and 13.4% adult females. More than 75% of the catch comprised two families, the Linyphiidae and the Theridiidae; 96% total was represented by four families. From the Linyphiidae family, the predominant species caught were *Erigone atra* Blackwell, *Porrhomma microphthalmum* (O.P.-Cambridge) and members of the *Tenuiphantes tenuis*-group. The Theridiidae were represented by *Theridion impressum* L. Koch and *Neottiura bimaculatum* (Linnaeus). Tetragnathidae were represented by *Pachygnatha degeeri* Sundvall, and Araneidae were mostly caught as spiderlings.

Fig. 1 shows the distribution of spiders caught over the whole year. The amount of spiders per day shows the highest peak in period 2 from beginning of July to late August. This peak is mainly dominated by adult females and immatures. Adult males were mainly caught in the 1st season from end of April to beginning of July and declined over the later seasons within all families.

Statistical analysis

The statistical analysis shows that nearly all measured weather parameters have an effect on the spider count collected with the Rothamsted insect survey trap. Also numerous parameters of the previous day are influential (Table 1). In addition, the model showed that especially the humidity of the previous day as well as the actual day influence the amount of spiders caught. The same effect could be observed for mean temperature at soil surface. The temporal separation into three distinct catching periods to minimize effects of crop management in the vicinity of the trap only shows an influence regarding family and sex of the aeronautic fauna. The model also shows that seasons have no direct influence on the amount of spiders. Only in regard to species and sex of the spiders an influence is detectable.

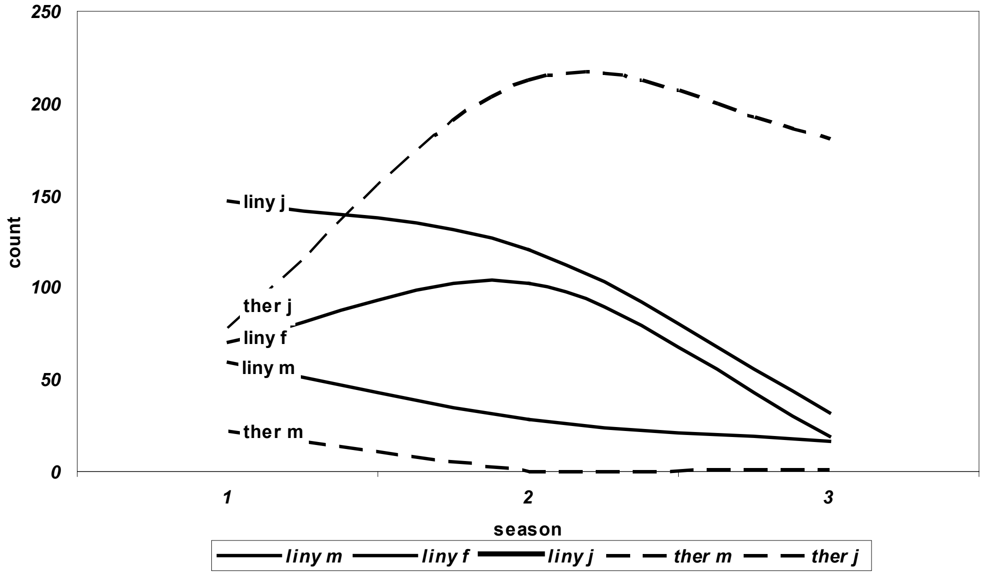

Fig. 2. Interaction between family, gender and season on catch amount of the Rothamsted trap.

Fig. 2 shows these effects concerning the Linyphiidae and Theridiidae. It clearly shows that the cause of higher spider count per season is indicative for the different preferences to specific meteorological conditions depending on family and gender within the sampling months. Another point is the specific date for aerial dispersal in the year which leads to higher counts of spiders in mid-summer.

DISCUSSION

In agreement with earlier publications, we could prove that the aeronautic spider fauna is comprised mostly of juvenile spiders (Dean & Sterling 1985).

Immature Linyphiidae already appeared during springtime, while Theridiidae, Tetragnathidae and Araneidae could be detected in higher counts starting from July. Adult males were caught from April to July and declined in amount over the later seasons within all families. Female spiders of the Linyphiidae family were caught especially from July to August. This is consistent with observations by Thomas & Jepson (1999). The reason for this can be the different speed of development, the divergence of their respective life cycles, their activity during the year as well as risk-spreading by females (Thomas & Jepson 1999) and the search for a mate by males (Plagens 1986). Another fact can be that weather parameters needed for successful initiation of ballooning differ between the families and gender depending on weight and silk length (Bell et al. 2005). The influence of weather parameters from the previous day lead to the conclusion that the initiation of ballooning had to occur earlier, validating the work of Thorbek (2002) with the assumption that the Rothamsted trap is a suitable method to measure especially long-term flights. But this also leads to the problem that the origin of spiders, the distance travelled and also the time of flight initiation can not be verified. In addition, the relative humidity (higher humidity and lower temperatures during the night in higher altitudes) could be influencing flight due to condensing water on the body of the spider as well as on the silk and leads to higher catch amounts. This could also explain the higher spider count during high humidity (90%) days.

Also sun radiation, wind parameters (mean and maximal wind speed per day) as well as temperatures at three different altitudes influences the convective conditions of the atmosphere and therefore initiation of ballooning (Reynolds et al. 2007). This results in different maximum flight heights that can be achieved during daytime, thus influencing flight distance (Reynolds et al. 2007). The importance of wind direction could also be shown regarding the total amount of individuals caught. This is important when assessing "source areas" of spiders although the exact origin cannot be predicted due to unknown flight times and distances.

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