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SHORT COMMUNICATION

Wandering in wet meadows – A mark-recapture study on *Pardosa paludicola* (Araneae: Lycosidae)

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Abstract. Among the variety of wolf spiders in Europe, there are some uncommon and poorly known species. An example is *Pardosa paludicola* (Clerck, 1757), which is classified as endangered and rare in some countries. We used a capture-mark-recapture method to examine the biology of mature *P. paludicola* individuals, focusing on the movement ranges of this spider. We marked 714 individuals and more than 10% of them were recaptured (♂ 4.5% and ♀ 14.7%). The median movement range was calculated at 5–6 m for both sexes and the maximum distances reached 58–69 m in 3–4 days. In the context of conservation efforts for this species, it seems important to provide large open areas of high humidity, with low human interference.

Keywords: Bee tag, movement range, phenology, spider conservation, wolf spider

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Wolf spiders (Araneae: Lycosidae) do not typically build webs, but freely hunt their prey or lie in ambush. These spiders are an important ecological group and major predators in some ecosystems (Kiss & Samu 2000; Koltz et al. 2019). Their movement ranges vary across different genera. Some wolf spiders lead a rather sedentary life when it comes to their predation strategy; instead of hunting actively, they dig burrows and stay in the vicinity of them, e.g., *Hogna* Simon, 1885 and *Lycosa* Latreille, 1804 (Persons et al. 2001; Reyes-Alcubilla et al. 2009). In some cases, the burrowing behavior and, consequently, the locomotory activity changes at certain stages of a spider's life, e.g., it may decline among spiders that burrow only during brood care or overwintering, or it can be high during seasonal activity, such as the 200 m^2 of the home range of *Arctosa cinerea* (Fabricius, 1777) (Framenau et al. 1996; Framenau 2005). In contrast, the *Pardosa* C. L. Koch, 1847 species do not exhibit burrowing behavior and they are more likely to change their hunting site (Ford 1978; Persons et al. 2001). Their movement and home ranges vary from 8 to 111 m, which is a rather high value, considering their relatively small body size (Hallander 1967; Kiss & Samu 2000; Seer et al. 2015). The movement ranges of wolf spiders may also differ between the sexes due to males searching for a female; but these differences are not always significant (Framenau et al. 1996; Kiss & Samu 2000; Framenau 2005). Locomotory activity is an important part of a species' life history and studying it is valuable for better understanding of their biology. It provides information about species' area requirements and potential limitations to their dispersal propensity (Entling et al. 2011). This allows for establishing whether species are particularly sensitive to the loss of connectivity between populations, which may be translated into taking appropriate conservation effort (Seer et al. 2015).

Some wolf spiders are well studied, e.g., because of their high abundance (Edgar 1971) or their significant role in agricultural ecosystems (Kiss & Samu 2000), but still little is known about many species, even if they are extremely rare or endangered. One of the latter spiders is *Pardosa paludicola* (Clerck, 1757). This palearctic species seems to live exclusively in open and damp areas and is larger than the majority of European *Pardosa* species (♂ 6–7 mm, ♀ 8–9.5 mm) (Nentwig et al. 2024). The currently available information about the biology of *P. paludicola* is very limited and based only on a small amount of data obtained from few specimens (Nentwig et al. 2024). In several countries, this species has a legislation and conservation status, such as Endangered (IUCN British Red List category) and Nationally Rare (British Rarity Status) in Great Britain (Bee et al. 2017), or Endangered (Czech Red List) in the Czech Republic (Řezáč & Růžička 2024). In Poland, *P. paludicola* was considered to be rare (BioMap diversity 2024). However, a recently discovered, relatively abundant population of *P. paludicola* allowed us to examine this species closer. The aim of our study was to investigate the movement ranges of mature individuals and the habitat requirements of *P. paludicola*, which are crucial for developing possible conservation measures for this species.

The research was carried out in a wet meadow (53°10′59.8″N 23°47′36.3″E) near Kruszyniany, NE Poland. This area of about 13 ha, divided by a field drain, was covered by vegetation mainly consisting of grasses (Poaceae), umbellifers (Apiaceae) and nettles (*Urtica dioica* L.). The vegetation changed very quickly from very low (5 cm) at the beginning of the study to quite high (about 1 m) at the end (Fig. 1C–D). The survey was conducted from 11 April to 29 May 2023, an appropriate period for two reasons: the phenology of the studied species (mature males and females are present in the environment) and the lowest height of vegetation (which turned out to be the most beneficial for the effectiveness of traps). The site was visited on average every second day, if the weather was favourable (only the rainy days were out because of their limiting effect on spiders' activity (Kiss & Samu 2000), between 9 am and 5 pm CEST. Two or three people spent about 2–4 hours on the site during each sampling day. In total, the data were collected during 16 days. A constant measurement of temperature and humidity in the study site was provided by three data loggers (iButton Maxim, Dallas) distributed on the ground across the study area.

The studied section of the grassland was 1.4 ha and was not isolated by any natural or artificial barriers from the rest of the meadow. The spiders were captured by pitfall traps and by direct catching. Six transects were outlined: three on each side of the field drain. Each transect consisted of 20 pitfall traps, situated 2 m from each other (Fig. 1B). The traps were opened only when researchers were present in the study area to prevent animal mortality in the traps. Direct catching was used in the distance up to 1–2 m from the traps, using plastic containers. It was particularly valuable when the vegetation grew higher and enabled spiders to avoid the traps by walking on the higher parts of it. The collected adult spiders were immobilised by being held between the researchers' fingers and individually marked with a colored and numbered honey bee tag attached to the prosoma by a small amount of shellac glue (Fig. 1A); the marking method follows, among others, Hofmann et al. (2020) and Framenau (2005). We have chosen shellac glue as an alternative to the cyanoacrylate-based adhesive involved in the mentioned studies because it is a natural and non-toxic product which remains flexible even after drying; this feature makes it less likely to hinder the movement of the marked specimen and reduces negative effects of potential researchers' mistakes

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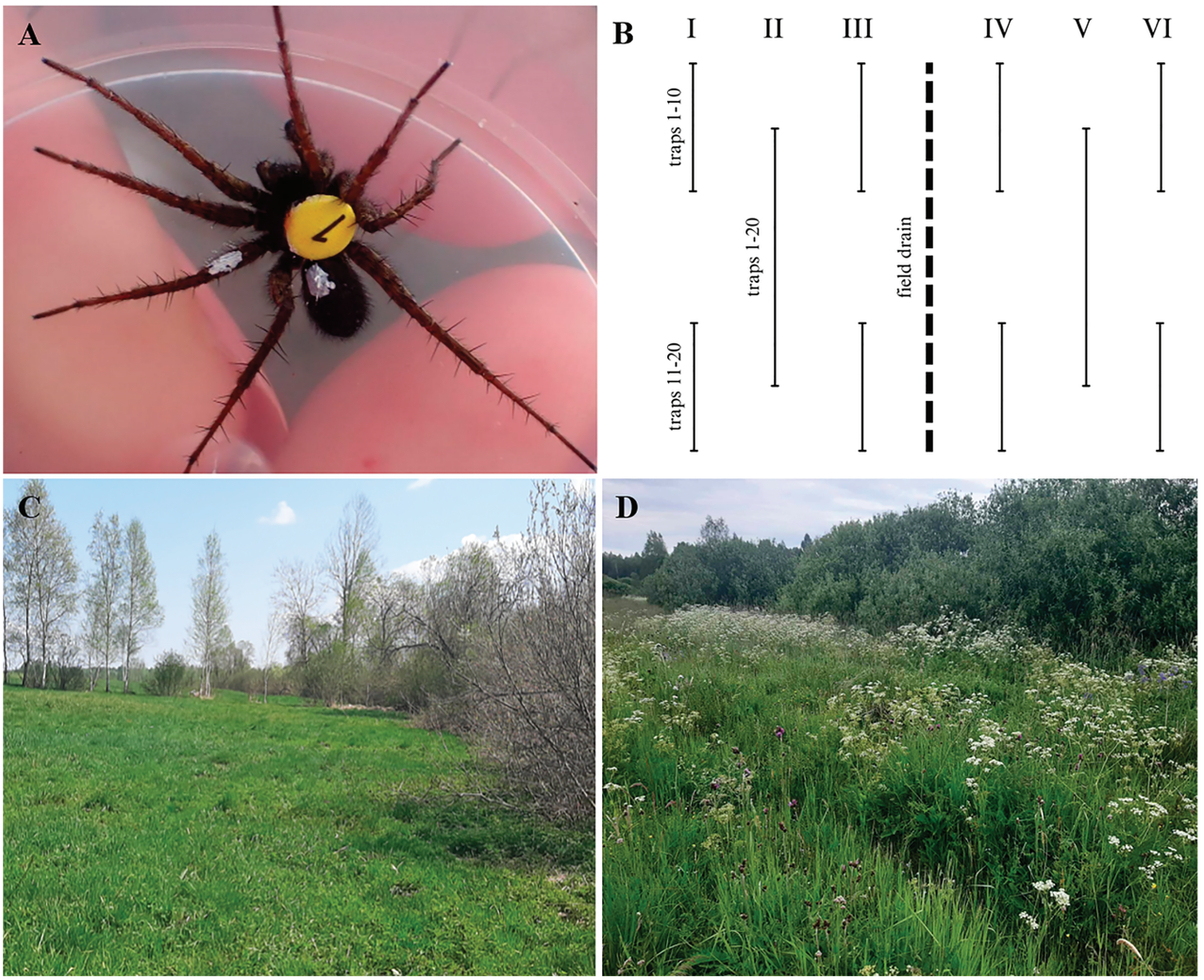

Figure 1.—Marked spider and the study area: A. Female of *Pardosa paludicola* with double marking – a yellow numbered tag on the prosoma and white spots on the opisthosoma and the leg, B. the scheme of transects' layout, C-D. the habitat of the studied population of *P. paludicola* at the beginning of the study, i.e., in the second week of April (C) and at the end of May (D).

and lack of precision. The spiders were additionally marked, with the code unique for each day, on the legs and opisthosoma, using a waterproof oleic paint marker (Edding® 750; Warsaw, Poland). The information about the place and time of each (re)capture of a spider was saved in a GPS device (Garmin®, GPSMAP® 64sx; Warsaw, Poland), as well as sex and the presence or absence of an egg sac in the case of females. Using Garmin BaseCamp software, the distances covered by the spiders between marking and the recapture were calculated (Garmin BaseCamp v. 4.7.5, Garmin Ltd.). Descriptive statistical analyses were performed using the STATISTICA (data analysis software system) version 13.0 (StatSoft, Inc. 2022). These analyses were a simple chi-square test for differences in the abundance of marked females and males, a Mann-Whitney U test for the comparison of movement distances of males and females, and a regression analysis for testing the effect of temperature on spiders' locomotory activity and the effect of time between marking and recaptures on the distances travelled by spiders. Non-parametric statistics were used, as the data were not normally distributed.

In total, 714 spiders (312 males and 402 females) were collected and marked. The significant dominance ($\chi^2(1, n = 714) = 11.34$, $P < 0.001$) of females among recaptured specimens can be explained by their longer life span (Edgar 1971) and therefore more occasions to get captured. We found a significant effect of temperature during visits to the study area (11–29°C) on the locomotory activity of spiders—at higher temperatures we observed and tagged more spiders ($R^2 = 0.62$, $F(1, 11) = 18.058$, $P = 0.001$).

We observed that males were active only until the second week of May, while the first egg sac-carrying females were found in the first week of May and by the end of that week almost all captured females carried an egg sac. In the third week of May, first spiderlings emerged. According to data from Germany, mature individuals of *P. paludicola* have already been found in March. Such an early date of occurrence in the environment and building the first egg sac indicates that *P. paludicola* is an early spring species, compared to other *Pardosa* in Central Europe, such as its companion species *Pardosa prativaga* (L. Koch, 1870), *Pardosa pullata* (Clerck, 1757) and *Pardosa palustris* (Linnaeus, 1758), whose mature individuals are observed only in April (Arachnologische Gesellschaft 2024; Bach et al. 2024) or ubiquitous *Pardosa lugubris* s. l. (Walckenaer, 1802), whose females usually begin caring for the egg sac in the second half of May (Edgar 1971, 1972).

In total, 73 recaptures were recorded (14 males and 59 females), which resulted in a recapture rate of 10.2% (4.5% for males and 14.7% for females). The vegetation in our study area was significantly higher than in similar studies on wolf spiders, which were frequently conducted on areas bare of vegetation, such as gravel banks and sandy beaches (Framenau 2005; Seer et al. 2015). This may be one of the reasons for our lower

Table 1.—Information on recapture and description of movement distances by *Pardosa paludicola* between marking and recapture. The total number of recaptures (including individuals for which no movement distance was obtained) is shown in parentheses.

Sex	Number of recaptures	Movement distances (m)						
		Minimum	Maximum	Median	Lower quartile (Q_1)	Upper quartile (Q_3)	Skewness (± SE)	Kurtosis (± SE)
♀	47 (Total 59)	0.50	58.65	6.00	2.64	24.93	1.32 (± 0.35)	0.79 (± 0.68)
♂	12 (Total 14)	1.78	69.82	5.04	3.33	23.32	1.63 (± 0.64)	1.55 (± 1.23)

recapture rate, closer to values achieved in the study on *Pardosa agrestis* conducted in a field with vegetation of 20–50 cm height (recapture rate: 3.6–20%) (Kiss & Samu 2000).

Of the 73 recaptures, 59 (12 males, 47 females) indicated that the spider had moved between initial capture and recapture (Table 1). The exact locations of the marking and recapture sites were obtained; on their basis the movement distances of males and females were calculated (Table 1). *Pardosa paludicola* seems to exhibit similar movement ranges (median: 5–6 m, maximum: 58–69 m) to those reported for other wolf spiders of similar size that do not burrow or burrow only during brood care. The diameter of movement of *P. agrestis* (Westring, 1861) has been estimated at about 7–9 m (Kiss & Samu 2000), the mean distances of *P. pullata* as 8–9 m (Hallander 1967), and the home range span of *Venatrix lapidosa* (McKay, 1974) as up to 55 m. However, the habitat of the latter was more limiting for the spiders' locomotory activity than in our study area (Framenau 2005). The movement ranges of *P. paludicola* also appear not to be particularly high compared to e.g., the 111 m home range span of *Pardosa agricola* (Seer et al. 2015), which may be an indication of being limited to a more stable habitat (Entling et al. 2011). Differences between sexes in movement range were not statistically significant ($P = 0.748$), which is accordance with most data obtained on *P. agrestis* and *V. lapidosa* (Kiss & Samu 2000; Framenau 2005).

The average time between marking and recapturing reached about six days; however, there was no indication that the distance travelled by the spiders would change with the time between marking and recapture(s) ($R^2 = 0.005$, $F(1,51) = 0.26$, $P = 0.61$). Only three females were recaptured twice, and the periods between recaptures varied from 2 to 14 days (with the distances of 43 m travelled in 2 days, 40 m in 4 days, 3–26 m in 7 days and only about 2 m in 14 days). Therefore, we consciously refrained from calculating activity based on the average daily distance and did not estimate the home range. However, we believe that the distances show the scale at which these spiders can forage. Our study area was relatively large and despite this, it still seemed to not fully cover the movement capabilities of the spiders; it was also not isolated from the remaining part of the meadow by any solid natural barriers which would reduce the migration of spiders.

The spiders were caught all over the study area; however, there were fragments of transects where spiders were found more often than in the others, namely close to the ditch and with uncovered wet soil (approximately 15% of individuals). The relative humidity (measured on the soil surface) in the study area was high (69–100%) over the entire period of the study. It confirms the preference of *P. paludicola* for areas of high soil moisture, which is in accordance with the niche position moisture value of 0.33 on the scale from wet to dry habitats calculated by Entling et al. (2007). Also, the openness of the studied meadow aligns with *P. paludicola*'s preference for open, very lightly shaded habitats (Entling et al. 2007). The meadow was not mowed throughout the study period. We believe that delaying the date of first mowing, and consequently postponing the disturbance of the habitat could be beneficial for *P. paludicola*, as it has been demonstrated for other invertebrates (Morris 2000; Knop et al. 2006; Humbert et al. 2012; Buri et al. 2016). This kind of open area is probably crucial for *P. paludicola*, which is supported by the absence of this species on regularly cultivated agricultural habitats (ARAMOB 2024).

We suppose that in order to maintain *P. paludicola* populations in high abundance it is necessary to provide sufficiently large, open areas with high moisture and low management intensity. Considering that *P. paludicola* is a species of a rather narrow niche which should exhibit rather low dispersal propensity (Entling et al. 2011), this type of habitat appears to have a considerable potential for spider conservation in the region. It seems unlikely for *P. paludicola* specimens to leave the stable environment which meets their very specific needs. However, we are aware that the development and implementation of possible conservation measures demands further, longer-lasting research to obtain more detailed information on the regularity of the population's features and their movement behavior.

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