Proceedings of the 15th European Colloquium of Arachnology. Edited by V. Růžička
Institute of Entomology, České Budějovice, pp. 11–21 (1995)

Distribution of foliage-dwelling spiders in uncultivated areas of agricultural landscapes (Southern Bavaria, Germany) (Arachnida, Araneae)

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Foliage-dwelling spider fauna, agricultural landscape, field and grassland margins, fallow areas, management, connectedness

Abstract. The spider community of the herbaceous layer was investigated in uncultivated margins and fallow land in six agricultural areas in Southern Germany. Some spider species were present in all areas investigated, while other species were absent from one or more areas. Significant differences in spider fauna were also observed between single study plots in one study area. The number and size of field and grassland margins and patches of fallow land, their vegetation structure and their connectedness with other uncultivated areas were tested for the cause of these differences. As a result of the present study the stability of vegetation structure seems to be the most important factor for the number of spider specimens per study plot, whereas the amount of uncultivated areas and the degree of connectedness are relevant factors for the number of species.

INTRODUCTION

Unmanaged areas represent those habitats in the agricultural areas of Central Europe that enable the development of stable vegetation structures between cultivated fields, meadows and pastures. These areas are important as wildlife habitat, movement corridors and refugial areas (Fry, 1994). Nevertheless, increasingly intensive farming has reduced continuously the quantity of uncultivated areas in agricultural landscapes. This has serious consequences for the spider community since habitat structure is one of the most important criteria for habitat selection (Hatley & MacMahon, 1980; Robinson, 1981). Duffey (1978) observed that even small differences in habitat structure have significant effects on density and species spectrum. Several authors studied the distribution of foliage-dwelling spiders in hay meadows (Kajak, 1971; Kajak et al., 1971; Nyffeler & Breene, 1990) and in arable land (Nyffeler & Benz, 1979; Łuczak, 1979) and the influence of adjacent habitats as colonization source (Bishop & Riechert, 1990). Most investigations of spider fauna deal with cultivated areas, their management and the way they are influenced by uncultivated margins. However, investigations focussing on uncultivated areas and their significance for the spider community in agricultural landscape are rare and mostly concern the ground-dwelling spider species (Maelfait et al., 1988; Nyffeler & Benz, 1981).

Therefore, the present study was undertaken to describe and analyse the foliage-dwelling spider guild of these uncultivated margins and fallow land and to address the following questions: Are there differences in species composition and abundance of spiders between the different areas situated in the same geographic region? Is there any correlation between the species distribution and specimens numbers and the different land use pattern of the areas investigated? These questions are of basic relevance for the definition of minimum standards for the spatial pattern of temperate agricultural landscapes.

METHODS

Data were collected by standardized observation (visual search) for spiders. This method was selected to minimize the disturbance of study plots during a series of investigations. Standardization was achieved by monitoring only species using the herbaceous vegetation layer as a habitat for foraging, web building and cocoon deposit, as well as counting the individuals in study plots of the same size by only one person. Investigations were conducted in study plots of 1 m x 50 m in uncultivated margins and fallow land. The number of study plots, this is margins or patches of fallow land or parts of them, varied between 8 to 14 per area investigated except for one study area ("Scheyern", abbreviated as "SY" in further text). In SY 21 plots were studied. Five of these plots were situated in new fallow land cultivated as fields until 1992.

Species were studied that are conspicuous by their body size, characteristic webs, hiding places or cocoons. Lycosid spiders were neglected because they are mainly ground-dwelling. Erigonid spiders are excluded from the investigations due to their small body size and the less conspicuous behaviour. They cannot be registered representatively by the used method. Juveniles and adults of species studied could be determined mostly to species level or at least genus level in the field without killing or even disturbing the animals. These restrictions to only conspicuous species were made in order to obtain comparable results between different areas. Sampling frequency was once per month and study plot from July to September in 1993.

The investigations are part of an interdisciplinary research project to study the development of areas under different landuse patterns Research Network Agroecosystems Munich (Hantschel & Lenz, 1993).

STUDY AREAS AND THEIR LANDUSE PATTERN

The investigations were conducted in six areas of agricultural land with a different amount of uncultivated margins and patches of fallow land. All the study areas are situated in the same geographic region, a hilly landscape derived from tertiary sediments between the rivers Isar and Danube in Southern Bavaria (Fig. 1).

One study area was an experimental estate near the monastery of Scheyern. Here, a long-term study is being carried out to investigate the influence of different cultivation intensities on abiotic and biotic resources (Pfadenhauer, 1992;

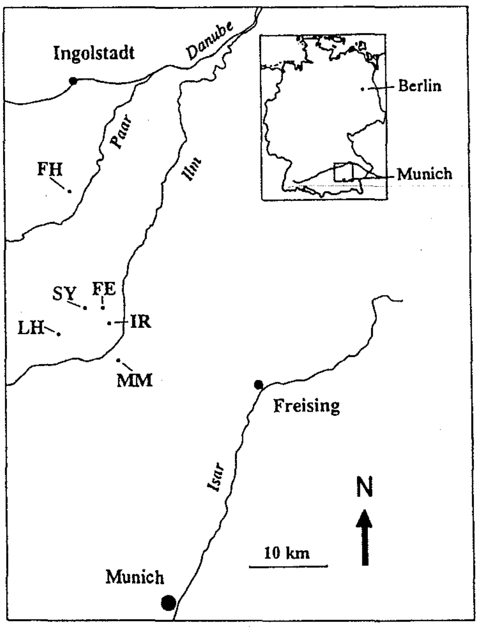

Fig. 1. Situation of the study areas FE, FH, IR, LH, MM and SY in Southern Bavaria, inset: a map of Germany.

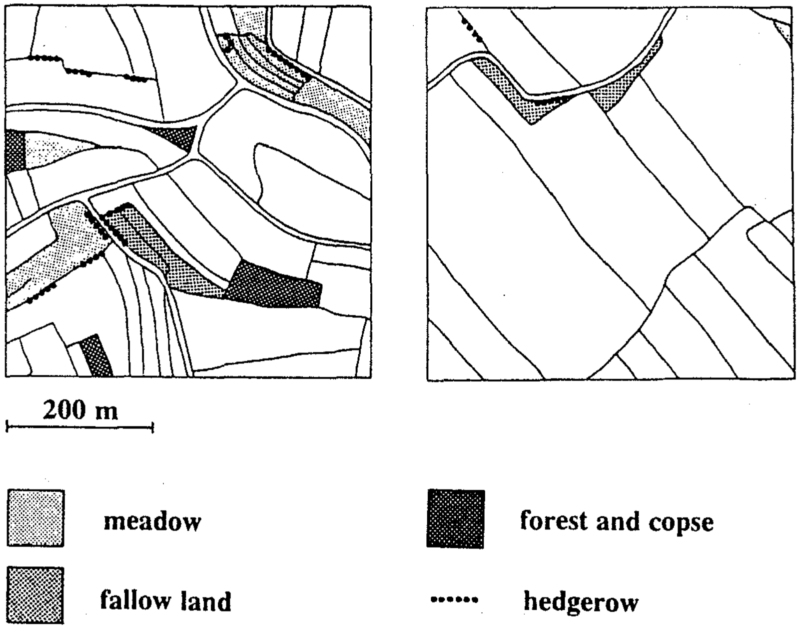

Fig. 2. Map-detail of the two study areas FH (left) and MM (right) showing their edge densities. Each plotted area covers 25 ha.

Hantschel & Kainz, 1993). During the start-up period of two years in 1991 and 1992 and in previous years, there were large intensively cultivated fields up to 30 ha and little fallow land. Since the end of 1992, the field size was reduced to maximum of 8 ha and cultivation intensity was changed to integrated farming in one part and organic farming in another part. New hedges, larger field boundaries, structured forest edges and more fallow areas were established.

The other five areas were cultivated in 1993 in the same way as in previous years and in ways characteristic for farming in this region. These areas are named "FE", "FH", "IL", "LH", "MM" (according to their neighbouring villages "Fernhag", "Freinhausen", "Ilmried", "Lichthausen" and "Mittermarbach"). The areas FE, FH and IL are characterized by a large proportion of uncultivated areas. Their arable land and meadows are situated mostly on slopes. LH and MM have only few uncultivated areas and many large fields on sloping ground. In these areas, fields frequently border directly on other fields, i.e. without uncultivated strips in between. Fig. 2 shows a map of the areas FH and MM, indicating their different densities of field and grassland margins.

Table 1 summarizes the structural features of interest of the six areas. The four environmental factors field size, quantity of large margins and fallow land and structural stability of uncultivated areas are independent of one another, whereas connectedness of uncultivated areas and edge density are a consequence of the

Table 1. List of structural features (left column) and their expression in the six study areas. "Edge density" is the summed length of edges between different patches of fields and grassland per unit area. The signs "+++" to "---" mark a decrease from many to zero patches of fallow land and from a very good to a poor connectedness of uncultivated areas, respectively. For definition of stability criterion of vegetation structure see Table 2.

Study areas	SY	FH	IR	FE	MM	LH
Edge density	210 m/ha	320 m/ha	300 m/ha	350 m/ha	155 m/ha	195 m/ha
Average size of fields	medium	small –medium	small –medium	small –medium	medium –large	medium –large
Number of large margins (>1.5 m width)	few old many new	many	some	some	two	one
Fallow land	few old many new	+++	+++	---	+	---
Stability of vegetation structure of uncultivated areas	medium	high	high	low	medium	low
Connectedness of uncultivated areas	++	+++	++	++	+	---

Table 2. Definition of the stability criterion of vegetation structure per study area as used in this study.

Stability of vegetation structure	Classification criterion
High stability	0–20% of the uncultivated areas were mowed or influenced by other mechanical treatments once per year
Medium stability	40–60% of the margins were influenced by mechanical treatments once per year
Low stability	80–100% of the margins were mowed or influenced by other mechanial treatments once or even twice per year

combination of the factors field size and quantity of larger margins and fallow land. FH has the best connectedness between unmanaged areas: Small fields and many fallow areas and larger margins result in a good connectedness of unmanaged areas in the agricultural landscape. In LH, only one large margin was found, i.e. the connectedness between unmanaged areas is poor. The edge density given in Table 1 is defined as the summed length of the edges between different patches of fields and grassland per unit area (25 ha) regardless of the presence or width of uncultivated strips in between.

In the study areas, the vegetation structure of uncultivated land was influenced by more or less periodic mowing, grazing, trampling or other human influence. These types of interference reduce structural stability of vegetation architecture during a season (for classification of degree of mechanical treatment see Table 2). The mechanical influences varied between the areas investigated. In FH and IR, no mechanical treatment of margins and fallow land was observed. In the area of FE, farmers mowed the majority of meadow margins (more than 80%) once or twice per year. Here even the grassy field margins (horizontal or sloping) were cut during the harvest. In consequence, the vegetation of nearly all uncultivated areas was destroyed at least once per year. Similarly, in LH the small margins were influenced intensively by cutting the vegetation during the harvest.

RESULTS

The numbers of spider species and individuals registered in this study showed considerable differences between the six study areas as well as between single study plots within one area. In Fig. 3 the total number of species is plotted against the total number of specimens for each study plot representing one margin or one patch of fallow land investigated in the six areas. In the area SY, the five study plots in the newly created fallow areas (see triangles in Fig. 3) showed fewer species (4–9) but significantly more specimens (43–84; $p < 0.01$, Mann and Whitney) than other study plots in this area. In contrast, a single study plot in an old patch of fallow land, used as meadow until 1990, accommodates 16 species (square in Fig. 3) with 63 specimens. In all other study plots in SY a maximum of 12 species per study plot was registered and the density peaked at 48 specimens per study plot.

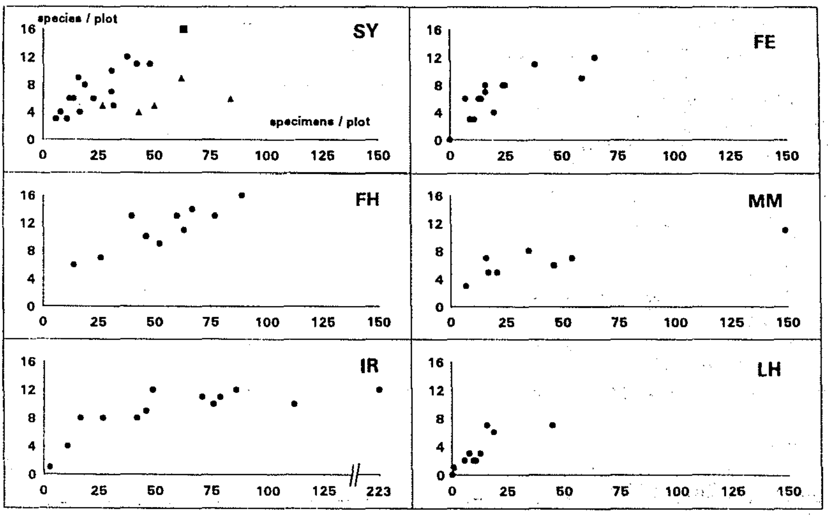

Fig. 3. Number of spider species and individuals in the six study areas in 1993. Each point represents one study plot with its number of species and specimens. In the area SY the triangles mark plots in new fallow land cultivated as fields up to 1992 and the square marks an old fallow land.

Table 3. Influence of margin width and mowing on spider fauna in the area of FE.

Study plot	Width	Treatment	Species	Specimens	
margin 3a	2.5 m	unmanaged	12	65	upper part of the inclinated margin 3
margin 3b	1 m	mowed	7	16	lower part of the margin 3
margin 24	1 m	mowed	0	0	small field margin

Table 4. List of foliage-dwelling spiders collected by standardized visual observation in six agricultural areas in Southern Bavaria (Germany). Sampling frequency was once per month and study plot from July to September in 1993. The occurrence of only one or two individuals during the study period is marked with "+". Some species only occur near forests or hedges, they are marked with "W". These species seem not to be typical for open agricultural landscapes. "?" indicates that the presence classification is not sure, because only few adults, but many juveniles of this genus were found, which cannot be determined to species level.

Species	Presence (max. six areas)	Total number of specimens	
Agelenidae			
Agelena gracilens C. L. Koch, 1841	+	1	
Agelena labyrinthica (Clerck, 1757)	6	64	
Araneidae			
Aculeperira ceropegia (Walckenaer, 1802)	6	275	
Agalenatea redii (Scopoli, 1763)	1	89	
Araneus alsine (Walckenaer, 1802)	2	6	W
Araneus diadematus Clerck, 1757	5	15	W
Araneus quadratus Clerck, 1757	4	265	
Araniella cucurbitina (Clerck, 1757)	4?	5	
Araniella opistographa (Kulczynski, 1905)	1?	1	
Argiope bruennichi (Scopoli, 1772)	6	490	
Atea triguttata (Fabricius, 1775)	+	1	W
Cyclosa conica (Pallas, 1772)	+	1	W
Cyclosa oculata (Walckenaer, 1802)	1	4	
Larinioides folium (Schrank, 1803)	5	323	
Mangora acalypha (Walckenaer, 1802)	6	43	
Nuctenea umbratica (Clerck, 1757)	2	2	
Clubionidae			
Cheiracanthium erraticum (Walckenaer, 1802)	1	20	
Clubiona lutescens Westring, 1851	1	2	
Clubiona neglecta O. P.-Cambridge, 1862	1	5	
Clubiona pallidula (Clerck, 1757)	2	3	W
Clubiona reclusa O. P.-Cambridge, 1863	6	102	
Dictynidae			
Dictyna arundinacea (Linné, 1758)	+	1	
Dictyna uncinata Thorell, 1856	+	1	

Table 4. (cont.)

Species	Presence (max. six areas)	Total number of specimens
Gnaphosidae		
Micaria formicaria (Sundevall, 1831)	2	5
Metidae		
Meta segmentata (Clerck, 1757)	6	105
Mimetidae		
Ero furcata (Villers, 1789)	+	1
Philodromidae		
Philodromus albidus Kulczynski, 1911	+?	1
Philodromus aureolus (Clerck, 1757)	+?	1
Philodromus cespitum (Walckenaer, 1802)	4?	4
Pisauridae		
Pisaura mirabilis (Clerck, 1757)	6	127
Salticidae		
Evarcha arcuata (Clerck, 1757)	6	177
Heliophanus flavipes (Hahn, 1832)	2	6
Sitticus floricola (C. L. Koch, 1837)	+	1
Tetragnathidae		
Tetragnatha dearmata Thorell, 1873	+?	2
Tetragnatha extensa (Linné, 1758)	2?	5
Tetragnatha pinicola L. Koch, 1870	3?	9
Theridiidae		
Enoplognatha latimana Hippa & Oksala, 1982	5	54
Enoplognatha ovata (Clerck, 1757)	6	116
Neottiura bimaculata (Linné, 1767)	5	8
Theridion impressum L. Koch, 1881	6	375
Thomisidae		
Misumena vatia (Clerck, 1757)	+	1
Xysticus audax (Schrank, 1803)	1?	3
Xysticus bifasciatus C. L. Koch, 1873	3?	6
Xysticus cristatus (Clerck, 1757)	3?	21
Xysticus kochi Thorell, 1872	3?	12
Xysticus ulmi (Hahn, 1826)	5?	25

The area FH is characterized by a very well-balanced proportion between the number of species and specimens: five study plots had more than 12 species and also high numbers of specimens (> 50 per plot). Even in the study plot with the lowest number of species, six species with 14 individuals were found. There were no plots in this area where no spiders were found. The maximum number of individuals was found in a single study plot in the area IR (223). Here, 8 to 12 species were found on 11 of the 13 study plots. In six study plots more than 50 specimens were registered. On one small margin (1 m in width) between two fields only one species was found.

In the area FE, 8 to 12 species were recorded on six study plots, but more than 50 specimens occurred only in two study plots. On one small field margin no individuals of herbaceous spiders were found.

In the area MM one study plot was very different from the others. Here, 10 species and 149 specimens were recorded, i.e. about three times more specimens than in the other study plots of this area. In six of eight study plots less than eight species and less than 50 individuals per study plot were found. There was no study plot without spider records in MM.

LH had only a poor spider fauna. The uncultivated strips accommodate few species (in maximum seven) and a low number of individuals (< 25, with one exception: 45).

A sloping meadow margin in FE with an upper unmanaged (study plot 3a) and a lower regularly mowed part (study plot 3b) is shown together with its species and specimen distribution on Table 3. In the unmanaged part more species (12) and specimens (65) were found compared with the mowed part (7, respectively 16). These differences are due to destruction of vegetation structure by mowing.

A list of all spider species found and their total number of specimens in the six study areas is shown on Table 4. Specimens of ten species e.g. the most dominant species *Argiope bruennichi, Theridion impressum, Aculepeira ceropegia* and *Evarcha arcuata* were found in all areas investigated. The other species were absent in at least one area. In each of the areas SY, FH, FE and IR, at least one species occurred only in one or two of these study areas. MM and LH showed none of these rarely occuring species. For instance, *Agalenatea redii* and *Cheiracanthium erraticum* were recorded only in FH, and the salticid *Heliophanus flavipes* only in FE and FH. *Araneus alsine* occurred only in SY and IR. Because of the restricted period of investigation it is not obvious whether some of the rarely found species were indeed present in only one area or normally inhabited other habitat types such as woodlands. Therefore, no clear statement of presence can be given (see "+" in Table 4).

For each area, the average number of species and individuals in one study plot is given in Table 5. FH had the highest number of species per study plot (on average 11.2), while LH had the lowest number of species (3.2) and specimens (12) per study plot. The average number of species per study plot decreases from FH, IR, SY, FE, MM to LH. The average number of individuals per study plot declines from IR, FH, MM, SY, FE to LH. Except for the study plots situated in fallow land, the numbers of species and specimens in SY were similar to that in FE.

The amount of uncultivated areas and the degree of connectedness (compare Table 1) decreases from FH, IR, FE, MM to LH. This parallels the decline of species numbers. The structural stability of uncultivated areas decreases from the two areas FH and IR (with highest stability) to MM and SY (with medium stability) and to FE and LH, where most of the vegetation was destroyed by mechanical treatments. FE has a low average number of species and specimens compared with the areas FH and IR, although their field size and edge density is similar to FE. This is due to the destruction

Table 5. Average number of species and individuals per study plot and maximum number of species recorded in each of the six study areas.

Study areas	SY	FH	IR	FE	MM	LH
Average number of species per plot	7.1	11.2	8.9	6.5	6.5	3.2
Average number of specimens per plot	32	53	65	23	43	12
Max. number of species per study area	27	25	25	23	15	15
Number of study plots in each area	21	10	13	14	8	10

of vegetation structure in the margins of FE. Mowing or cutting of large margins caused a strong decline in numbers of specimens, but also a clear decrease in numbers of species, e.g. in the area FE.

The study areas can be separated into two groups according to edge densities: FE, FH and IR have similar high edge densities of 300 to 350 m/ha, whereas the edge densities of MM, LH and SY were much lower (155 to 210 m/ha). FE has the highest and MM the lowest edge density. Nevertheless, both areas have the same average number of species per study plot and FE even a lower spider density per study plot than MM.

These results indicate that there is a correlation between the distribution of foliage-dwelling spiders and the quantity of uncultivated land in agricultural landscape, and also its quality, i.e. the stability of vegetation structure of these uncultivated areas. While number of species depends on the proportion of uncultivated to cultivated areas, the number of individuals declines mainly with the loss of structural stability of uncultivated areas. Therefore, number, quality and management of uncultivated areas have a strong influence on the composition of spider community in agricultural landscapes.

DISCUSSION

The role of field margins in nature conservation depends on size, spatial arrangement and local site conditions (Fry, 1994). Spider fauna depends directly on habitat structure (Duffey, 1966; Scheidler 1990). Destroying vegetation structure by mechanical treatments will reduce spatial variability (Duffey, 1975) and therefore, reduce the spider fauna of the herbaceous layer. In the area FE only few specimens per study plot were observed, although the number of larger margins is similar to that in IR. As shown in Table 3, this was a result of mowing or cutting of most of the margins. There are several reasons, why boundaries were managed by farmers, although, this is time-consuming. In some cases it was to prevent the development of hedgerows. In other cases the farmers feared crop damage by pest arthropods and slugs or the immigration of weeds (e.g. *Urtica dioica, Cirsium arvense* or *Galium aparine*). Some authors (Kajak, 1971; Nyffeler & Breene, 1990) describe the negative effect on spider densities by habitat disturbance in hay meadows after mowing. Nyffeler & Benz (1981) collected 10 to 100 times more foliage-dwelling spiders in fallow land than in cultivated land. They explained this by destruction of habitat and cocoons as a result of mowing and cultivation. Nowadays, all the vegetation structure even in uncultivated areas is ordinarily destroyed by cutting in minimum once per year. It is necessary to reflect on the resulting negative implications on the local fauna, which are documented here with the example of the foliage-dwelling spiders.

The size of margins seems to be an important factor for spider composition. In FH many margins were larger than 1.5 m in width. Here, a high average number of species and individuals per plot is present compared with low average numbers of species and specimens in LH, where most of the margins were very narrow (< 1 m in width). Especially these smaller margins seem to be affected more by mechanical treatments of the neighbouring cultivated areas than larger margins, where an undisturbed central zone can be established. Only a reduced spider fauna can exist on small margins. It is not clear, whether this is caused by the smaller width of the margins itself, more frequent mechanical treatment, or a combination of these factors.

Another important factor for spider distribution is the degree of connectedness between margins and fallow areas. It seems that a higher degree of connectedness facilitates colonization of "damaged" margins by spiders (Nyffeler, 1982), and, therefore, connectedness will lead to a good connectivity of spider habitats (for concepts see Baudry & Merriam, 1988).

As it is shown by areas FE and MM, no correlation between edge density and average number of species or individuals exists. Thus, edge density is not a relevant feature for the foliage-dwelling spider fauna.

A more diverse spider fauna in agricultural landscape requires

☐ larger margins,
☐ fallow land as a source of colonization,
☐ the connectedness of uncultivated areas,
☐ stable vegetation structure of margins.

As a result, habitat and reproduction of herb-layer spiders is usually restricted to unmanaged or only non-intensively managed areas in agricultural landscape. The foliage-dwelling spider guild may serve as bioindicators for quantity and quality of uncultivated areas similar to other invertebrate indicator systems for the evaluation of grassland management (Siepel et al., 1992).

ACKNOWLEDGEMENTS. The scientific activities of the research network "Forschungsverbund Agrarökosystem München" (FAM) are financially supported by the Federal Ministry of Research and Technology (BMFT 0339370). Rent and operating expenses of the experimental farm in Scheyern are paid by the Bavarian State Ministry for Education and Culture, Science and Art. Special thanks to M. Gebhardt, Freising, for valuable comments on this manuscript and to Dr. B.-G. Horseman, Freising, for improving the English language.

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