

PSEUDOSCORPIONS IN FIELD MARGINS: EFFECTS OF MARGIN AGE, MANAGEMENT AND BOUNDARY HABITATS

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ABSTRACT. Pseudoscorpions (*Chthonius ischnocheles* (Hermann) and *C. orthodactylus* (Leach) *sensu strictus*) were collected using a D-Vac over two-years from 60 field margins at Oxford University farm at Wytham, U.K. Old and new grassland margins were subjected to six different treatments involving spraying, non-intervention and four different cutting intensities. Significantly more pseudoscorpions were found in old compared to new margins, suggesting they may be attracted to litter build-up over time. Pseudoscorpion numbers were reduced on treatments subjected to two cuts annually, particularly when a summer cut was included, although this effect was ameliorated when the cuttings were left. However, pseudoscorpions were most numerous on treatments which involved no management because of the increase in leaf litter which may replicate a woodland environment. Adjacent hedges appear to buffer the effects of management: margins with adjacent hedges (rather than ditches or tracks) having more individuals. In contrast to results for other invertebrate groups, sowing wildflower seed did not significantly increase the abundance of pseudoscorpions. The effect of different treatments on pseudoscorpion numbers demonstrates that they are useful indicators of the effects of management practice.

Leaf litter is the ancestral habitat of pseudoscorpions, with deeper litter, such as that in woodlands, providing an ideal stable environment (Jones 1970). Few studies have examined them in grasslands despite some species occurring commonly in this ecosystem. Fewer still have considered the role of habitat management on pseudoscorpions in grassland margins. Thus, stable woodland environments have provided nearly all the ecological and taxonomic work for common pseudoscorpion families, such as the Chthonidae, in Britain

(e.g., Gabbutt & Vachon 1963; Gabbutt 1967; Goddard 1976; Wood & Gabbutt 1978). Particular attention has been paid to the ecology and life history of *Chthonius ischnocheles* (Hermann) and to a lesser extent *Chthonius orthodactylus* (Leach) *sensu strictus*, both of which are widespread species. It is not surprising that there has been little work on grassland pseudoscorpions since only the *Nanolpium* species (Garypoidea, Olpiidae) from Africa are consistently collected from grass, probably because grasslands are too exposed for many other pseudoscorpions (Judson & Heurtault 1996). In the only British reference to grassland pseudoscorpions, Salt et al. (1948) found high densities (19.56 m⁻²) in agricultural fields in Cambridgeshire, but unfortunately did not report the species' names. Grasslands are a marginal habitat for several British species including *Chthonius ischnocheles* and *C. orthodactylus* (Legg & Jones 1988), probably because deep litter is found in large amounts only under hedges and in man-made piles. Despite this, Rapp (1978)

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compared the distribution of *Microbisum confusum* Hoff. in two contrasting areas of tall grass and mixed prairie. He determined that grazing caused a decline in the number of pseudoscorpions because of adverse changes to moisture and litter depth. Our paper is the first to examine changes in pseudoscorpion numbers within a unique farm scale environment that has been block designed and replicated to test for successional processes over a long period of time. Over the last ten years, the Oxford University farm at Wytham has been used to test the effect of management on a variety of other grassland arthropods such as spiders (Baines et al. 1998), butterflies (Ferber et al. 1996) and the Hemiptera (Smith et al. 1993), producing a better understanding of the habitat requirements of these groups in an agricultural context. We use this field experiment, designed to evaluate the wildlife conservation benefits of a variety of management techniques for arable field margins, to examine the effects of age, management and proximity to mature boundary habitats on pseudoscorpions. Our hypothesis that low intensity management and stable conditions found in hedges will support more individuals is based on a pseudoscorpion's sensitivity to litter depth and mutable habitat structures.

METHODS

Site management.—The surveys took place at the site of an experiment established in 1987 on 60 field margins at Oxford University farm (SP 472 097) at Wytham (Smith et al. 1993; Feber et al. 1996). Old margins ($n = 60$) around the fields existed pre-1987 and are about 1 m wide. In 1988 these old margins were extended 1 m into the field to a total width of 2 m and producing new margins ($n = 60$). In 1990 sterile strips were cultivated between the margin and the crop, allowing access to the margins without trampling. Six management treatments in 50 m strips were randomized in a block design across the 60 margins. Treatment A had no management ($n = 12$); B was cut in spring and autumn and the hay collected ($n = 12$); C was cut in spring and summer and the hay collected ($n = 12$); D was cut in summer only and the hay collected ($n = 12$); E was cut in spring and summer and the hay left ($n = 6$); F was sprayed with herbicide (glyphosate) in the same way as the crop ($n = 6$). Those treatments with a

sample size of 12 (A–D) were subdivided into margins which were sown with wildflower seed in March 1988, and those which were left to colonize without sowing ($n = 6$ in each case). Cutting took place in spring (April), summer (June) and autumn (September) using an Allen scythe and brush cutters. The cuttings were left to dry and the hay was collected or left depending upon the treatment. Glyphosate (Roundup Biactive[®], Monsanto) was applied to six margins (F) at a rate of 3 liters ha^{-1} at a field volume of 200 liters ha^{-1} using an Oxford precision sprayer. The habitats adjacent to the margins were recorded: ditches ($n = 56$), hedges ($n = 38$), and tracks ($n = 26$).

Sampling.—Pseudoscorpion species (*Chthonius ischnocheles* and *C. orthodactylus*) were collected for two field seasons in 1995 and 1996 using a Dietrick Vacuum suction sampler (D-Vac). During each season, samples were collected in spring (May), summer (July) and autumn (September). Five sucks of 30 seconds were made, each at a 10 m interval along a 50 m margin, and were aggregated to give one sample. The samples were taken separately from old and new margins. Specimens were separated from debris in the laboratory and stored in 70% methanol. No attempt was made to collect silken chambers and this may have underestimated the true number of females of both species and protonymphs of *C. orthodactylus* (Gabbutt 1970; Goddard 1976). D-Vac sampling is biased towards collecting samples from the litter layer. We made no attempt to collect samples from the soil which may have underestimated actual numbers within each margin. Adult specimens were identified using Legg & Jones (1988), and nymphal stages were identified using Gabbutt & Vachon (1963) and unpublished drawings by Mark Judson (Muséum National D'Histoire Naturelle, Paris).

Statistical analysis.—Both species, and the six collections over two years, were aggregated to simplify analysis. The Kolmogorov-Smirnov two sample test indicated that it was not possible to transform the data to normality, therefore we used non-parametric statistics to test for difference. Non-specific Meddis rank means tests were used, blocking by treatments not under investigation and using post hoc analyses to identify ideal rank orders where significant results were obtained (Med-

dis 1984). The level of significance for all the tests was where $P \leq 0.05$.

RESULTS AND DISCUSSION

A total of 247 specimens (*Chthonius ischnocheles*: 57♂, 47♀, 54 tritonymphs, 8 deutonymphs = 166. *C. orthodactylus*: 34♂, 24♀, 21 tritonymphs, 2 deutonymphs = 81) was recorded over the two year period. As a proportion of the total number of invertebrates collected from the field margins during this study ($\sim 6 \times 10^5$, excluding Collembola and Acari), the pseudoscorpion population was less than 0.05%. This highlights the relatively minor role of pseudoscorpions in grassland litter compared with woodland litter and soil, in which pseudoscorpions are at relatively high densities (Goddard 1976; Gabbutt 1967). *Chthonius ischnocheles* were twice as abundant and twice as widely distributed over the field margins compared to *C. orthodactylus*. Overall, pseudoscorpions exploited 43.4% of the available field margin habitat ($n = 120$) but in only 9.6% of samples ($n = 120$) did the two species occur together. The ratio of males to females was slightly biased in favor of males for both *C. ischnocheles* (1.2:1) and *C. orthodactylus* (1.4:1). In both species, tritonymphs contributed substantially to the total numbers (*C. ischnocheles* = 32.5%; *C. orthodactylus* = 25.9); but deutonymphs were rare (*C. ischnocheles* = 4.8% ; *C. orthodactylus* = 2.5). No protonymphs were recorded.

Age of margins.—Significantly more pseudoscorpions were found in old margins compared with new ($H = 9.471$, $P = 0.002$, $df = 1$). This may be a due to litter build-up over time, since deeper litter supports more individuals and suitable prey (Jones 1970). Both Baines et al. (1998) and Frank & Nentwig (1995) recorded more spider species, and more individuals, on older field margins compared to new. Although spiders and pseudoscorpions differ in their habitat requirements, it may be that the longer the field margin has to develop, the more stable and ultimately more suitable the litter environment becomes.

Management.—The timing and the intensity of management had a significant impact on the abundance of pseudoscorpions (see Table 1) found in the field margins ($H = 12.712$, $P = 0.026$, $df = 5$, rank order: A>D,E,B>F>C). No management (A) was associated with higher abundances (Table 1) when compared

Table 1.—Comparison of the effect of treatment on total pseudoscorpion numbers expressed as a rank. Species counts are also given but were not tested separately and should not be compared with the *post hoc* rank scores. The test using a non-specific Meddis rank means test was significant ($P = 0.026$). The *post hoc* ranks range from 1 (the highest) to 4 (the lowest) scores; D, E, B are not significantly different and therefore have the same rank score.

Treat- ment	<i>Chthonius</i> <i>ortho-</i> <i>dactylus</i>	<i>Chthonius</i> <i>ischno-</i> <i>cheles</i>	Combined spp. total	<i>Post</i> <i>hoc</i> rank
A	37	58	95	1
B	4	25	29	2
C	9	10	19	4
D	25	28	53	2
E	4	26	30	2
F	2	19	21	3
Totals	81	166	247	—

with other treatments, probably because it allowed litter build-up, provided cover and a comparatively stable microclimate. Timing and frequency of cutting are critical for other invertebrate groups (e.g., Morris & Rispin 1988) with summer cuts being deleterious to spiders (Baines et al. 1998). When a summer cut is combined with a spring cut and the clippings are collected on both occasions (C), it has a more serious effect on pseudoscorpion numbers (Table 1). Effectively this management treatment produces a grassland sward that is short, with minimal litter development and an unstable microclimate. Rapp (1978) recorded a similar effect under grazing where the abundance of *Microbisum confusum* was determined by the thickness of the litter and available soil moisture. Frequent cutting of grassland creates a high degree of disturbance and structural alteration through removal of standing vegetation (Morris 1979). Plant architecture and floral composition are governed by management (Brown & Gibson 1990) which in turn causes the microclimate within the sward to change (Morris 1968; Morris & Rispin 1988). Dramatic fluctuations in the microclimate, particularly humidity and temperature, will have a negative impact on pseudoscorpions, (Weygoldt 1969; Rapp 1978). *Chthonius ischnocheles* can recover lost water with changes in humidity quickly and will migrate in adverse conditions (Caplin 1974;

Legg & Jones 1988) but probably not over a sustained period with little vegetation cover.

Management treatments B, D and E were similar to each other in terms of the abundance of pseudoscorpions (Table 1), but supported fewer individuals than did A. These results suggest that a single summer cut (D) or two cuts which avoided the summer period (B) have less impact than a spring and summer cut with removal of the vegetation (C). When two cuts close together are necessary, leaving the hay on the margins appears to ameliorate the effects of this intensive regime (E). Ideally, we advocate that, in order to achieve a balance with the habitat requirements of other invertebrate groups, managements B, D and E are acceptable compromises, and leaving grass piles on the margin would increase litter availability, but probably encourage weeds (Smith pers. comm.). Our study suggests that pseudoscorpions are sensitive to herbicide applications (F), although this is not as deleterious to pseudoscorpions as a spring and summer cut with removal of vegetation (C) (Table 1). Such spraying generates a deeper litter over a period of months, creating an ideal habitat for pseudoscorpions (Jones 1970) but it is suggested that consequent changes in microclimate may render conditions unsuitable.

Boundary habitats.—The three types of boundary habitat adjacent to the field margins had a significant impact on the numbers of pseudoscorpions found in the field margin ($H = 7.286$, $P = 0.025$, $df = 2$, rank order: $H > D > T$). Margins adjacent to a hedge (H) had more individuals than those adjacent to a ditch (D), but the poorest adjacent habitat was a track (T). Moisture, light and food availability are often relatively stable in hedgerows (Hance et al. 1990), but in field systems which have a high level of disturbance from management (Morris 1979) these must be in a state of flux (although soil moisture may not change significantly: White & Hassall (1994)). The hedge and, to a lesser extent, the ditch could act as a buffer and possible overwintering site and refuge from extremes of management. Tracks are less likely to buffer populations as they are highly disturbed by farm traffic and subject to substantial diurnal variations in temperature.

Wildflower seeded margins.—No significant difference was detected in abundance be-

tween margins sown with a wildflower seed mixture and those left to be colonized naturally ($H = 0.969$, $P = 0.674$, $df = 1$). As most pseudoscorpions live within the litter, their numbers are not as directly affected by the diversity of vegetation in field margins, as are the numbers of spiders, which are dependent on vegetation structural complexity and diversity (White & Hassall 1994; Baines et al. 1998). However, there are benefits of sowing to other groups of invertebrates, e.g., *Maniola jurtina* L. (Lepidoptera) (Feber et al. 1996).

Conclusions.—Although pseudoscorpions are not an abundant group in grasslands, they are good indicators of mutable habitat structures. The differences detected among different management regimes, age structures and adjacent habitats supports our hypothesis that the management of field margins for arthropods should be consistent over time and of low intensity creating a suitable litter environment. Hedges clearly buffer the populations of pseudoscorpions within field margins and should be conserved. Although sowing field margins with wildflowers had no detectable effect, this practice benefits other invertebrate groups and should be encouraged.

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