The spatial distribution of carabids (Coleoptera: Carabidae) in relation to a shelterbelt

JENS ERIK LYNGBY & HANS BRIX NIELSEN

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The effect of shelterbelts on the spatial distribution of carabids was investigated in May–September 1978, in an alfalfa field near Aarhus, Denmark. The sampling was done by pitfall traps, placed in a line perpendicular to the shelterbelt. A total of 5962 carabids was caught: *Calathus fuscipes* was the predominant species. The spatial distribution of breeding types was calculated, showing that autumn breeders were most abundant in the field. The index of diversity was highest in the middle of the shelterbelt, declining significantly with distance from it.
The carabids were grouped according to spatial distribution patterns, as follows: I: Species with constant spatial distribution throughout the research period (a: Species associated with the shelterbelt (e. g. *Calathus piceus, Trechus quadristriatus, Notiophilus biguttatus,* and *Carabus nemoralis*)) (b: Species associated with the border of the shelterbelt (e. g. *Calathus erratus, Amara bifrons, Amara communis,* and *Harpalus rufipes*)) (c: Species associated with the field (e. g. *Amara aenea, Amara ovata,* and *Broscus cephalotes*)). II: Species with variable spatial distribution in relation to the shelterbelt throughout the research period (*Calathus fuscipes, Pterostichus melanarius, Calathus melanocephalus* and *Nebria brevicollis*).
The spatial distributions and the reasons for these were discussed, and it was concluded that the shelterbelt has a significant effect on the carabid fauna.

Jens Erik Lyngby & Hans Brix Nielsen, Zoologisk Laboratorium, Ole Worms allé, DK-8000 Århus C, Danmark.

Introduction

The effect of shelterbelts on the carabid fauna of agricultural land has been the subject of several investigations, for instance Bonkowska (1970), Fuchs (1969), Gersdorf (1965), Gorny (1971), Pollard (1968b, c), Thiele (1960, 1964, 1971), Tischler (1958), Trittelvitz & Topp (1980); recent reviews were presented by Rotter & Kneitz (1977) and Thiele (1977).

Shelterbelts may increase the number of predators of insect pests in cultivated fields (e. g. Pollard, 1968a). Carabids have been reported to predate on the eggs, larvae, and pupae of a wide variety of insect pests (Basedow, 1973; Dempster et al., 1959; Finlayson & Campbell, 1976; Holliday & Hagley, 1978; Mitchell, 1963; and Scherney, 1961).

According to some authors (Thiele, 1960, 1971; Tischler, 1958), the interaction between carabid populations of shelterbelts and of cultivated fields is of minor proportions, whereas other authors (Pollard, 1968b; Fuchs, 1969) suggest that these interactions are considerable.

The purpose of this investigation was to examine the effect of shelterbelts on the spatial distribution of carabids, and to elucidate the interaction between the carabid fauna in shelterbelts and fields.

Study area and methods

The investigation was carried out from May–September 1978 in an alfalfa field on the farm "Lyngbygaard" 8 km west of Aarhus, Denmark. The 15 ha. field was bordered to the north, east and west by a shelterbelt which was approximately 20 m wide and 5 m high. The vegetation of the shelterbelt was dominated by *Picea abies* L., *Pinus silvestris* L., and *Betula* sp.; the herb vegetation was rather sparse and the ground was covered with coniferous needles. The shelterbelt was bordered by a dense growth of *Rosa rugosa* Thunb. To the south, the alfalfa field bordered four fields with grass, wheat, barley, and summerrape, respectively. The soil was rather sandy.

The alfalfa was sown in the spring of 1976, which means that during the two years previous to the investigation, the ground had not been disturbed by any deep mechanical treatment. In 1978 the alfalfa was harvested three times, viz. June 6th, August 1st, and October 6th.

The activity and abundance of carabids were recorded by pitfall traps made from plastic flowerpots (diameter 10.5 cm) in which a plastic jar was placed to minimize disturbance of the trap surroundings during tending. Benzoic acid was used as a preservative; detergent was added.

The pitfall traps (n = 36) were placed in the east-west oriented shelterbelt (3 stations: north (N), middle (M), and south (S)) and in the alfalfa field on a line perpendicular to the shelterbelt (distance of stations from the edge of the shelterbelt: 0, 2, 5, 10, 25, 50, 75, 100, and 150 metres). At each station three pitfall traps were placed at intervals of one metre. Due to the distances to the north-south oriented shelterbelts (about 250 m) any interferences from these was excluded.

In order to reduce the effect of accidental fluctuations, the stations were grouped as follows: Shelterbelt (N, M, and S), border area (0, 2, and 5 m), intermediate field (10, 25, and 50 m), and central field (75, 100, and 150 m). The pitfall traps were emptied weekly from May 11th to September 1st. The samples were preserved in 70% alcohol. Carabids from nine sampling dates (intervals of 14 days) were sorted. The carabids identified were not kept.

Data on air temperature and precipitation from Ødum Experimental Station, 17 km north of "Lyngbygaard", were utilized. After a short period of warm weather in May-June, the summer was relatively cold; furthermore, in April, May, June, and August, the precipitation was below normal.

Results and discussion

A total of 5962 carabids, representing 39 species, was caught. The predominant species were *Calathus fuscipes* and *Pterostichus melanarius*, contributing about 43% and 17% of all carabids, respectively. The majority of the species was caught in very low numbers (Tab. 1). Most carabids were caught near the end of the sampling period; maximum catch was obtained 150 metres from the shelterbelt and, apparently, the catch increased slightly near the edge (station 2 m) of the shelterbelt (Tab. 2). This may be explained by the prolonged period of activity in this area, due to higher temperatures (cf. Fuchs, 1969).

Table 1: List of species caught (total number of individuals and percentage (> 0.5%) of total carabid catch). Names of species in accordance with Hansen (1968).

	Number	Percent
Calathus fuscipes Goeze.	2527	42.89
Pterostichus melanarius Illig.	1039	17.43
Calathus erratus Sahlb.	379	6.36
Calathus piceus Marsh.	360	6.04
Amara bifrons Gyll.	313	5.25
Nebria brevicollis Fabr.	304	5.10
Calathus melanocephalus L.	263	4.41
Amara aenea Deg.	208	3.49
Amara familiaris Duft.	141	2.37
Amara ovata Fabr.	83	1.39
Trechus quadristriatus Schrank.*	51	0.86
Amara communis Panz.	31	0.52
Notiophilus biguttatus Fabr.	31	0.52
Carabus nemoralis Müller	25	–
Harpalus rufipes Deg.	23	–
Broscus cephalotes L.	20	–
Calathus micropterus Duft.	18	–
Loricera pilicornis Fabr.	17	–
Leistus rufomarginatus Duft.	12	–
Harpalus affinis Schrank.	11	–
Amara apricaria Payk.	10	–
Amara aulica Panz.	10	–
Carabus convexus Fabr.	8	–
Bembidion lampros Hbst.	6	–
Leistus rufescens Fabr.	6	–
Clivina fossor L.	5	–
Pterostichus strenuus Panz.	5	–
Carabus hortensis L.	4	–
Harpalus rubripes Duft.	4	–
Amara consularis Duft.	3	–
Badister bipustulatus Fabr.	3	–
Harpalus seladon Schauberger	2	–
Pterostichus oblongopunctatus Fabr.	2	–
Notiophilus aquaticus L.	2	–
Agonum viduum Panz.	1	–
Carabus coriaceus L.	1	–
Dromius quadrinotatus Panz.	1	–
Pterostichus nigrita Fabr.	1	–
Harpalus tardus Panz.	1	–
Total catch	5962	

*Among "*Trechus quadristriatus*" some specimens of *Trechus obtusus* Er. might occur.

Table 2: The distribution of the total catch of carabids on the 12 stations May–September 1978. (3 pitfall traps at each station).

Shelterbelt			*Border area*			*Intermediate field*			*Central field*		
N.	M.	S.	0 m	2 m	5 m	10 m	25 m	50 m	75 m	100 m	150 m
359	263	318	438	535	386	429	325	571	776	679	883

Spatial distribution of breeding types

The spatial distribution of spring breeders and autumn breeders (Larsson, 1939) was calculated as percent of carabid species and individuals, respectively (Fig. 1). Autumn breeders were predominant in all sites, especially when individuals were considered. Apparently, autumn breeders were most abundant in the central field, and spring breeders in the shelterbelt. The spatial distribution of spring breeders and autumn breeders might be an effect of the shelterbelt.

The results presented above are not in agreement with those of Thiele (1969) and Larsson (1939), who found that spring breeders dominated in fields and autumn breeders in forests.

Species diversity

The fauna of cultivated fields is relatively poor in species but rich in individuals; this might be caused by the homogenizing effect of cultivation (Müller, 1968). The presence of shelterbelts increases the number of species in cultivated fields (Pollard, 1968b; Lewis, 1969).

In the present study the index of diversity α ($S = \alpha \log_e (1 + N/\alpha)$; S: number of species, N: number of individuals) (Lewis & Taylor, 1967) was calculated by iteration at each station. A linear regression of index of diversity on distance from the middle of the shelterbelt was made (station M to 150 m) (Fig. 2). From the middle of the shelterbelt the species diversity declined significantly with distance from the latter site ($P < 0.05$); this suggests that the species diversity of an appreciable part of the field is increased by the shelterbelt.

Carabid distribution in relation to the shelterbelt

Among the abundant carabid species four well-defined distribution patterns were observed:

I: Species with constant spatial distribution throughout the research period.
  a) Species associated with the shelterbelt.
  b) Species associated with the border of the shelterbelt.
  c) Species associated with the field.

II: Species with variable spatial distribution in relation to the shelterbelt.

Group Ia: In this group maximum activity was recorded in the shelterbelt, declining distinctly with increasing distance from the latter site (Fig. 3). This group included the following species: *Calathus piceus, Trechus quadristriatus, Notio-*

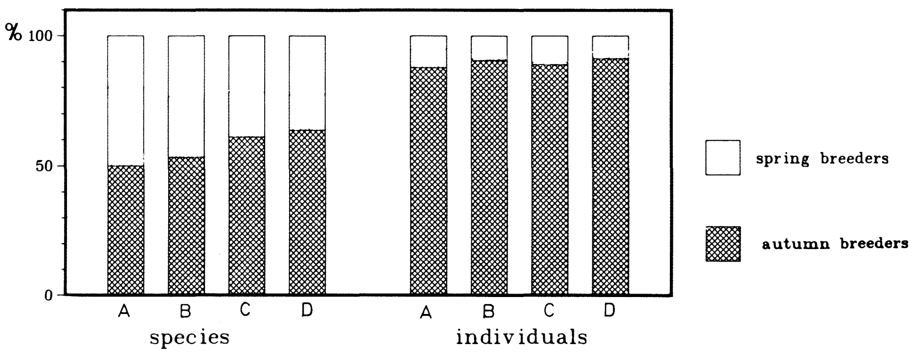

Fig. 1. The spatial distribution of spring breeders and autumn breeders in percent of species and individuals, respectively. A = shelterbelt, B = border area (0–5 m), C = intermediate field (10–50 m), and D = central field (75–150 m).

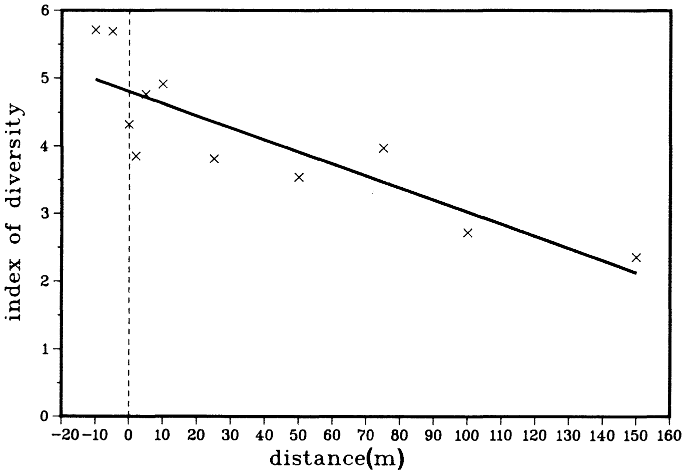

Fig. 2. The index of diversity (α) as a function of distance from the shelterbelt. The linear regression of index of diversity on distance from the middle of the shelterbelt was y = – 0.018x + 4.800.

philus biguttatus, Carabus nemoralis, Calathus micropterus, Leistus rufomarginatus, Carabus convexus, Pterostichus strenuus, Clivina fossor, Carabus hortensis, and *Badister bipustulatus;* some of these species are normally caught in relative humid biotopes such as forests (Hansen, 1968). The carabid fauna of the shelterbelt differed distinctly from that of the field. Thiele (1960, 1971) found that the carabid fauna of a shelterbelt is an impoverished forest fauna, however with more eurytopic species than a typical forest fauna. Comparable results were obtained in the present study.

Group Ib: Apparently, species of this group preferred the border area, which is most affected by the shelterbelt. This distribution pattern was observed in *Calathus erratus, Amara communis,* and *Harpalus rufipes* (Fig. 4); maximum abundance of these species occurred in the border area, viz. 36.7%, 64.5% and 65.2% of total catch of each species, respectively. Presumably, species with a larger area of maximum acivity may also be included in this group; for instance, in *Amara bifrons* maximum activity was recorded 0–50 metres from the shelterbelt (Fig. 4). In the daytime, the temperature and relative humidity are generally higher near a shelterbelt than in the neighbouring field (Rosenberg, 1974). Such microclimatic factors are important for the distribution and survival (Jørum, 1976) of carabids, presumably resulting in an active search of certain species for the border area.

Group Ic: In the species of this group the relative abundance increased with distance from

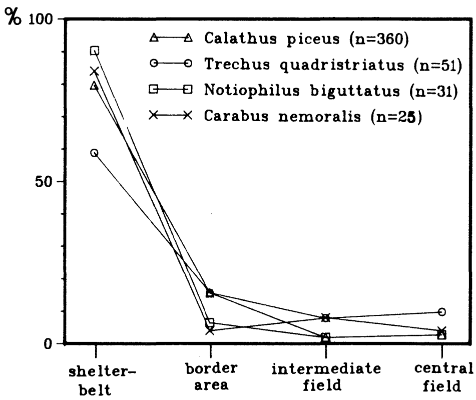

Fig. 3. The spatial distribution of species showing maximum activity in the shelterbelt and a distinct decline with increasing distance from it. (Group Ia, percent of total catch per species).

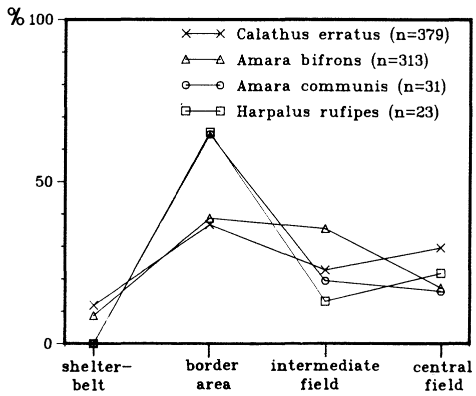

Fig. 4. The spatial distribution of species associated with the border area (group Ib; percent of total catch per species).

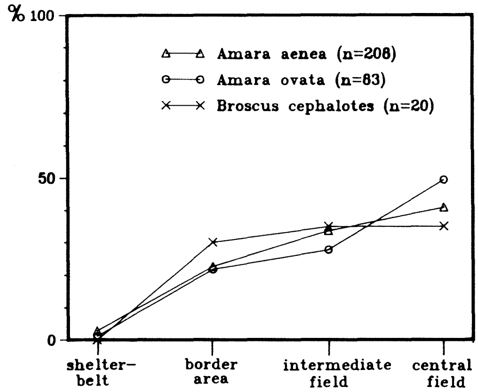

Fig. 5. The spatial distribution of species showing increasing activity with increasing distance from the shelterbelt (group Ic, percent of total catch per species).

the shelterbelt. *Amara aenea, Amara ovata, Broscus cephalotes,* and *Loricera pilicornis* were typical species of this group (Fig. 5). In contrast to group Ia, characterized by forest species, this group is dominated by species of open land (Hansen, 1968).

Group II: This group included *Calathus fuscipes, Pterostichus melanarius, Nebria brevicollis,* and *Calathus melanocephalus,* all of which throughout the research period showed variable spatial distribution in relation to the shelterbelt. *N. brevicollis* seemed to show an association to the shelterbelt which was different from that of the three other species. In mid- and late May, the maximum activity of *C. fuscipes* and *C. melanocephalus* (Fig. 6) was recorded in the shelterbelt, and that of *P. melanarius* and *N. brevicollis* in the border area. In June and July, the maximum activity of *C. fuscipes, P. melanarius,* and *C. melanocephalus* was displaced to the field, reaching a maximum in the central field in early August (3/8). The acitivty increased in the border area in mid-August (17/8), but the distribution pattern observed in early August was re-established in early September (1/9). The activity displacement of *N. brevicollis* occurred in late May and reached a maximum in the central field in early June (8/6).

The four species showing variable spatial distribution all are autumn breeders. Several investigations indicate the many autumn breeders may hibernate as imagos (Jørum, 1976; Schjøtz-Christensen, 1965); further, carabids have been reported to migrate from fields into forest areas (Scherney, 1961) or shelterbelts (Pollard, 1968b) for hibernation. Probably, the specimens of *C. fuscipes, P. melanarius,* and *C. melanocephalus* trapped in May-June, and the specimens of *N. brevicollis* trapped in May, were imagos, which had hibernated. The maximum activity observed in the shelterbelt in spring and early summer suggests that the shelterbelt creates better conditions for hibernation of the imagos than the field. The activity displacement in late June –

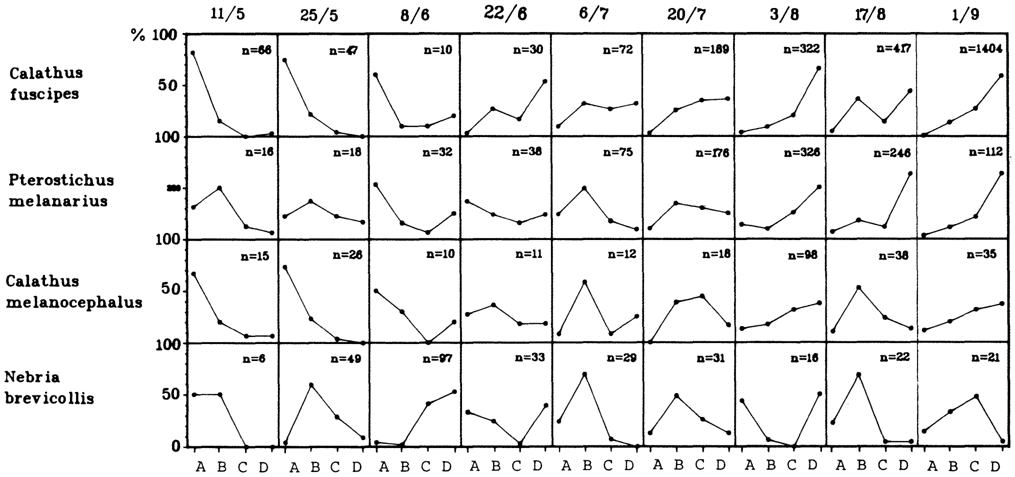

Fig. 6. The spatial distribution of *Calathus fuscipes, Pterostichus melanarius, Calathus melanocephalus,* and *Nebria brevicollis* showing variable distribution in relation to the shelterbelt. (group II, percent of catch on nine sampling dates). A = shelterbelt, B = border area (0–5 m), C = intermediate field (10–50 m), and D = central field (75–150 m).

early July (*N. brevicollis* in May) could be explained by emigration from the shelterbelt into the field. Migration of carabids in relation to shelterbelts was observed by Pollard (1968b), Fuchs (1969), Thiele (1964), and Jones (1976). Ericson (1978) found that *P. melanarius* migrates 5–32 m/day, and Rivard (1965) mentions a value of 20 m/day. These results support that the displacement of maximum activity is caused by migration.

In early July (in early June for *N. brevicollis*), the newly-hatched imagos appeared, and were clearly predominant in the middle of July. The catches in the field were appreciably larger than in the shelterbelt. This might indicate that the newly-hatched imagos hibernated in a larval stage in the field, now causing the greater catch here. The lower catch of *N. brevicollis* in July and August may be explained by the aestivation parapause of this species (Jørum, 1976). During the parapause the maximum activity was recorded in the border area (except 3/8).

The preference of *C. fuscipes, P. melanarius,* and *C. melanocephalus* for the border area in mid-August might be an effect of the harvest in early August (1/8), which induced changes in the microclimate, such as greater fluctuations in temperature. Fuchs (1969) found that carabids, e. g. *P. melanarius* seek into shelterbelts during unfavourable periods. However, according to Pauer (1975), carabids escape unfavourable conditions by burying themselves. The rise in activity in the area near the hedge (17/8) is probably caused by migration of carabids from the field, which actively seek an area with a favourable microclimate; this change in distribution is most pronounced in *C. fuscipes* and *C. melanocephalus.*

As previously mentioned, the relative humidity is higher in shelter, for instance under a dense crop or near a hedge. It was observed that the carabids in this group preferred the border area when the vegetation cover was sparse, e. g. in the spring and after a harvest. When the vegetation cover was dense, they avoided the border area. The changes in distribution patterns could probably be explained by alterations in the microclimatic conditions in the field. This means that the effect of the shelterbelt on these carabids varies, being mainly dependent on the relative influence of the hedge and the crop on the microclimate.

Conclusion

As previously mentioned, some authors (Thiele, 1960, 1971; Tischler, 1958) mean that the interaction between carabid populations of shelterbelts and of cultivated fields is of minor proportion, whereas other authors (Pollard, 1968b; Fuchs, 1969) suggest that these interactions are considerable. Pollard (1968b) mentions that shelterbelts play an important role in the life cycle of *Bembidion guttula* F. and *Agonum dorsale* Pont., and Fuchs (1969) demonstrates that there are several interactions between the beetle fauna of shelterbelts and that of fields, especially with regard to seasonal migration.

Seemingly, in the carabid species associated with either the shelterbelt or the field, no interaction, i. e. migration from one area to the other, occurred. This supports the view proposed by Thiele (1960) and Tischler (1958). On the other hand, in the species in which seasonal variation in spatial distribution occurred, for instance, the dominating *Calathus fuscipes* and *Pterostichus melanarius,* the present observation agreed with those of Pollard (1968b) and Fuchs (1969).

The classification of the carabids into four groups (Ia, b, c, and II), according to spatial distribution patterns, might be used generally, although the species composition of the individual groups and the kind of association to the shelterbelt of the individual carabid species (Bonkowska, 1970; Gorny, 1971; Tischler, 1958) may differ, according to the conditions at the site of the investigation.

The increased diversity in the intermediate area compared to the central field, the change in relative abundance of breeding types with distance from the shelterbelt, and the different spatial distribution patterns observed, indicate that the shelterbelt has a significant effect on the carabid fauna. Furthermore, the change in distribution pattern of the species in group II, in early summer and after harvest, indicates that these carabids migrate, dependent on the relative influence of the shelterbelt and the crop on the microclimate.

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Sammendrag

Fordelingen af løbebiller i forhold til et læhegn

Effekten af læhegn på fordelingen af løbebiller i en lucernemark blev undersøgt ved hjælp af fangglas (n = 36) anbragt dels i læhegnet, dels i en linie vinkelret på dette.

Der blev fanget 5962 løbebiller, hvoraf hovedparten var efterårsforplantere. *Calathus fuscipes* udgjorde næsten 43%.

Løbebillerne kunne inddeles i følgende fire grupper m. h. t. fordelingsmønstre i forhold til læhegnet:

I: Arter med konstant fordeling i forhold til læhegnet gennem fangstperioden.
- a) arter tilknyttet læhegnet (bl. a. *Calathus piceus, Trechus quadristriatus, Notiophilus biguttatus* og *Carabus nemoralis*).
- b) arter tilknyttet kanten af læhegnet (bl. a. *Calathus erratus, Amara bifrons, Amara communis* og *Harpalus rufipes*).
- c) arter tilknyttet marken (bl. a. *Amara aenea, Amara ovata* og *Broscus cephalotes*).

II: Arter med varierende fordeling i forhold til læhegnet gennem fangstperioden (*Calathus fuscipes, Pterostichus melanarius, Calathus melanocephalus* og *Nebria brevicollis*).

Den varierende fordeling gennem sæsonen i gruppe II kan forklares, dels ud fra bedre overvintringsforhold for imagines i læhegnet, dels ved migration i forhold til læhegnet.

Læhegnet forøgede diversiteten af løbebiller på en stor del af marken.

På grundlag af de fundne resultater konkluderedes, at læhegnet i den foreliggende situation havde en betydelig effekt på løbebillefaunaen på marken.