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EFFECTS OF NEW AGRICULTURAL MANAGEMENT PRACTICES ON THE STRUCTURE AND DIVERSITY OF GROUND-BEETLE COMMUNITIES (*COLEOPTERA, CARABIDAE*)

E. FOURNIER (*), M. LOREAU (*) and P. HAVET (**)
(*) Laboratoire d'écologie CNRS/UMR 7258. Ecole Normale Supérieure. 46, rue d'Ulm. F-75230 Paris Cedex 05.
(**) Direction de l'évaluation et de la prospective. Office National de la Chasse. 5, rue Saint Thibault. F-78610 Auffargis.

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ABSTRACT

*The structure and diversity of ground-beetle communities (*Coleoptera, Carabidae*), was chosen as an indicator of the impact of two new management practices applied in an intensive agrosystem. These soil-dwelling polyphagous predators are likely to be influenced by both management changes: 1) the simplified soil practice, which preserves the soil structure, may have a positive effect on carabid beetles as well as on their potential prey, and 2) newly planted hedges represent a new and undisturbed habitat for these insects, and may also increase prey availability. The results presented here only concern the effect of the presence of hedges. They show a change in the structure of carabid beetle communities: indices of species richness, concentration of dominance, equitability and logarithmic series alpha index, all indicate a significant decrease in structural diversity as a function of the distance from the hedge. Communities are characterized by a lower number of dominant species when moving away from the hedge. Those trends can be explained by two non-exclusive facts. First, the number of species decreases significantly with distance. Second, the different species do not have the same patterns of total activities and densities, and three groups can be distinguished: species preferring the hedge, species present in it only, finally species whose distribution does not seem to be affected by the presence of a hedge.*

I. INTRODUCTION

The intensification of agriculture has been a general trend in Europe since the end of the second world war, and has led to a degradation of the landscape. The French region of Beauce is a typical example of this phenomenon: here openfield landscapes are characterized by very large plots (mean 25 ha) and a rarity of less pertubated habitats such as hedges, groves, or woods. From the ecological point of view those intensive agro-ecosystems show a high spatial homogeneity, a low species richness, a reduction of genetic diversity and a simplification of food webs, all features that contribute to a decrease in biodiversity (BARBAULT, 1992). Those trends incite local

actors to think about new management solutions consistent with sustainable agriculture developments.

Consequently two new practices have been used since 1995 on a farm situated in Beauce. First, hedges were planted during the winter 1994/1995. Second, ploughing was replaced by a system of superficial soil management ("HORSCH" system), which acts in surface (10 cm depth) and thus preserves the soil structure and the ground-dwelling animals.

In order to follow the impact of those changes on the ecosystem, we chose to study the diversity and the structure of ground-beetle communities (*Coleoptera, Carabidae*) as potential indicators. First, as they live on the soil surface and feed on other ground-living invertebrates, those insects are likely to be influenced by both practices. The hedge represents a new, undisturbed and permanent habitat for the beetles (POLLARD, 1968c; LYS, 1992; LYS, 1994), and may allow a diversification of their potential prey (MOORE *et al.*, 1966; POLLARD, 1968a, b; LEWIS, 1969). Also the use of a simplified soil practice has a direct impact on carabid survival (STASSART and GREGOIRE-WIBO, 1983), and may again be beneficial to their potential prey. Carabid beetles present other interests as well. Being polyphagous predators, they may feed on some agricultural pests: they are therefore likely to be used in biological survey of crops (THIELE, 1977; SUNDERLAND and VICKERMAN, 1980; POLLET and DESENDER, 1985; POLLET and DESENDER, 1986). Moreover they are part of the diet of several game birds (such as grey partridge) (SERRE, 1985).

During the year 1996 we set a sampling program covering a part of the farm concerned by the new practices and the surroundings. The aims were to study the influence of several factors on the diversity and structure of carabid communities, first within the managed area: (1) the effect of the distance from the hedge through the adjacent cultivated plots, (2) the effect of the type of crop; second comparing the managed area and the surroundings: (3) the effect of soil management, and (4) the comparison with closed habitats (forest). The results presented here only concern the first factor.

II. MATERIALS AND METHODS

II.1. SITE OF STUDY AND STRUCTURE OF HEDGES

The farm is situated in Ouarville, near Chartres (100 km south of Paris). Hedges were planted as shown on Figure 1a. They are composed of two elements: (1) rows of shrubs of 6 meters wide ("hedge s.s."), and (2) a mixed crop of fodders (oats and cabbages). This mixed crop has a length of 100 meters and is inserted between 2 lines of shrubs of 200 meters each. Moreover, another type of mixed crop (oats and sorghum) stretches out over 9 meters on each side of this composite line (Figure 1b).

II.2. SAMPLING METHOD AND DESIGN

We used pitfall traps made of plastic bottles in order to collect beetles (GREENSLADE, 1964; BAARS, 1979a; DESENDER and POLLET, 1988). They were filled with a 4% formalin solution with detergent, and emptied every two to four weeks during a period of five months (from the beginning

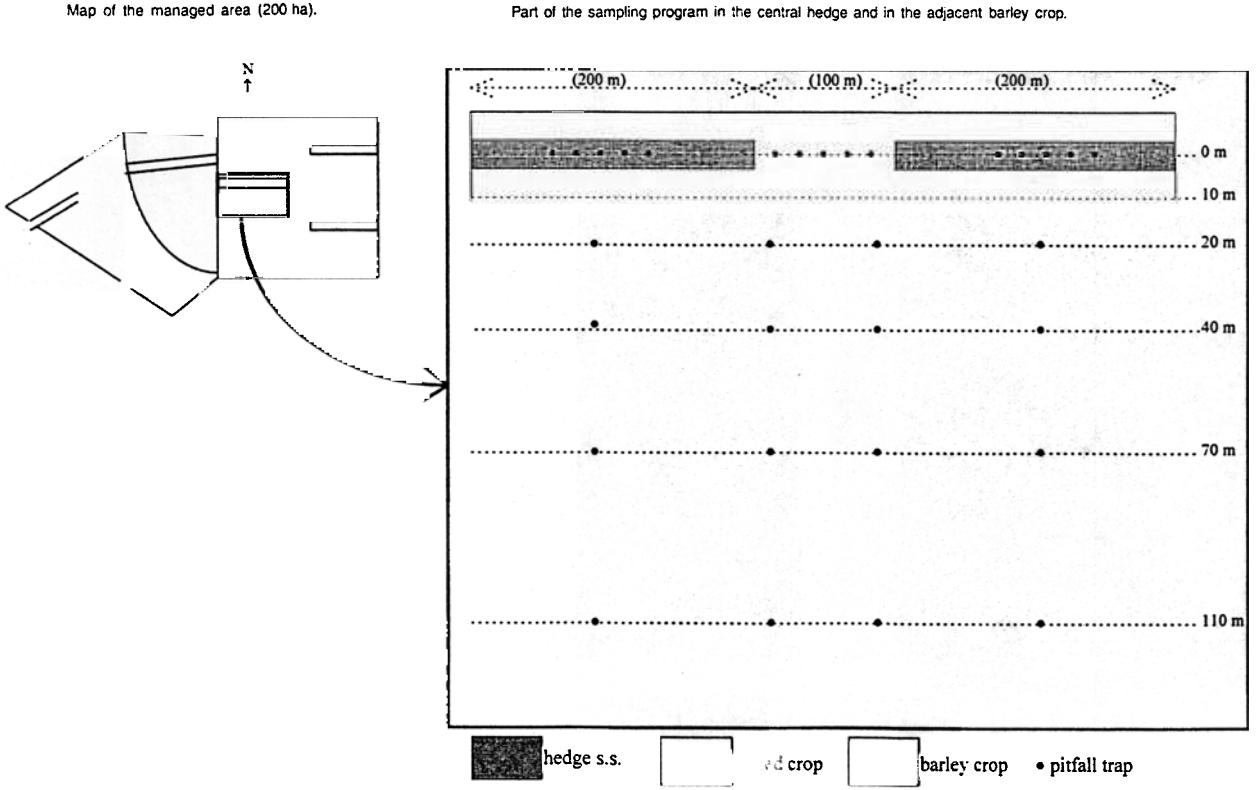


Figure 1: Sampling program corresponding to the present results.

Figure 1 : Plan d'échantillonnage.

of April to mid October 1996, except five weeks in August). They were in-stalled in hedges and at different distances along transects through the adjacent cultivated plot. The results presented here only concern the central hedge ("line 2") and the adjacent transects through spring barley (Figure 1b).

We also estimated absolute densities using fenced pitfalls (DESENDER and MAELFAIT, 1986). The size of each fenced area was one square meter, in which two traps were installed. They were emptied every day during 8 days in June 1996. 12 enclosures were installed in the hedge (8 in the hedge s.s., 4 in the mixed crop) and 3 at 110 meters in the crop.

II.3. DESCRIPTION OF DIVERSITY AND COMMUNITY STRUCTURE

The results of the pitfall trap catches were used to calculate several indices that describe the diversity and structure of the communities (HILL, 1972; SOUTHWOOD, 1978; LOREAU, 1984). For each trap (k) we calculated:

1) number of species censused, or species richness: S_k.

2) total capture of each species i over the whole period: $N_{i,k}$ (with i = 1 to S_k)

It is a measure of the total "activity density" of each species, which is a function of both absolute density and activity. Several authors showed that it gives a good estimation of the ecological importance of each species in a biotope (THIELE, 1977; BAARS, 1979a).

3) species relative abundance:

$$p_{i,k} = \frac{Ni,k}{\sum_i N_{i,k}}$$

Relative abundance is used to describe ecological dominance.

Dominance-diversity curves can be plotted, where the rank of the species (in order of decreasing ecological importance) is on the x-axis, and its ecological importance on a logarithmic y-axis.

4) dominance concentration:

$$C_k = \sum p_{i,k}^2$$

Defined by Simpson (1949), it accounts for the distribution of the relative abundances between the dominant species.

5) equitability:

$$E_k = \frac{S_k -}{\log_{10}(p_{1,k} - p_{s,k})}$$

It is calculated from the equitability indice of Whittaker (1972) and takes more the rare species into account than C_k.

6) indice indicating the type of S/N relationship: α_k, defined by

$$S_k = \alpha_k \times \ln(1 + N_k / \alpha_k) \qquad (\text{with } N_k = \sum_i N_{i,k})$$

This index, derived from the logarithmic series, is well adapted to the type of obtained dominance-diversity curves.

II.4. ESTIMATES OF ABSOLUTE DENSITIES

We recorded the total captures for each species in each fenced area at the end of the 8 days. The mean total capture was taken as an estimate of the absolute density of the species in the site.

III. RESULTS

In the total area (hedge and crop), 34 species were censused. Irrespective of the distance from the hedge, two species were dominant: *Pterostichus melanarius* and *Pterostichus cupreus*. However, two trends were observed.

First, there was a change in the dominance relationship between the two dominant species (Figure 2): for example in the hedge the relative abundances are 33% for both *Pterostichus melanarius* and *Pterostichus cupreus*; at 20 meters, they represent respectively 63% and 17% of the total capture, and at 110 meters, 74% and 13%. This is consistent with the patterns of the total capture as a function of the distance for each species (Figure 3). *Pterostichus melanarius* is one of a group of species for which the total capture did not vary or slightly increased with distance from the hedge ("hedge indifference"). Absolute densities in the hedge and at 110 meters

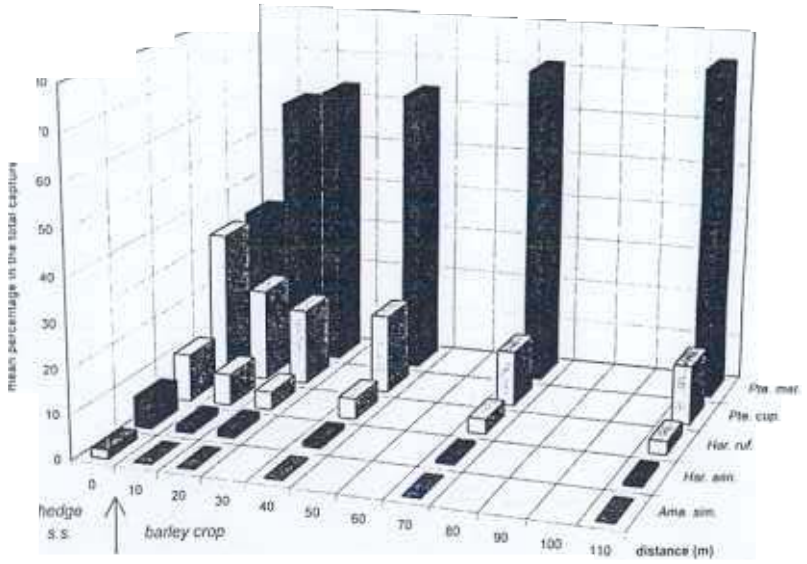
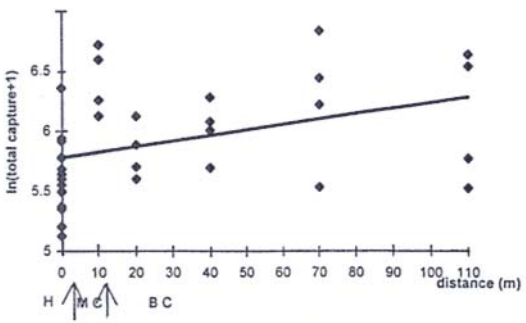
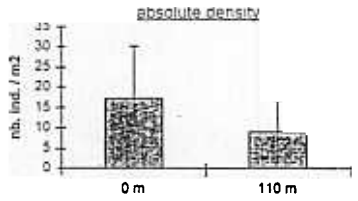


Figure 2: Mean percentage in the total capture for five important species at each distance.

Figure 2 : Pourcentage moyen dans la capture totale pour cinq espèces importantes à chaque distance.
(*Pte. mel. : Pterostichus melanarius; Pte. cup. : Pterostichus cupreus; Har. ruf. : Harpalus rufipes; Har. aen. : Harpalus aeneus; Ama. sim. : Amara similata*).

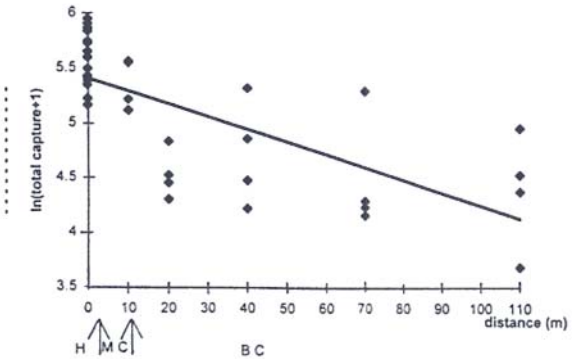
Fig. 3a : *Pterostichus melanarius.*

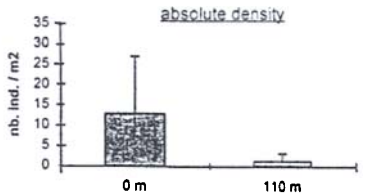




(Kruskal-Wallis test : H/D = 1.025, P>0.05)

Fig. 3b : *Pterostichus cupreus.*





(Kruskal-Wallis test : H/D = 4.797, P > 0.05)

Figure 3: Patterns of total capture and estimations of absolute density for *Pterostichus melanarius* (Fig. 3a) and *Pterostichus cupreus* (Fig. 3b).

Figure 3 : Patterns de captures totales et estimations des densités absolues pour *Pterostichus melanarius* (Fig. 3a) et *Pterostichus cupreus* (Fig. 3b).

n the crop confirmed this trend for *Pterostichus melanarius*, with no significant difference between the two sites (Figure 3a). On the contrary, *Pterostichus cupreus* belongs to another group of species whose total capture decreased significantly with distance ("hedge preference"). Here the difference between the absolute densities at 0 and 110 meters was significant (Figure 3b). The third group consists of species that were strictly confined to the hedge.

The second trend was a significant decrease in the number of species with distance (Figure 4).

The indices of structural diversity (Figure 5) confirmed these trends: while the concentration of dominance increased significantly with distance from the hedge, equitability and alpha-diversity decreased significantly. Thus all indices indicated a decrease of local diversity when moving away from the hedge.

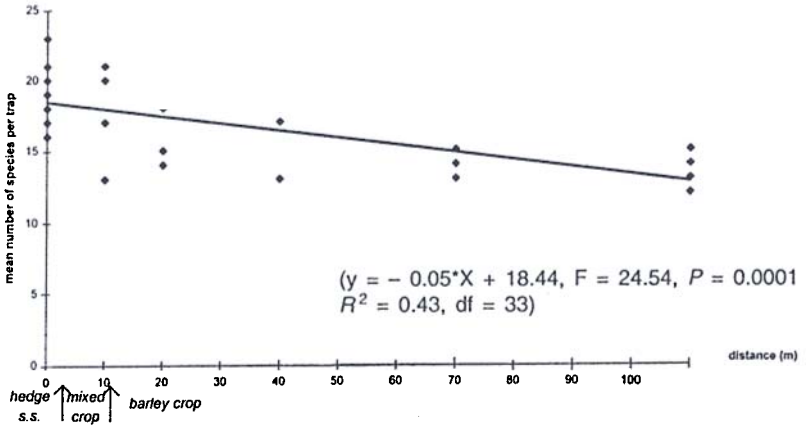


Figure 4: Decrease in the number of species with distance.

Figure 4 : Diminution du nombre d'espèces avec la distance.

IV. DISCUSSION AND CONCLUSION

The 34 species censused in the area (hedge and crop) are species of open habitat or very eurytopic species (JEANNEL, 1941; JEANNEL, 1942; LINDROTH, 1974; LINDROTH, 1992). Indeed the hedges are young (1 year after plantation at the beginning of the study) and are composed of shrubs which are not higher than three meters. Therefore they are very different from a closed habitat like a forest. Moreover they do not form any corridor between the cultivated area and the woods present in the surroundings: there is a weak probability of recolonization by species of closed habitats from those surrounding forest areas (BUREL, 1989; PETIT and BUREL, 1996). On the other hand, hedges have a profound effect on the species that were probably already present within the cultivated area before the plantation: the occupation of space by those species seems to be strongly modified.

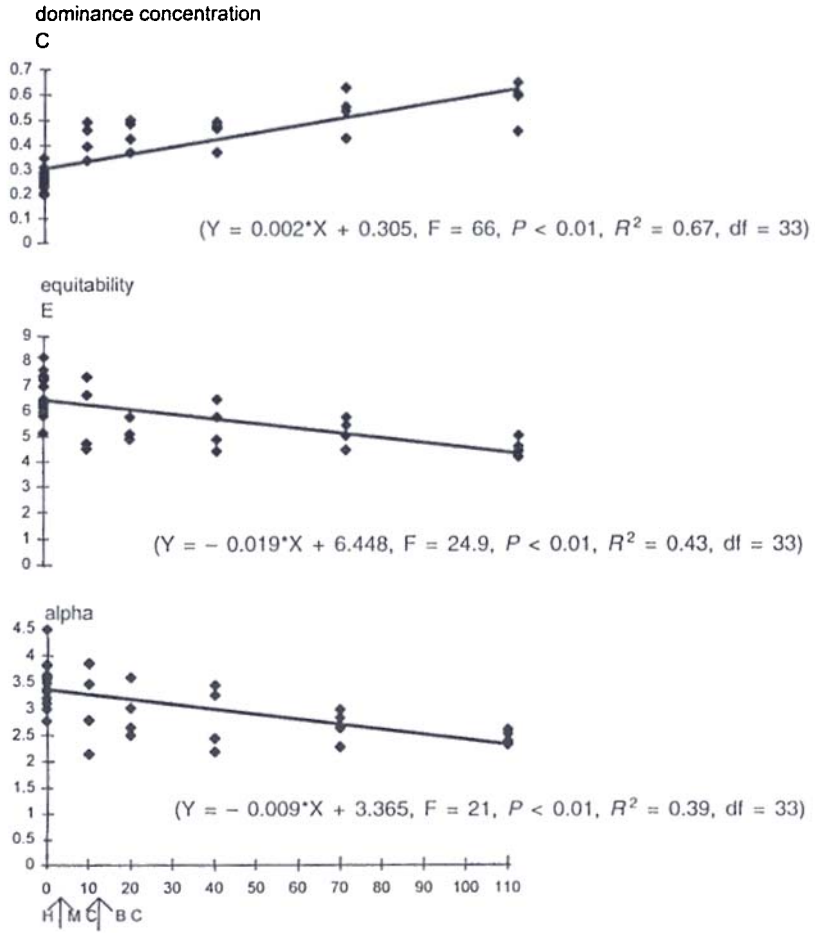


Figure 5: Evolution of C, E and α with distance (H: hedge s.s., MC: mixed crop, BC: barley crop).

Figure 5 : Variation de C, E et α avec la distance (H : haie s.s., MC : culture intercalaire, BC : culture d'orge).

Regarding the indices of diversity, S_k, C_k, E_k and α_k all describe the alpha-diversity of communities, that is to say the local diversity within a community (SOUTHWOOD, 1978). They essentially differ in the manner of taking into account the dominant species (HILL, 1972). S_k, a measure of the species richness within a sample of the community, is strongly affected by the presence of rare species. C_k expresses the repartition of the ecological importances of the dominant species, whereas E_k takes into account the whole community. α_k is part of a group of indices which describe the type of theoretical S/N distribution underlying the dominance-diversity curves. Here these

curves are well fitted to a logarithmic model, correctly described by the α indice.

The variation of all the indices as a function of the distance from the hedge indicate a decrease in the structural diversity of the community: a smaller number of species dominate the community more and more when moving away from the hedge. In fact *Pterostichus melanarius* is the only species which is captured in great quantities even far from the hedge.

One hypothesis that could explain the changes in community structure is a difference in the use of food resources between species and between habitats. We assumed that the hedge generates a difference in the distribution and availability of potential prey of carabids. In order to examine this hypothesis, samplings of available prey were carried out in 1996 and 1997 following three different methods: examination of the other invertebrates captured in pitfall traps (1996 only), sampling of soil fauna by watering a soil quadrat with a formalin solution (1996 and 1997), and extraction of soil-fauna using Berlese funnels. Those data have not been analysed yet. An experiment was also performed in June and July 1997, based on a manipulation of beetle satiation in the different types of habitats (hedge, inserted culture, and crop at 20 and 110 meters from the center of the hedge) (BAARS, 1979b; DEN BOER, 1986).

Those investigations should allow us to understand how those types of field margin strips act on invertebrate communities within cultivated areas.

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EFFETS DE NOUVELLES PRATIQUES AGRICOLES SUR LA STRUCTURE ET LA DIVERSITÉ DE COMMUNAUTÉS DE CARABIDÉS *(COLEOPTERA, CARABIDAE)*

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MOTS-CLÉS : *Carabidae*, diversité structurelle des communautés, nouvelles pratiques agricoles, haies basses-tiges, Beauce, France.

RÉSUMÉ

La structure et la diversité des communautés de carabidés (Coleoptera, Carabidae) *ont été choisies comme un indicateur de l'impact de deux nouvelles pratiques agricoles utilisées dans un agrosystème céréalier intensif. Les coléoptères carabiques sont des prédateurs polyphages qui vivent à la surface du sol; ils sont susceptibles d'être influencés par les deux types de changement : 1) l'utilisation d'une technique simplifiée de travail du sol, qui préserve la structure du sol, peut avoir un effet positif sur les carabidés eux-mêmes ainsi que sur leurs proies potentielles; 2) des haies nouvellement plantées représentent un habitat non perturbé pour ces insectes, et peuvent également augmenter la disponibilité en proies.*

Les résultats présentés ici concernent les effets de la présence de la haie. Ils montrent une modification de la structure des communautés de carabidés : les indices de richesse spécifique, concentration de dominance, équitabilité et indice alpha des séries logarithmiques, indiquent tous une décroissance significative de la diversité structurale en fonction de la distance par rapport à la haie. Au fur et à mesure que l'on s'éloigne de la haie, les communautés sont caractérisées par un nombre plus faible d'espèces dominantes.

Ces tendances peuvent être expliquées par deux faits non exclusifs. Premièrement, le nombre d'espèces diminue significativement avec la distance. Deuxièmement les différentes espèces n'ont pas la même distribution spatiale d'activités et de densités, et on peut distinguer trois groupes : des espèces qu'on trouve exclusivement dans la haie, des espèces qui préfèrent la haie, et finalement des espèces qui semblent indifférentes à la présence de la haie.