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Spatio-temporal variability of fruit feeding insects used as ecological indicators in West Africa

Photograph 1.
Cattle crossing a maize field typical of the study area.
Photograph J. Bouyer.

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RÉSUMÉ

VARIABILITÉ SPATIO-TEMPORELLE DES INSECTES MANGEURS DE FRUITS UTILISÉS COMME BIOINDICATEURS EN AFRIQUE DE L'OUEST

Les insectes mangeurs de fruits se sont récemment avérés de très bons bioindicateurs de santé des écosystèmes savanicoles d'Afrique de l'Ouest. Au Burkina Faso, la fragmentation grandissante des paysages dans diverses régions rend le développement de ce genre d'outils de suivi particulièrement utile. Cette étude a été réalisée pour mesurer la variabilité spatio-temporelle des densités apparentes d'insectes, de la famille des Nymphalidae et des Cetoniinae, attirés par des pièges appâtés de bananes fermentées, afin de fournir aux gestionnaires des zones protégées des recommandations quant à leur utilisation comme bioindicateurs. Deux paysages (une zone de pâture et une zone de culture) ont ainsi été échantillonnés plusieurs fois pendant différentes périodes de la saison des pluies et pendant deux années, et ce sur une durée variable (5 à 10 jours). L'étude s'est déroulée à Koro, au Sud-Ouest du Burkina Faso. L'impact de ces facteurs de variation sur la comparaison des deux types de pression anthropique a ainsi été analysé. L'étude a confirmé l'utilité de ces bioindicateurs et un impact plus important des cultures sur l'écosystème. Les résultats sont discutés et des recommandations présentées pour l'utilisation de ces insectes comme bioindicateurs, dans le cadre de la gestion des terroirs.

Mots-clés : Nymphalidae, Cetoniinae, anthropisation, fragmentation des paysages, indicateur écologique, suivi environnemental.

ABSTRACT

SPATIO-TEMPORAL VARIABILITY OF FRUIT FEEDING INSECTS USED AS ECOLOGICAL INDICATORS IN WEST AFRICA

Fruit-feeding insects have recently been demonstrated to be very useful as ecological indicators of ecosystem health in the West-African region. In Burkina Faso, located in the West-African savannah area, an increasing fragmentation of the land in several regions urges the need of an evaluation and monitoring tool for savannah ecosystem health. The present study was designed to assess the spatio-temporal variability of the apparent densities of Nymphalidae and Cetoniinae species attracted to banana traps, in order to provide recommendations for managers as to how to use them as ecological indicators. Two landscape types only (a grazing and a cropping area) were thus sampled repeatedly during two years, at two periods of the rainy season and for a variable duration (from 5 to 10 days) in Koro, a village located in south-western Burkina Faso. The impact of these factors of variability on the discrimination of these two types of anthropogenic pressures was then assessed. The study confirmed the usefulness of these groups as ecological indicators and a higher impact of cropping than grazing on ecosystem health. The results are discussed and guidelines are provided for the use of fruit-feeding insects in the framework of landscape management.

Keywords: Nymphalidae, Cetoniinae, anthropization, ecological indicators, landscape fragmentation, environmental monitoring.

RESUMEN

VARIABILIDAD ESPACIO-TEMPORAL DE LOS INSECTOS FRUGÍVOROS UTILIZADOS COMO BIOINDICADORES EN ÁFRICA OCCIDENTAL

Los insectos frugívoros han demostrado recientemente que son excelentes bioindicadores de la salud de los ecosistemas de sabanas de África Occidental. En Burkina Faso, la creciente fragmentación de los paisajes en diversas regiones hace que el desarrollo de este tipo de herramientas de seguimiento sea especialmente útil. Este estudio se realizó para medir la variabilidad espacio-temporal de las densidades aparentes de insectos de las familias de Nymphalidae y Cetoniinae, atraídos por trampas cebadas con bananos fermentados, para proporcionar recomendaciones a los gestores de áreas protegidas respecto a su utilización como bioindicadores. Así pues, durante dos años se muestrearon dos paisajes (un área de pastos y una de cultivo) en varias ocasiones y en distintos períodos de la temporada de lluvias, y con una duración variable (5 a 10 días). El estudio se llevó a cabo en Koro, en el suroeste de Burkina Faso. Seguidamente, se evaluó el impacto de estos factores de variación en la comparación de los dos tipos de presión antrópica. El estudio confirma la utilidad de estos bioindicadores y el mayor impacto de los cultivos sobre el ecosistema. Se discuten los resultados y se proporcionan recomendaciones para el uso de estos insectos como bioindicadores en el marco de la ordenación del territorio.

Palabras clave: Nymphalidae, Cetoniinae, antropización, fragmentación de paisajes, indicador ecológico, seguimiento ambiental.

Introduction

Like in most Sub-Saharan West-Africa, the clearing and deforestation between 1950 and 1990 have changed the land in several regions of Burkina Faso (figure 1), which has undoubtedly affected the biodiversity of wild fauna and ecosystem health (GODET *et al.*, 1997). In the Mouhoun river basin for example, the fragmentation of riverine forests has lead to a very heterogeneous distribution of insects like tsetse (GUERRINI *et al.*, 2008) and a reduction of gene flow between the remaining populations (BOUYER *et al.*, 2009; BOUYER *et al.*, 2007b). Given the current issues on sustainable management of natural resources, an evaluating and monitoring tool for the health of savannah ecosystems is essential. One way to monitor ecosystem health is the use of ecological indicators (HILTY, MERENLENDER, 2000). Terrestrial arthropods are increasingly recommended to evaluate environmental changes (KREMEN, 1992). Biological indicators are used to assess the environment state, to anticipate future changes and to diagnose environmental problems (DALE, BEYELER, 2001). The criteria for taxonomic group selection, their properties and limitations have been established as follows (DALE, BEYELER, 2001; HILTY, MERENLENDER, 2000; NOSS, 1999): to be easily measurable (practical, inexpensive), to respond early to a stress of the ecosystem (natural or anthropogenic degradation) in a significant, known and predictable way.

The clearing and degradation of natural vegetation by human beings cause changes in plant biodiversity, which itself lead to changes in wildlife composition, especially insects. Thus, some species, initially rare in natural environments become common due to disturbance and vice versa (BOUYER *et al.*, 2007b; TARRIER, BENZYANE, 2003).

The survival of fruit-feeding insects depends both on the existence and abundance of their host plants and on the land management system. For example, the presence of feeding plants is not the only determinant factor for the presence of specific species of charaxes (*Nymphalidae*: *Charaxinae*), (MONFORT, 1992). Other factors must be considered that determine their presence or abundance. These include the habitat fragmentation, the disturbance associated with human activities and landscape composition. For example, a diversified agricultural landscape with a mosaic structure will harbour higher biomass of epigeal insects than that found in agricultural landscapes with uniform monoculture (DAJOZ, 2000). Previous studies have shown the impact of land management systems on the density and diversity of fruit feeding insects (FERMON *et al.*, 2000).

In the W regional park, a trans-boundary protected area shared by Burkina Faso, Niger and Benin and located in south-eastern Burkina Faso, fruit feeding insects of two major groups i.e. beetles and butterflies (*Scarabeidae: Cetoniinae* and *Nymphalidae* respectively) were used to study the impact of various management strategies (none, hunting, traditional and intensive crops, grazing) of the peripheral areas on ecosystem health (BOUYER *et al.*, 2007b). Insects whose imagoes (adults) are fruit feeders (*Cetoniinae* and *Nymphalidae*) have the great advantage of being easily trapped using cheap traps lured with bananas, in addition to many other interesting properties that make them good candidates as ecological indicators (BOUYER *et al.*, 2007b; DALE, BEYELER, 2001; HILTY, MERENLENDER, 2000; NOSS, 1999). Indeed, the study conducted in the W regional park showed that each of these fruit feeding groups have a score of 19 out of 24 (BOUYER *et al.*, 2007b) according to the Brown's criteria (BROWN, 1991). Both groups used simultaneously have a score of 23 out of 24, which makes them excellent ecological indicators (BOUYER *et al.*, 2007b). These criteria are: taxonomically and ecologically highly diversified; species with high ecological fidelity, relatively sedentary; species nar-

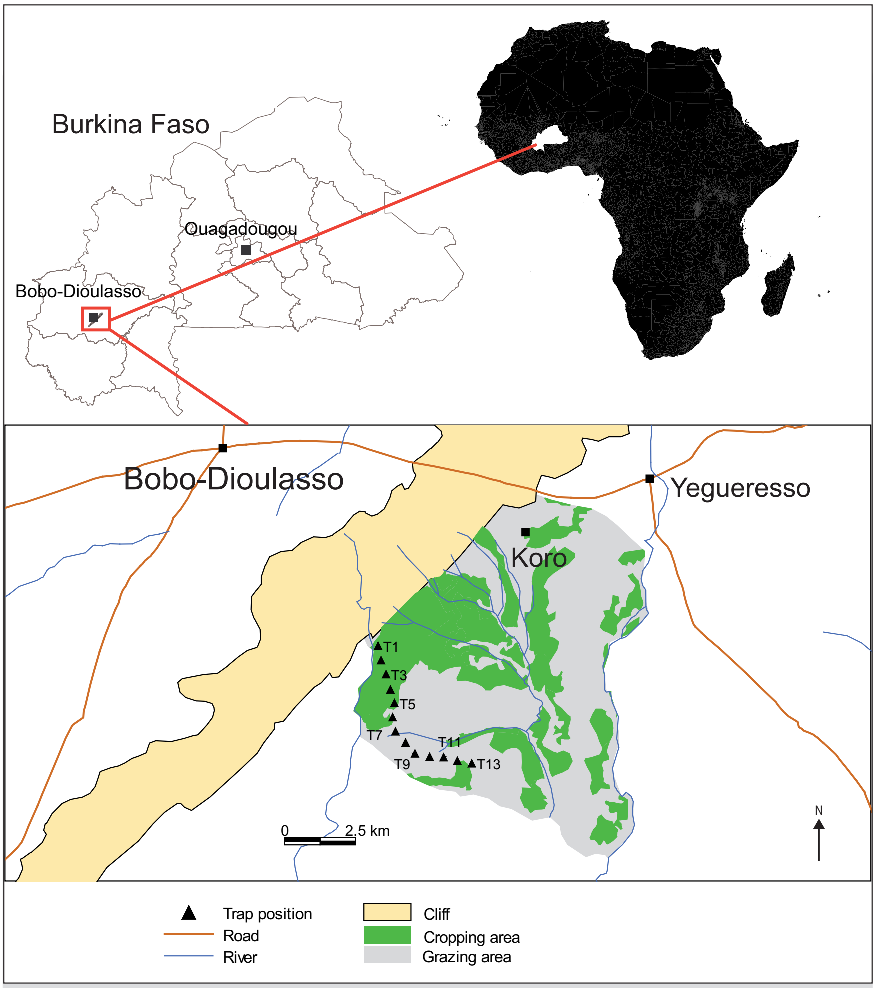

Figure 1.
Location and composition of the research site
(source of the landscape classification: BDOT/2002).

Photograph 2.
Farmers in a cotton field typical of the study area.
Photograph J. Bouyer.

Photograph 3.
Maize harvest in a field close to Koro.
Photograph J. Bouyer.

Photograph 4.
Pastoral area located at the bottom of the cliff.
Photograph J. Bouyer.

Photograph 5.
Cattle grazing in the study area.
Photograph J. Bouyer.

rowly endemic, or if widespread, well differentiated; taxonomically well known, easy to identify; well studied; abundant, non-furtive, easy to find in the field; damped fluctuations (always present); easy to obtain large random samples of species and variation; functionally important in ecosystem; response to disturbance predictable, rapid, sensitive, analyzable and linear; associates closely with and indicates other species and specific resources.

The previous study was however limited in time (one single survey of 10 days) and the spatio-temporal variability of the apparent densities was not assessed, whereas it proved to be important to take into consideration in other settings (Spitzer *et al.*, 1993). In the present study, we thus analyzed the spatial and temporal variability of the same fruit feeding insects in an independent site of the same ecological area, to better assess their reliability as ecological indicators of ecosystem health, and to define the best sampling protocol (including sampling period and duration).

Materials and methodology

Study site

The study area is located in the Sudano-Guinean area of western Burkina Faso – latitude 11.10°N, longitude 4.24°W, altitude between 400 and 500 meters (m) – with 900 millimeters (mm) of annual rainfalls. The study site is around the settlement of Koro. It is located about 20 kilometers (km) east to Bobo-Dioulasso, the second largest city of Burkina Faso. Koro's territory covers 6.000 hectares with 2.083 inhabitants who mostly belong to the *Bobo* ethnic group, followed by the *Fulani* and the *Dioula*. The village of Koro is bordered in the North-West by the cliff of Banfora and extends on a plain with a slight slope to the South-East.

The territory of Koro is divided in three sectors: Koro I in the North, where it was founded; Koro II in the West and Koro III in the South and South-East. The net agricultural influence covers 47 % of the soil surface (figure 1). The cropping areas are spread over the piedmont of the cliff and along the rivers, wetter and probably richer in nutrients drained by rainwater. Sandy soils predominate in Koro I and Koro II whereas gravelled soils predominate in Koro III. This soil distribution explains why agriculture is more developed in Koro I and Koro II whereas livestock breeding is predominant in Koro III, with the presence of *Fulani* camps.

The territory of Koro represents four landscapes, which differ from each other by the degree of agricultural influence. In the North, within the areas of Koro I and II, the influence of agriculture is very important. Fallow farmlands are rare, and cotton maize and sorghum are continuously cultivated. It is a savannah park landscape with *Faidherbia albida* (Del.) A. Chev., *Vitellaria paradoxa* Gaertn. F. and *Parkia biglobosa* (Jacq.) Benth. as predominant tree species. The best soils of the village for cropping activities are located there. In the South of the land (Koro II and III), the landscape harbours a fairly wooded vegetation including clearings. Unexploited areas correspond to unfertile soils. In the East and South-West, uncultivated areas are covered with woodlands, which are managed by grazing. In the West, at the foot of the cliff, two permanent springs are found, where crops and fruit trees are raised. The unused parts are occupied by strips of gallery forest, of which survival depends on the boulders that cover the soil.

Ecological surveys

A 7 km long transect was achieved from the top of the cliff, intercepting two different landscapes: the cropping area (photographs 1 to 3) and the grazing area (photographs 4 and 5) of the plain of Koro (figure 1). The landscape classification presented in figure 1 was achieved in 2002 by a Burkinabe national program (BDOT/2002). The cropping area has increased moderately since this time and was updated following field censuses. Along this transect, entomological traps were set every 500 m approximately, in 13 sites where one tree was randomly selected to hang them. Each trapping point was georeferenced using a Global Positioning System (GPS).

Photograph 6.
Charaxes trap used in this study containing some butterflies: entering easily, the butterflies are attracted to the top by positive phototactism after licking the fermented bananas, and cannot escape.
Photograph J. Bouyer.

In each point, a charaxes and a beetle trap were both set on trees at a height of 4 to 6 m above the ground (Bouyer *et al*., 2007b). The trap used for *Cetoniinae* was a plastic water bottle of 1.5 liters, into which two windows of about 8 x 5 centimeters (cm) were made in the upper part. The trap used for *Nymphalidae* was constituted by a cylindrical net (60 cm high and 30 cm of diameter) placed 3 cm over a square plank (35 cm sides) (photographs 6). It is a classical trap often used in fruit-feeding butterflies surveys (Fermon *et al*., 2000). In both trapping methods, the bait was decomposed bananas mixed with sugar and exposed to the sun in a closed container for four days before being used. Insects, attracted by decomposed fruits, could enter the trap but rarely exit.

Three entomological inventories were carried out during 5 to 10 successive days each in Koro (koro1, koro2 and koro3). The first one (koro1) was done at the beginning of the rainy season during the month of July of year 2006 and lasted 5 days. A second inventory (koro2) was achieved during the month of October of the same year and lasted 10 days. The third inventory (koro3) was done during the month of October of year 2007 and lasted six days. Traps were emptied between 12.00 p.m. and 2.00 p.m., alternatively in one direction and then the other (from 1 to 13 and then 13 to 1) every second day. Insects were recorded by species and by trap (apparent density per trap and per day or ADT) and released after diagnosis. Only few doubtful insects were stored for subsequent identification by taxonomists. The taxonomy of these groups is well documented and their identification is mainly straightforward (Larsen, 2005; Sakay, Nagai, 1998). Among the inventoried species, the apparent densities of species were merged by mimetic complex (morphospecies difficult to differentiate by non specialists), as described before (Bouyer *et al.*, 2007b), to facilitate their use as ecological indicators. Daily densities in a trap were thus considered as successive measurements of the apparent density of the trapping site.

In each trapping site, a phyto-sociological census was also carried out to assess the type of vegetation and its disturbance level. At each point, the flora species present were listed within a radius of about 20 m.

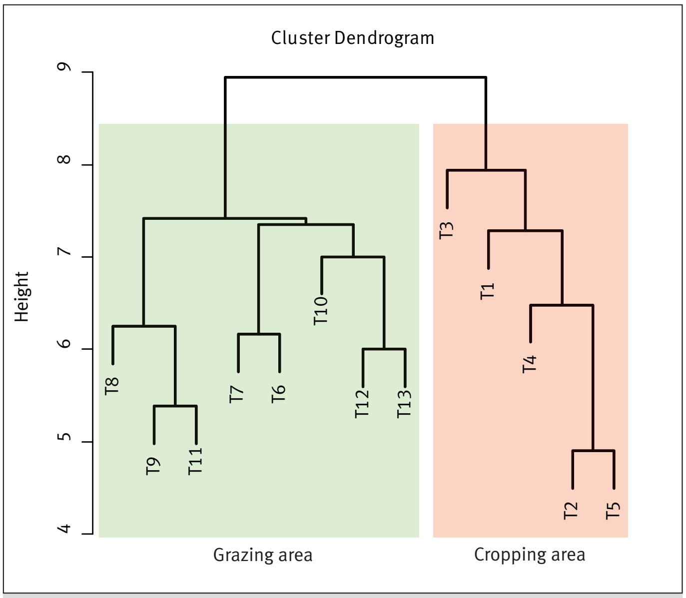

Figure 2.
Cluster dendrogram of the trapping sites, implemented from the Euclidian distances between sites obtained from the presence / absence of 172 plant species.

Data analysis

All the analyses were achieved using the R software, version 2.10.0 (R Development Core Team, 2010).

A Factorial Correspondence Analysis (FAC) was applied to the floristic data coded in presence/absence, to explore the species composition of the trapping sites. A hierarchical classification was then applied to the floristic data (Euclidian distances) to check the homogeneity between trapping sites, and to identify the clusters (cropping and grazing landscapes) to be compared using entomological data.

The apparent density per trap and per day (ADT) is the mean number of individuals of a given species captured in a trap during one day. Only the *Nymphalidae* and *Cetoniinae* species with ADT ≥ 1 in at least one trapping site were kept for further analysis of their densities (Bouyer *et al.*, 2007b).

A mixed-effects linear model was used to fit the ADTs of the five selected species (Laird, Ware (1982). The landscape (cropping and grazing area), year (2006 and 2007), season (early and late rainy season) and trapping day (from 1 to 10) were the fixed effects. A random effect was added, with the trapping site as the grouping factor, to take pseudoreplication into account. The quality of the models was controlled by plotting the residuals against the fitted values.

In addition, a Principal Component Analysis (PCA) was applied to the mean apparent densities of the ecological indicators in the trapping sites measured during the second inventory (late rainy season 2006) to explore their relationship with the floristic clusters, which were projected on the first plan of this PCA.

The spatial autocorrelation between ADT was investigated using Morand I test, applied on neighbourhood matrices, generated with 1 Km distance ranges, from 0 to 3 km, as described in details elsewhere (Bouyer *et al.*, 2006).

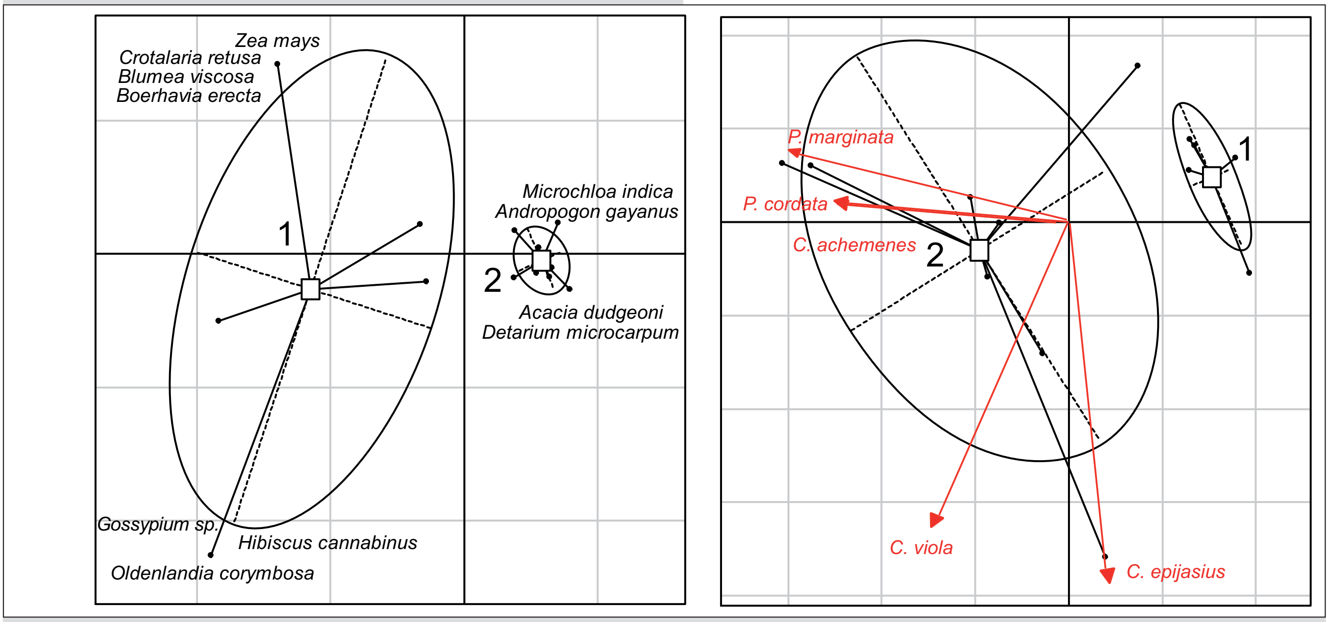

Figure 3.
Projection of the clusters (1: cropping area, 2: grazing area) as obtained from hierarchical analysis applied on the floristic data on the first plans of the factorial correspondence analysis applied to the same data (left) and of the principal component analysis applied to the mean apparent densities of the ecological indicators (right).

Results

Floristic inventories and typology of the trapping sites of Koro

Five out of the 13 trapping sites were located in the cropping area and 8 in the grazing area. They were fully discriminated by the hierarchical cluster analysis (figure 2).

A total number of 172 plant species were recorded, from which 58 were observed in the cropping area only, 70 in the grazing area only and 44 in both areas. All the species and surveys were taken into account in the factorial correspondence analysis. The first axis of the FAC separated the cropping from the grazing areas (figure 3). The second axis discriminated various plant species favored by cotton crops, like *Oldenlandia corymbosa* L. and *Hibiscus cannabinus* L., from those favored by cereal crops, like *Blumea viscosa* (Mill.) Badillo, *Boerhavia erecta* L. and *Crotalaria retusa* L.. The dissimilarities between sites were higher in the cropping than in the grazing area (figures 1 and 2). Since these two cropping systems are generally operated in rotation, there is however no particular reason to consider their ecological impact separately. The records corresponding to the pastoral area were characterized by plant species like *Acacia dudgeoni* Craib ex Holl., *Detarium microcarpum* Guill. & Perr. and *Microchloa indica* Beauv., the two letters being characteristic of unfertile soils. The persistence of grasses like *Andropogon chinensis* (Nees) Merr. and *Andropogon gayanus* Kunth in some sites but not in the others revealed an heterogeneous grazing pressure.

Regarding flora, the grazing area represents an intermediate degradation between the natural formations and the cropping areas.

Photograph 7.
Adult *Charaxes epijasius* resting on a trunk (side).
Photograph J. Bouyer.

Photograph 8.
Adult *Charaxes epijasius* resting on a trunk (front side).
Photograph J. Bouyer.

Photograph 9.
Adult *Charaxes aechemenes* resting on a trunk (front side).
Photograph J. Bouyer.

Photograph 10.
Charaxes varanes feeding on a fermentating exsudate bleeding from a plant wound.
Photograph J. Bouyer.

Photograph 11.
Diplognatha gagates feeding on a fermentating exsudate bleeding from a grass.
Photograph J. Bouyer.

Photograph 14.
Charadronota quadrisignata feeding on a fermentating exsudate bleeding from a grass.
Photograph J. Bouyer.

Photograph 12.
Chondrorrhina abbreviata feeding on a fermentating exsudate bleeding from a grass.
Photograph J. Bouyer.

Photograph 13.
Adult *Pachnoda marginata*.
Photograph J. Bouyer.

Insect species richness

Five savannahs *Nymphalidae* species (photographs 7 to 10) were observed (*Charaxes epijasius* Reiche, *Charaxes achaemenes* van Someren, *Charaxes varanes* Mabille, *Charaxes viola viola* Butler and *Hamanumida daedalus* Fabricius) and only one forest species (*Bicyclus pavonis* Butler), which can also survive in dense savannah. Twelve species of *Cetoniinae* (photographs 11 to 14) were surveyed, including 11 savannah (*Pachnoda marginata* (Drury), *Pachnoda vuilleti* Bourgouin, *Pachnoda concolor* Schürhoff, *Pachnoda cordata* (Drury), *Rhabdotis sobrina* (Gory & Percheron), *Chondrorrhina abbreviata* (Fabricius), *Diplognatha gagates* (Forester), *Polybaphes sanguineolenta* (Olivier), *Polybaphes aequinoctalis* (Olivier), *Charadronota quadrisignata* (Gory & Percheron) and *Oxythyrea guttifera* Afzelius) and 1 forest species (*Chlorocala africana* (Drury)). Among the *Nymphalidae* species, 3 species harboured ADT ≥ 1 in at least one trapping site and were selected for further analysis (*C. epijasius*, *C. viola*, *C. achaemenes*) (Larsen, 2005). Among the *Cetoniinae* species, 2 only harboured ADT ≥ 1 in at least one trapping site (complex *P. marginata* and complex *P. cordata*).

Insect apparent densities according to landscapes

As expected from former results, the apparent densities of the 5 species selected as ecological indicators were generally higher in the grazing than in the cropping sites (figure 3), confirming that this second anthropic pressure has a higher impact on ecosystem health. Interestingly, the sites were however more variable within the grazing area than within the cropping one, in opposition to what was observed with the composition of plant species. This might be due to variable grazing pressures, but also to the border effects in traps bordering the cropping area: this is presented in figure 4, where a lower density is observed for *C. viola* in trap 6 and *P. marginata* complexe in traps 6, 12

Table I.
Fixed effects of the mixed-effects linear models and their significance for each insect species.

Insect species	*C. epijasius*		*C. viola*		*C. achemenes*		*P. cordata*		*P. marginata*	
Fixed effects	value	p-value	value	p-value	value	p-value	value	p-value	value	p-value
Intercept	-1105	*	211	NS	204	NS	1889	*	138	NS
Grazing area	0.481	NS	1.564	**	0.297	*	1.638	*	-0.07	*
Year 2007	0.551	**	-0.106	NS	-0.102	NS	-0.943	*	1.723	NS
Late rainy season	0.130	NS	2.010	***	0.153	NS	2.587	***	0.251	***
Trapping duration	0.033	NS	-0.045	NS	-0.050	**	0.507	***	0.507	***

and 13 than in the other trap positions of the same landscape, and a higher density for *C. viola* in trap 12 and 13. Morevover, the spatial autocorrelation was significant up to 2 km ($p < 0.05$) for all species except *C. epijasius*, which tend to reduce the observed differences between landscapes around their borders.

Table I presents the fixed effects of the mixed-effects linear models and theirs significance for the apparent density of each insect species. The type of landscape (cropping vs grazing) was a significant fixed effect for all species except *C. epijasius*, confirming the usefulness of these insect groups to characterize anthropic pressures on savannah ecosystems.

Temporal variability of insect densities

Some temporal effects were however also significant (table I) and should thus be taken into consideration when comparing various level of anthropic pressures.

First, the trapping duration had a significant impact on the apparent densities of both *cetoniinae* species, and on *C. achemenes*, which is illustrated in figure 5, where the apparent densities of the *P. cordata* cpx are presented for some trapping sites. This was particularly the case after 6 days of trapping.

Second, the impact of the season (late versus early rainy season) was significant for *C. viola* and both *cetoniinae* species, with the densities increasing at the end of the rainy season.

Finally, the densities were significantly higher in 2007 than 2006 for *C. epijasius* and *P. cordata*.

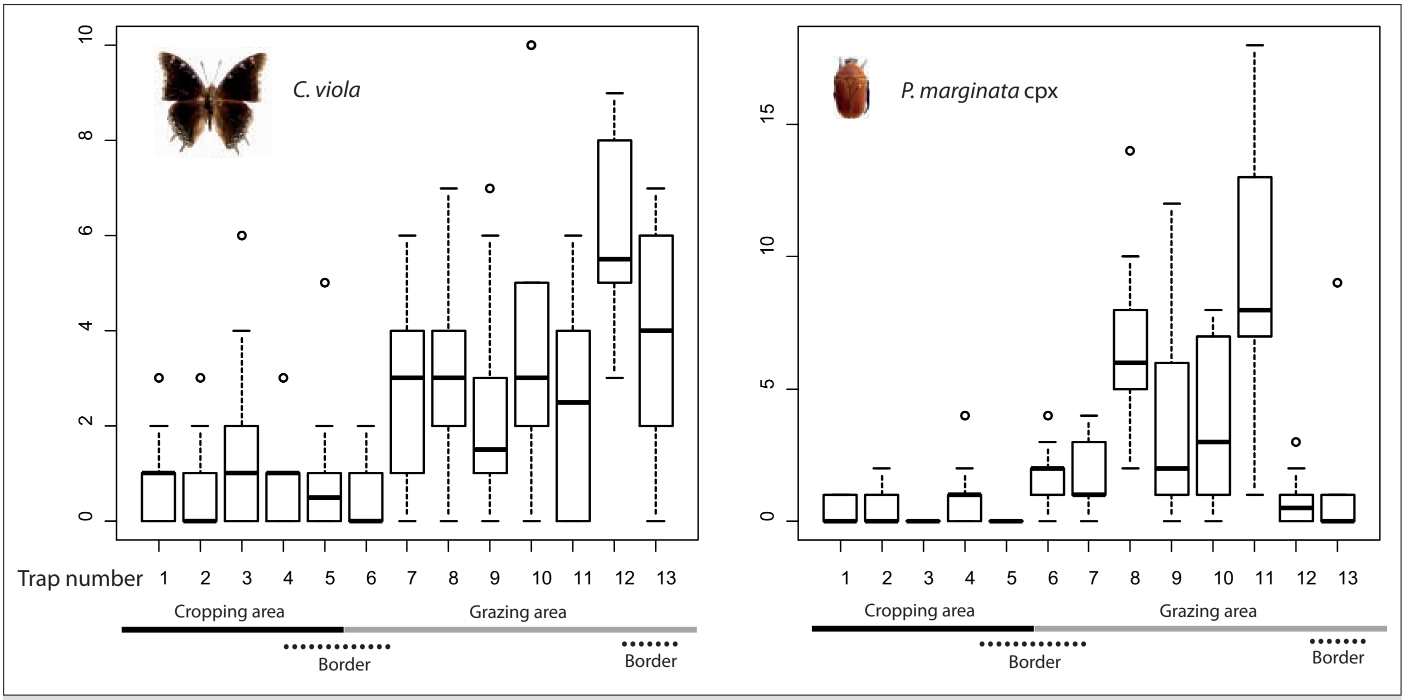

Figure 4.
Boxplots of the apparent densities of *Charaxes viola* (left) and the *Pachnoda marginata* complex along the transect of Koro during the late rainy season 2006. The dotted lines represent the border areas corresponding to traps 6, 12 and 13 (see map in figure 1).

Discussion

Properties of the fruit-feeding insects and recommendations for their use as ecological indicators

The five species used as ecological indicators (*C. epijasius*, *C. viola*, *C. achemenes, P. marginata* and *P. cordata* complexes) are widely distributed and do not display high ecological fidelity (Bouyer *et al*., 2007b). *C. epijasius* and *C. viola* are species of open savannah but are also found in degraded tropical forests (Joly, 2003; Larsen, 2005). *P. marginata* and *P. cordata* complexes are ubiquitous, in most of African countries (Sakay, Nagai, 1998), and favour open vegetation maintained by grazing. All the considered species are however very sensitive to ecosystem disturbance, in one sense or the over. It has been demonstrated in other studies that widespread species may decline just as much as rare species (Leon-Cortes *et al*., 2000). In these ecosystems, all species were disfavored by cropping activities, except *P. marginata*.

In spite of their mobility, which causes significant spatial autocorrelation up to 2 km, their densities grows and drops quickly according to human activity. It is however necessary to take spatial autocorrelation into consideration, especially in the mosaic landscapes like that of Koro, which are more and more observed with the fragmentation of natural vegetation in Burkina Faso. Actually, the ecotones are subject to a "border effect", *id est* an increase or decrease in densities, well-known in other insect species like tsetse in Burkina Faso (Bouyer *et al*., 2006). The transects must thus be long enough to quantify this spatial autocorrelation, and penetrate deep enough into the "pure" landscapes, as far as possible from the borders (at least 2 km in the present study).

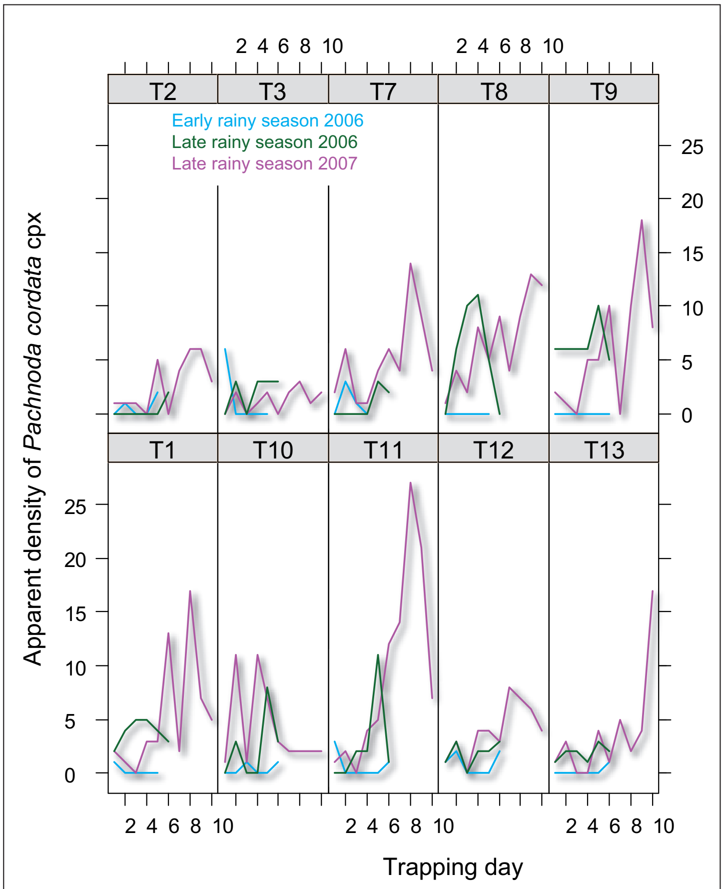

Figure 5.
Evolution of the apparent density of *Pachnoda cordata* complex according to the trapping duration in 10 trapping sites, during the three trapping events.

In contrary to what is observed in forest ecosystems (Faria *et al*., 2009; Ramos, 2000), vertical variation is negligible in savannah, where the tree stratum is low. However, seasonal variations are important to take into consideration: insect densities increase noticeably during the rainy season in comparison to the dry season, and even during the rainy season, which is probably related to the second generation, more abundant that the first one. It is therefore necessary to use a fixed sampling period to compare various landscapes. In this study area, the best period is the end of the rainy season (September-October), when the apparent densities are maximal and allow a better differentiation of anthropic levels. It is thus advisable to use meteorological data in each site to target the best sampling period.

The inter-annual variations were significant for 2 out of the 5 species only, and their importance was limited. Moreover, some variations in the anthropic pressure from one year to the other cannot be excluded (for example an increased or decreased use of insecticides). They should not represent a major drawback for the use of these indicators.

Finally, the trapping duration must be taken into consideration while comparing landscapes. The observed increase catches with trapping time might be related to an evolution of the quality of the bait. Actually, the bananas tend to become drier and probably exhale different compounds when maturating thanks to the fermentation process. A trapping period of maximum 6 days is thus recommended, or the bait should be completely removed and replaced, to avoid this source of noise in the measured densities.

Ecosystem health in Koro

In Koro, the ADT of 3 out of the 5 species selected are higher in the grazing than in the cropping area, which is in line with what was observed in the W park peripheral (Bouyer *et al*., 2007b). In the W park, the highest insect densities were observed in protected area for the *Nymphalidae* and the buffer area with grazing and traditional crops for the *Cetoniinae*. The comparison between Koro and the W park show that grazing leads to an intermediary disturbance of the ecosystems, in comparison to cropping activities, which can favor some species. Similar results were found elsewhere (Dajoz, 2000; Ramos, 2000), where the mosaic landscapes (coffee plantation/forest) generally harbored higher butterflies densities than the continuous coffee plantation landscapes and forests (Horner-Devine *et al*., 2003).

In Koro, the grazing area is scattered with few cropping hamlets and stockbreeder camps and the grazing pressure is not homogeneous, as revealed by plant inventories. This probably explains the observed heterogeneity of the apparent densities of the monitored species between the trapping sites of this landscape. Grazing when moderate favor some insect species while rent cropping using a lot of inputs are always unfavorable. Several studies showed that low disturbance levels have a positive effect on diversity and abundance of insect (Bobo *et al.*, 2006; Brown, 1991; Ramos, 2000; Sparrow *et al.*, 1994; Wood, Gillman, 1998), in accordance with the intermediate disturbance theory (Connell, 1978). In contrast, other studies indicate adverse effects of disturbance on tropical butterfly communities (Brown, 1997; Fermon *et al.*, 2001; Fermon *et al.*, 2000; Hamer, Hill, 2000; Hamer *et al.*, 1997; Hill *et al.*, 1995; Lewis, 2001; Spitzer *et al.*, 1997; Spitzer *et al.*, 1993; Thomas, 1991).

In this study, both plant and insect inventories lead the conclusion that Koro pastoral areas seem less disturbed than the cropping areas, but they are still more than the control natural areas of the W park. The cotton cropping areas of the W Park had similar low densities as Koro for all insect species whereas the grazing area seemed more disturbed in Koro (Bouyer *et al.*, 2007b). In addition, the species richness was considerably lower in Koro than in the W park (despite a longer trapping duration): in Koro, only 6 (67 %) out of the 9 *Nymphalidae* species, and 12 (75 %) out of the 16 *Cetonninae* species recorded in the W park were observed.

The fragmentation of Koro environment is an ongoing process and biodiversity will keep dropping unless protective measures are taken. Additional surveys will be lead in Burkina Faso (ASECC[1] project, in the framework of the RIP-IECSA[2] initiative), along a climatic transect from the North (Djibo) to the South (Folonzo), to investigate the ability of these groups to differentiate the impacts of global climatic changes from local anthropogenic activities and their interactions on ecosystem health.

Conclusively, the analysis of the apparent densities of fruit feeding insects in traps baited with banana allowed discriminating various types of anthropogenic pressures in another area of Burkina Faso than the W regional Park, confirming their usefulness as ecological indicators of ecosystem health for landscape managers in West Africa. However, the significant variations of their densities with seasons and trapping duration make it necessary to adopt a rigorous and homogeneous sampling frame to compare landscapes. Moreover, the transect between landscapes must be long enough to correct for spatial autocorrelation between sampling sites which is related to insect dispersal, to be able to assess border effects properly.

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[1] Adaptation des systèmes d'élevage au changement climatique global en Afrique de l'Ouest (Adaptation of cattle farming systems to global climatic changes in West Africa).

[2] Recherches interdisciplinaires et participatives sur les interactions entre les écosystèmes, le climat et les sociétés d'Afrique (Interdisciplinary and participative research on interactions between ecosystems, climate and African societies).

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