QUALITY STRUCTURE OF THE NOCTUIDAE FAMILY IN SELECTED HABITATS OF THE AGRICULTURAL LANDSCAPE

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Abstract: The aim of the study was to compare the Noctuidae moths in three selected farmland environments, using ecological indices. The study was conducted from 2003 to 2006 on fields sown with winter wheat, sugar beets, maize and winter rape plants. The subject of the study was the imago of moth caught by light traps. Light traps (Polish brand) were located at: the Institute of Plant Protection, the Agricultural Research Station in Winna Góra, the Sugar Beet Breeding Research Station in Więcławice and the Institute of Plant Protection in the Poznań research garden. The collected Noctuidae imagines were identified and characterized quantitatively and qualitatively. The Noctuidae imagines were analyzed using Shannon-Weaverś diversity index (H), Simpsonś dominance index (d) and Marczewski-Steinhaus index of similarity (MS %). The results showed a higher similarity between species composition in the agrocenos of Poznań and Więcławice. The smallest diversity of species, reflected in the lowest value of the diversity index and the high value of the dominance index, was observed in the biotic community of Winna Góra which reveals a few Noctuidae, namely: *Agrotis segetum* (Schiff. et Den.), *A. exclamationis* (L.), *Xestia c-nigrum* (L.), and *Discestra trifolii* (L.).

Key words: cutworms, monitoring, bioindicators, ecological index, light-trap

INTRODUCTION

As many as 150,000 species belong to the Lepidoptera order, of which about 25,000 are owlet moths (Noctuidae). The owlet moths mainly inhabit areas of moderate climate. Approximately 60% of their species live in the northern hemisphere, approximately 25% in the southern hemisphere, while the remaining 15% in the tropics. In Poland, the owlet moth family belongs to the larger taxonomical group of insects and is represented by approximately 500 species of moths (Buszko and Nowacki 2000; Fibiger and Hacker 1991; Napiórkowska-Kowalik 1996).

The majority of owlet moth species known in Poland are characterized by a vast distribution. Due to their environmental value, they can easily accommodate to changes occurring in the environment as a result of human activity (Napiórkowska-Kowalik 1996; Nowacki 1989, 1992; Winiarska 1982). Most owlet moths are eurybionts that inhabit various forest and meadow biotopes as well as open areas. In agrocenoses, they constitute about 50% of all species of moths. The majority of owlet moths are economically important pests of cultivated areas (Razowski and Palik 1969). Approx. 70% of the species are polyphagous, this includes nearly all Noctuinae, Hadeninae, Noctuidae and many other owlet moths. They have a broad trophic spectrum from a few dozen host plants (Napiórkowska Kowalik 1996; Nowacki 2006).

Large population fluctuations, particularly visible in agrocenoses, are an important feature of many of the Noctuidae. The quantity and quality changes which repeat every year in specific seasons, result from differences in the biotic cycles of the species. Those species with the same biotic cycles constitute phenological groups. The largest group was composed of summer species that were active in the imago stage, in July and August. The smallest group included autumn and winter species flying in the autumn, and even in warmer periods of winter, and in spring following the diapauses (Nowacki 1989; Buszko and Nowacki 1991; Honék 1999).

Owlet moths were the objects the present study started in the Wielkopolska and Kujawsko-Pomorskie provinces in 2003. Representatives of this family occupied chosen habitats. The term "group formation" or "communities" used in this article refers to a group of similar kinds co-occurring in a given area. These species accompany or approach from other habitats to get food or to search for a wintering spot (Piekarska-Boniecka 2005).

The aim of research was to compare the Noctuidae structure in farmland and woodland environments, with the aid of ecological indicators.

MATERIALS AND METHODS

During the field trials from 2003–2005, dynamics of the flight of cutworms on sugar beet crop were monitored. Owlet moth which had been caught alive in light-traps were the subject of the research. Light traps (Polish brand)

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located in the Institute of Plant Protection (IPP) research garden (Poznań – 52°23′N, 16°54′E), IPP Agricultural Research Station in Winna Góra (52°12′N, 17°27′E) and the Sugar Beet Breeding Research Station in Więcławice (52°78′N, 18°25′E), were used for catching the moths. The light-traps were set up on the selected experimental plots of sugar beets from May to October. The beets were at growth stage BBCH 12–30. The number of caught moths were systematically recorded three times per week.

The caught insects were identified to species, protected and summarized (Borowiak and Chrzanowski 2007; Nowacki 1992, 1998; Esbjerg 2003). Analysis of the studied moth family was done, and a quality-quantitative structure of Noctuidae "communities" was determined. These structures were compared in the different types of agricultural landscapes.

Based on the number of species and total population of the caught individuals, the following indexes characterizing the Noctuidae community were specified:

– structure of the species domination in the Noctuidae groups, expressed by the so-called relative abundance calculated according to the following formula (Kasprzak and Niedbała 1981):

$$D = \frac{s}{S} 100\ (\%)$$

where:
s – number of individuals belonging to the given species caught within 2 years in one trap on the tested area
S – total number of individuals of all species of the cenotic unit tested
D – structure of the species domination in the Nuctuidae groups

– Shannon-Weaver index (1963) that determines the species diversity. The index value is calculated based on the following formula:

$$H' = \sum_{i=1}^{S} \frac{n_i}{N} \log 2 \frac{n_i}{N}$$

where:
S – number of species in the group (total),
n_i/N – of i-th species in a group composed of S species,
n_i – population of the i-th species in a team with N total number of individuals
H′ – Shannon-Weaver index

– species richness index acc. to the Simpson's formula (1949):

$$d = \frac{S-1}{\log N} \times 100\%$$

where:
d – Simpson richness index
S – number of species in the community
N – total number of individuals caught

– species evenness is a diversity index, a measure of biodiversity which quantifies how equal the community is numerically. The evenness of a community can be represented by Pielou's evenness index (1966):

$$J' = \frac{H'}{H_{max}} = \frac{H'}{\log_2 S}$$

where:
H′ – the number derived from the Shannon diversity index and H′ max is the maximum value of H′
S – the total number of species
J′ – Pielou's evenness index

– Marczewski-Steinhaus index, the simplest of these diversity index comparisons that computes the percentage similarity between two samples (1959):

$$MS = \frac{c}{a + b - c} \times 100\%$$

where:
MS – Marczewski-Steinhaus index
a – the total number of species in sample ≠ 1
b – the number of species in sample ≠ 2
c – the number of species common to both samples

– The Shannon-Weaver diversity index, $\hat{H}'$was estimated using:

$$\hat{H}' = \log 2N - \frac{1_i}{N} \sum_{i=1}^{S} n_i \log_2 n_i$$

where:
S – the number of species,
n_i – the proportion of the total number of entries in the i-th class.
N – number of individuals in the group
$\hat{H}'$ – estymator Shannon-Weaver diversity index

Means and standard errors were then calculated from the no standardized indices, and the variance was approximated by:

$$\mathrm{var}(\hat{H}') = \frac{1_i}{N^2} \left[\sum_{i=1}^{S} n_i \log_2^2 n_i - \frac{1}{N} \left(\sum_{i-1}^{S} n_i \log_2 n_i \right)^2 \right]$$

where:
N – the number of observation (Hutcheson 1970)
n_i – population of the i-th specien in a team within
var (H′) – variance Shannon-Weaver diversity index
S – the number of species

The $\hat{H}'$indices were compared by a t-Student test:

$$t = \frac{\hat{H}'_a - \hat{H}'_b}{\sqrt{\mathrm{var}(\hat{H}'_a) + \mathrm{var}(\hat{H}'_b)}}$$

where:

t – is distributed Student-t with v degrees of freedom of the form (test Hutcheson index) $\mathrm{var}(\hat{H}'_a)$ and $\mathrm{var}(\hat{H}'_b)$ estimator of the variance between the values of H′ for a group a and group b

with degrees of freedom ν:

$$v = \frac{\left[\mathrm{var}(\hat{H}'_a)+\mathrm{var}(\hat{H}'_b)\right]^2}{\frac{\mathrm{var}^2(\hat{H}'_a)}{N_a}+\frac{\mathrm{var}^2(\hat{H}'_b)}{N_b}}$$

where:

N_a and N_b – the numbers of entries in the two groups.

var (H′) – formula for the variance of H′

$\mathrm{var}(H'_a)$, $\mathrm{var}(H'_b)$ – formula for the variances of H′ in the two groups

v – degrees of freedom

The collected cutworm imagines were identified, and quantitatively and qualitatively characterized. The results from the growth chamber studies were analyzed statistically. The Freeman-Tukey test at the level $\alpha = 0.05$ was applied to evaluate the significant differences.

RESULTS AND DISCUSSION

Overview of faunistic and ecological characteristics of Noctuidae

During the four years of the research in three types of agricultural landscapes, over 17.5 of the thousands of specimens of the Noctuidae family were caught by 3 light traps (8,528 specimens in 2003; 3,702 in 2004, in 2,067 in 2005, and 3,398 in 2006). They represented 113 species belonging to 10 subfamilies.

Most species belonged to two subfamilies: Hadeninae (39 species) and Noctuinae (21 species), and they made up about 92% of the total number of caught moths. A large number of populous species of moths typical for this kind of a landscape was detected in the material. In the phenological groups of one-generation species, the majority were spring and summer species that are active in the imago stage in June with moth flights taking place in July and August. They included species from such genera as *Orthosia* spp., *Cuculia umbratica* L., *Apamea monoglypha* Hufn., *Melanchra pisi* L. and the summer species *Cosmia trapezina* L., *Mythimna conigera* Schiff., *Noctua pronuba* L. The multi-generation species had flights which lasted uninterruptedly from May to September, and even to the first decade of October. The majority of these species (*e.g. Agrotis segetum* Schiff., *A. exclamationis* L., *Xestia c-nigrum* L., *Mythimna pallens* L., *Mamestra brassicae* L., *Lacanobia oleracea* L.) are well-known pests of very economically significant crop plants. The two migrating species which were also observed; *Agrotis ipsilon* Hufn. and *Autographa gamma* L., occur but probably do not winter in Poland.

The most populous group in the tested Noctuidae community were the species characteristic of open areas, related trophically to synantropic and meadow plants. The second most populous group was composed of species characteristic of the forest and scrub plant community which feed on trees and bushes. The third of the most populous groups included species characteristic of environments linked directly with agrocenoses of beets, rape and cereal plant fields.

For determining the characteristics of the Noctuidae community, the Shannon-Weaver species diversity index was used. Based on the obtained values, it can be shown that the higher the index, the larger the species diversity of the tested community (Tables 1, 2).

Table 1 shows the resemblance of two kinds of biotic communities as well as determining the number of species appearing simultaneously. The Poznań environment has a large number of species, about 70%, occurring simultaneously, like at Więcławice.

Table 1. Resemblance of Noctuidae species of two biotic communities from the Wielkopolska and Kujawsko-Pomorskie province in 2003–2006

Location	Number of species occurring simultaneously	Semblance of species [MS %]
Poznań Winna Góra	59	56.2%
Poznań Więcławice	78	69.0%
Winna Góra Więcławice	56	52.3%

Table 2. The richness, diversity and species evenness of Noctuidae species of two biotic communities of the Wielkopolska and Kujawsko-Pomorskie province in 2003–2006

Place	Number of specimens	Number of species	Diversity [H′]	Richness [d]	Species evenness [J′]
Poznań	4,209	96	4.655	26.213	0.707
Winna Góra	1,569	68	4.214	20.966	0.692
Więcławice	11,920	95	4.684	23.060	0.713

J′ – Pielou's evenness index; H′ – diversity index Shannon-Weaver; d – richness index – Simpson index

The enclosed table 2 shows that the highest values were recorded on the areas located in Więcławice and Poznań. The conclusion drawn from the above is that the species diversity of the given community depends on the natural environment, and according to literature available, probably also on the humidity of the habitat.

A slightly different approach that complements the conclusions from the diversity index is presented on the basis of the Simpson's richness index. The index of Simpson's richness of the Noctuidae family in examined communities, is included in the range from 0.69 to 0.71. The index is based on the probability theory in which the species abundance is measured by the sum of the probability of occurrence of all species in the tested community. When the occurrence of species is considered in view of this approach, the best species richness is clearly visible in Poznań and Więcławice, while it is the worst on the area tested in Winna Góra (idle field).

Variance of estimator $\hat{H}$ for appointed Noctuidae communities on areas of the Winna Góra, Poznań and Więcławice, is included in borders and was from 1.03 to 1.11. The minimum value was (1.03) for the biotic community of Poznań, in Winna Góra it was (1.10), and the highest value (1.11) was for the biotic community in Więcławice.

Monitoring of the Noctuidae community can be an element of a broader environmental monitoring system, the objective of which is to determine the direction of changes occurring in the tested biocenoses. Despite its significant ecological valency, the Noctuidae community reacts to all anthropogenic and biotic disturbances. According to the available data, it is known that for the last 50 years significant changes have occurred in the Noctuidae community in the center of Warsaw. In the last 20 years, a considerable impoverishment of the species composition was noted. These durable and constant communities were a group of 25–30 species composed of very populous and populous species and several less populous species. The element that changes in time is a group of species in the center of Warsaw which have small populations that occur only occasionally. The group has decreased by at least 70% (Winiarska 2003).

Vanishing of rare species seems to be caused primarily by unfavorable environmental changes occurring as a result of the intense development in that area (densely developed areas, decreased surface of urban green areas, changes in plant species composition, increased pollution levels, and other similar factors) (McGeachie 1989; Leinonen *et al*. 1998; Butler *et al*. 1999).

CONCLUSIONS

Monitoring of the Noctuidae community can disclose changes in the biodiversity, such as the number of species co-occurring in a given area. Changes of various kinds in biocenoses detected at the right time, can significantly influence adequate economic steps aimed at maintaining a balanced ecosystem of either open areas or agrocenoses.

The four-year-long research and observations of the Noctuidae family needs to be treated as a pilot study. The obtained results should be a starting point for further observations about the influence of the structure of species in the Noctuidae communities on the increasing degradation process of the environment.

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POLISH SUMMARY

STRUKTURA JAKOŚCIOWA SÓWKOWATYCH (NOCTUIDAE, LEPIDOPTERA) WYBRANYCH SIEDLISK KRAJOBRAZU ROLNICZEGO

Celem czteroletnich badań było porównanie struktury sówkowatych jako bioindykatorów procesów ekologicznych zachodzących w środowisku pól uprawnych, lasów i ugorów, za pomocą wskaźników ekologicznych. Badania przeprowadzono w latach 2003–2006, w miejscowościach: Winna Góra, Poznań (województwo wielkopolskie) i Więcławice (województwo kujawsko-pomorskie). Przedmiotem badań były odłowione za pomocą pułapek świetlnych motyle sówkowatych. Określono skład ilościowy i jakościowy odłowionych motyli. Do analizy porównawczej materiału zastosowano indeks różnorodności Shannonna-Weavera (H), dominacji Simpsona (d) oraz ocenę wariancji wskaźnika Shannona (varH'). Wyniki badań wykazały większe podobieństwo składu gatunkowego agrocenoz Poznania i Więcławic. Stwierdzono, iż najmniejszą różnorodnością gatunków, potwierdzoną małą wartością indeksu różnorodności oraz dużą wartością indeksu dominacji, charakteryzowała się cenoza Winnej Góry. Wskazuje to na kompensację tylko kilku gatunków sówkowatych, w tym przypadku np. *Agrotis segetum* (Schiff. et Den.), *A. exclamationis* (L.), *Xestia c-nigrum* (L.) i *Discestra trifolii* (L.).