Communities of herpetobional invertebrate agroecosystems at different levels of intensification

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Abstract. Human economic activity, including agriculture, leads to an inevitable decrease in the biodiversity of natural fauna and flora, both in the cultivated areas and in the surrounding natural ecosystems. The degree of these violations depends on a number of factors, including the agrotechnical measures used and the level of chemicalization. The species composition has been researched and the characteristics of the ecological structure of herpetobiont invertebrates in areas with crops of grain crops differing in the level of chemicalization and adjacent virgin areas with natural vegetation are given. It was revealed that the most numerous orders in areas with extensive and intensive cultivation technologies are: Coleoptera (Carabidae), Opiliones (Phalangiidae) and Hymenoptera (Formicidae). It has been established that geographically adjacent agrocenoses, which differ in terms of the level of anthropogenic impact, and their border areas, are similar in their species composition. At the same time, an increase in the level of intensification of the cultivated areas leads to a significant restructuring of the structure of communities of terrestrial invertebrates. The dynamic density of most species in areas with intensive processing technology was lower than in fields with a low background of chemicalization. Also, in areas with intensive technology, a decrease in species richness and a decrease in the relative number of dominant groups were noted. Low values of the diversity index in areas with extensive cultivation technology compared to not cultivated, border areas indicate an uneven distribution of invertebrate groups in these areas.

1. Introduction

In recent years, one of the most urgent tasks of agricultural science is the development of new methods of land use, allowing the production of environmentally friendly products without negative consequences for the environment. One of the important ways to solve the ecological problem can be the improvement of technologies for the cultivation of agricultural crops and the transition to organic farming [1-3]. Human economic activity, including agriculture, leads to an inevitable decrease in the biodiversity of natural fauna and flora, both in the cultivated areas and in the surrounding natural ecosystems [4, 5]. The degree of these
violations depends on a number of factors, including the agricultural measures used and the level of chemicalization [6]. The results of researches carried out in countries with an intensive type of agriculture indicate that the rejection of the application of chemical fertilizers and pesticides leads to an increase in the number and species diversity of many groups of living organisms [3]. The most vulnerable component of agroecosystems is the litter and topsoil, which serve as a habitat for many living organisms, including soil and terrestrial invertebrates (herpetobionts) [7, 8]. It is them, the inhabitants of the ground layer of biogeocenoses, that can be used as indicator organisms of the state of the agroecosystem [7]. This group of invertebrates is widespread in territories with varying degrees of anthropogenic pressure and quickly responds to changes in the local ecological situation [9, 10]. A correct comprehensive analysis of the factors (cultivated culture, intensity of cultivation) that determine the diversity of terrestrial invertebrates living on cultivated areas cultivated using various technologies, taking into account the historical specifics of the formation of agrocenoses in the forest-steppe zone of the Asian part of Russia, has not yet been carried out. 

Our work is aimed at researching the species structure and biodiversity of herpetobiont communities on crops with different intensification levels and adjacent areas of virgin vegetation. The aim of this work was to assess the variability of the biodiversity indicators of terrestrial invertebrates, as the most vulnerable group of organisms inhabiting agrocenoses, depending on the level of intensification of work sites.

According to the results of standardized censuses carried out on crops treated using various technologies and adjacent areas with natural vegetation, the indicators of the dynamic abundance, species richness and diversity of herpetobiontic invertebrates were compared.

2. Materials and methods

The material was collected in the forest-steppe zone of the southern part of Western Siberia, during the growing season on crops of grain crops in the suburban farms of Novosibirsk. Investigated 2 groups of sites located in close proximity to each other, having a landscape similarity and the same set of cultivated crops. The experimental plots were divided into two groups: with extensive and intensive cultivation technologies. Early maturing varieties of wheat and corn were used as model plant species. The plots of group No 1 were characterized by moderate use of herbicides, without repeated treatments and application of insecticides. The plots of group No 2 had a high level of chemicalization, were subjected to repeated treatments with the use of insecticides and top dressing. On wheat crops No 1 and No 2, we applied seed dressing, herbicides in different quantities and dosages (Jaguar Sureks, Luger, Saratsin), on wheat plot No 2 there was a second treatment in the tillering phase and top dressing. On sowing corn No 1 we used: herbicide (soil) Bayer Adengo, insecticide Proteus Bayer, in plot No 2 we used: herbicide MaisTerPower, Propulse, after the herbicide on the 8th leaf, inter-row treatment with an insecticide Break was carried out (2 times. 1st after herbicide and again after 2 weeks). On both groups of plots, in addition to their uncultivated, adjacent territories, there were carried out: moldboard plowing, early spring harrowing. Untreated areas located between crops and a dirt road (respectively - border No 1 and border No 2) were used as control sites for catching. To collect the material, the method of soil traps was used [11, 12]. The traps were simultaneously installed at each site, 5 pieces in a line, every 5 m. The material was sampled once every 5 days. The dynamic population density of herpetobionts was calculated as the number of specimens per 100 trap-days (hereinafter specimens / 100 t-d). For a quantitative assessment of species diversity, the Simpson diversity and evenness indices were used [10-14]. To determine the degree of similarity of species diversity in the researched areas, the Jaccard coefficient was calculated. During the research period, more than 2000 specimens of invertebrates were captured.

3. Results and discussion

Among the captured invertebrates, the most numerous, nine main taxonomic groups are considered in detail (table 1). The majority of the captured invertebrates were representatives of the order Coleoptera.
Haymakers (Opiliones), Orthoptera (Orthoptera), ants (Formicidae), and other groups were also captured (table 1). The relative abundance in maize and wheat fields treated with moderate pesticide application was significantly higher than in the fields of the corresponding intensively applied crops and in nearby untreated plots, despite the fact that the relative abundance in untreated plots adjacent to the fields, cultivated using intensive technology was almost twice as high as in similar plots adjacent to fields with moderate pesticide application (table 1).

Table 1. The dynamic density of herpetobionts in terms of 100 trap-days and the indices of diversity and evenness of Simpson on crops of cereals processed using various technologies and adjacent untreated areas.

| Place of catch          | Wheat No1 | Wheat No2 | Corn No1 | Corn No2 | Control area No1 | Control area No2 |
|-------------------------|-----------|-----------|----------|----------|------------------|------------------|
| Carabidae               | 676       | 112       | 152      | 20       | 88               | 168              |
| Silphidae               | 0         | 0         | 0        | 0        | 4                | 4                |
| Curculionidae           | 0         | 0         | 0        | 0        | 4                | 4                |
| Araneae                 | 4         | 12        | 8        | 4        | 8                | 4                |
| Opiliones               | 32        | 68        | 8        | 4        | 16               | 48               |
| Hymenoptera             | 4         | 44        | 52       | 12       | 0                | 32               |
| Formicidae              | 20        | 8         | 20       | 22       | 280              | 352              |
| Caelifera               | 0         | 8         | 0        | 0        | 4                | 48               |
| Ensiferia               | 4         | 0         | 0        | 0        | 8                | 60               |
| Others                  | 12        | 20        | 12       | 16       | 68               | 80               |
| Total                   | 752       | 272       | 252      | 78       | 512              | 900              |
| Ds                      | 1.23      | 3.74      | 2.40     | 4.62     | 2.83             | 4.53             |
| Eb                      | 0.12      | 0.37      | 0.23     | 0.46     | 0.28             | 0.45             |

Ds is the Simpson species diversity index,
Eb is the Simpson evenness index.

Figure 1. Dynamic density of Carabidae species in the researched areas, specimens / 100 t-d.
Table 2. Jaccard Similarity Coefficient.

|                | Wheat No1 | Wheat No2 | Corn No1 | Corn No2 | Control area No1 | Control area No2 |
|----------------|-----------|-----------|----------|----------|------------------|------------------|
| Wheat No1      | 0         | 0.75      | 0.86     | 0.86     | 0.6              | 0.7              |
| Wheat No2      | 0.75      | 0         | 0.86     | 0.86     | 0.6              | 0.7              |
| Corn No1       | 0.86      | 0.86      | 0        | 1        | 0.5              | 0.6              |
| Corn No2       | 0.86      | 0.86      | 1        | 0        | 0.5              | 0.6              |
| Control area No1 | 0.6      | 0.6       | 0.5      | 0.5      | 0                | 0.9              |
| Control area No2 | 0.7      | 0.7       | 0.6      | 0.6      | 0.9              | 0                |

Figure 2. Dynamic density of Opiliones species in the researched areas, ind./100 t-d.

Figure 3. Dynamic density of Formicidae species in the researched areas, ind./100 t-d.
At each site, one or two groups of herpetobionts predominated numerically (table 1). Haymakers, Hymenoptera (Hymenoptera), mainly ants, ground beetles (Carabidae), Short-tailed Orthoptera (Caelifera) were found on the site with wheat crops No 2. Short-mouthed Diptera were added to wheat crops of plot No 1. On the maize crops of plot No 2, hay-makers, spiders (Araneae), hymenoptera (mainly ants), as well as dipterans were caught, and ground beetles were added to them in plot No 2. In the border areas, in addition to the above groups of insects, there were dead eaters (Silphidae), weevils (Curculionidae), and Orthoptera (Ensifera), which were absent in other areas, or were seen in single specimens. Representatives of the Orthoptera order were absent in the fields with maize crops in plots No 1 and No 2 (table 1). The border area of the site No 2 is represented by all researched taxonomic groups. Representatives of the carabid family were found in all areas under research, where 2 genera predominate: Harpalus and Poecilus. Ground beetles accounted for about 50% of the total species composition on wheat crops of plot No 1, No 2 and on a plot with corn No 1, and about 20% at borders No 1 and No 2. Ants were found at the border of sites No 1 and No 2. On the plots with wheat No 1, the most numerous groups were ground beetles and hay makers. On plots with crops of wheat No 2 - ground beetles, hay-makers and Hymenoptera. In fields with corn crops, as well as in areas with wheat, the most common were ground beetles, hymenoptera. In the border areas of both sites, ants constituted a significant part of all insects.

The species richness of ground beetles in the researched biotopes is represented by 17 species (figure 1). The most common species were Harpalus rufipes, Dolichus halensis, Poecilus cupreus. Poecilus fortipes. H. rufipes, found in all areas (figure 2). P. cupreus and P. fortipes are numerous and are observed at 4 sites. H. macronotus, which lives mainly in the steppe zone, is rare in the Novosibirsk region. In our catches, this species was found only in the area with wheat crops No 1, in a single specimen. The overwhelming majority of captured ground beetles are predators - polyphages [15, 16].

The data presented in figure 1 indicate a significantly higher number of ground beetles in the plot with wheat No 1 as compared to the plot with wheat No 2. The similarity of the species composition and indicators of the relative abundance of Carabidae at the boundaries of the first and second sites was revealed (figure 1).

The species composition of hay makers is represented by Phalangium opilio and Homolophus sp. The dominant species is Phalangium opilio, which is present in all plots. Homolophus sp. was caught only in the border area No 2 (figure 2) [17, 18].

Most of the captured ants belonged to the genera Formica, Lasius (figure 3). In areas with crops, species of the genus Formica predominated, mainly F. aquilonia and F. rufibarbis. Myrmica rubra and L. niger formed the basis of the complex of border areas [19-21].

The relative abundance in the extensively cultivated maize and wheat fields was significantly higher than in the corresponding intensive cultivated crops and in nearby untreated plots. According to the results of the catches, it was revealed that 1 or 2 groups of herpetobionts predominate at each site. Ground beetles make up about half of the total species composition on wheat crops and border areas of both groups, to a lesser extent on corn crops of the first group. The most numerous of the species was H. rufipes. This species is widespread on the territory of our country and is a pest of grain crops [13, 14]. Ground beetles of the genus Harpalus are omnivorous, with a predominance of herbivorous food in the diet. In our catches, this genus is represented by four species, which were found mainly on crops of wheat fields. Poecilus are predators. Two species of this genus were found in greater numbers on wheat crops of the first plot and in areas of border areas. D. halensis is a predator; it is present in all plots and in the greatest number in the field with wheat crops of the first plot. Thus, representatives of various trophic groups are characteristic of ground beetles on wheat No 1. The maximum values of the Simpson species diversity index, calculated separately for the carabid family, turned out to be the highest in the border area No 2. In wheat fields, regardless of the processing technology, the index values were higher than in the border area.

Haymakers were represented by two species, Phalangium opilio and Homolophus sp. Both are...
carnivores, but they can also consume plant foods. Most of the individuals caught were females. Perhaps this is due to their physiological and behavioral characteristics. They descend to the ground to lay eggs and are more likely to fall into traps.

Ants make up a significant part of the species richness of terrestrial biocenoses. The faunal ant complexes that have formed in the fields and in the virgin territory adjacent to the plots differ significantly in the distribution of species. Ants of the genus *Formica*, mainly *F. aquilonia* and *F. rufibarbis*, predominated in the areas with crops. The basis of the complex of border areas was formed by *M. rubra* and *L. niger*, which are the most eurytopic species. The abundance of these species in cultivated areas was significantly lower than in border areas.

Relatively small indices of the index of species diversity in the wheat plot No 1 in comparison with the second plot indicate differences in the dominance structure. In particular, this is expressed by the predominance of ground beetles in relation to the total number of invertebrates in this area. Also, the relative number of ground beetles here is several times higher than the corresponding indicators in other areas. In this regard, the index of species diversity in the first site is lower than in the second. The situation is similar in areas with corn crops. For example, in plot # 1 with corn crops, Simpson's diversity index is lower than in plot # 2. The largest indicator of species diversity was found in the border area No 2. Representatives of all discovered taxonomic groups are present in this area. The values of the Jaccard index demonstrate a fairly high similarity of the population between the sites (table 2). The similarity of the structure of communities of herpetobionts on crops of the same culture with different processing technology is higher than between crops and border areas.

In areas with crops of both crops, when using intensive processing technology, the species diversity of all invertebrate herpetobionts was higher, but lower relative abundance. In the border areas, the opposite is true. Despite the more favorable conditions in the border area of group No 1, the relative abundance of most species in the areas bordering with intensive processing technology (border No 2) was higher than in the fields of the first group. This can be explained by the fact that border No 2 differed from plot No 1 in moist loose soil and pronounced green vegetation, which creates favorable conditions for most of the groups of insects researched by us. Low values of the diversity index in areas with extensive cultivation technology compared to not cultivated, border areas indicate an uneven distribution of invertebrate groups in these areas. Thus, intensive processing reduces the number of all groups, primarily the dominant ones, due to which the indicators of diversity increase. This may indicate the negative impact of increased intensification of the cultivated areas on the herpetobiotic invertebrate communities. Our data show that an increase in the intensity of cultivation of cultivated areas affects the dynamic abundance, species richness, and species diversity of terrestrial invertebrates.

4. Conclusion
The results obtained show that geographically adjacent agrocenoses, which differ in terms of the level of anthropogenic impact, and their border areas are similar in their species composition. At the same time, an increase in the level of intensification of the cultivated areas leads to a significant restructuring of the structure of communities of terrestrial invertebrates. Arable land, where the impact of agricultural practices was minimal, is generally characterized by greater species diversity and a higher abundance of invertebrates. Based on the results of long-term observations, it will be possible to draw a conclusion about the change in the dynamics of the number of insects in the researched areas and formulate certain requirements for the conditions of farming in our region in order to increase the level of use of biological approaches to preserve species diversity and sustainable use of agricultural areas.

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