The influence of natural climatic conditions on the species diversity of insects in the conditions of the southern forest-steppe zone of Chelyabinsk region

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Abstract. The influence of natural climatic conditions on the species diversity of insects in the cereal-grass biocenosis on the territory of peasant farm "Markovo-1" located in the southern forest-steppe zone of Chelyabinsk region has been studied. During the survey of entomofauna on the territory of peasant farm "Markovo-1" 19 herpetobiont species have been identified in the biocenosis which are represented by 9 families. 51 species of hortobionts belonging to 8 orders and 25 families were identified. Entomofauna was represented by the following orders: Dragonflies (Odonata), Coleoptera (Coleoptera), Diptera (Diptera), true Hemiptera or bugs (Hemiptera), Neuroptera (Neuroptera), Lepidoptera (Lepidoptera), Orthoptera (Orthoptera), Lepidoptera (Lepidoptera). 421 herpetobionts and 482 hortobionts were identified in the cereal-grass biocenosis. Insects of the order Coleoptera belonged to 16 families and 32 species. The largest number of species were the representatives of the family of Ground beetles (Carabidae) and Lamellate beetles (Scarabaeidae) (5-6 species). The number of other families of this order was not so significant (1-3 species). Insects of the Lepidoptera order were represented by 6 families and 15 species. During the phytosanitary control of the studied agrocenosis the economic thresholds of insect harmfulness were determined. According to the results of the survey of the territory of the farm several species of insect pests the representatives of different orders and families true Hemipterans or Bugs (Hemiptera) the family of shield Bugs (Pentatomidae), the species of Corn Bugs (Eurygaster integriceps) were found from the discovered herpetobionts and hortobionts. Order Lepidoptera, family - Scoops (Noctuidae), species - Winter Scoops (Agrotis segetum Den.et Schiff.); family - Fireflies (Pyralidae), species - Meadow Moth (Pyralidae); family of Weevils (Curculionidae), beetroot Weevil Species (Bothynoderes punctiventris G.). A species Click Beetle (Agriotes sputator L.) belonging to the family of Click Beetles (Elateridae) is found only once.

1. Introduction
Currently the structural analysis of the entomofauna of the southern forest-steppe zone of Troitsk district of Chelyabinsk region is of considerable interest due to the influence of various natural climatic factors on the insect development cycle [1,2,3,4].

Of no small importance for the study of entomofauna is the factor that among insects there are plant pests that cause great harm to crops. As a result of fluctuations in natural climatic conditions the species, sex, age and spatial structure of entomofauna populations are changing, the phenological timing of their development is shifting which in general affects the stability of insect biodiversity in the southern forest-steppe zone [5,6,7,8].
In this regard the aim of the study was to study the influence of natural climatic conditions on the species diversity of insects in the conditions of the southern forest-steppe zone of Chelyabinsk region.

2. Materials and methods
The study of the species diversity of insects was carried out in a cereal-grass biocenosis on the territory of peasant farm "Markovo-1" of Troitsk district of Chelyabinsk region in the period of spring-summer 2021.

The dynamics of monthly and annual precipitation amounts, maximum daily precipitation amounts, average monthly and annual air temperature were studied according to the data of the Troitsk meteorological station.

In order to get an idea of the species diversity of herpetobionts and hortobionts in the cereal-grass biocenosis surveys were conducted using standard methods: installing Barber traps (to determine the species diversity of herpetobionts) and the method of mowing with an air net (to determine the species diversity of hortobionts) as well as manual collection (for the design of entomological collections).

All the data obtained were statistically processed using the Excel MS, Office XP.

3. The results of the study
The survey of entomofauna on the territory of peasant farm "Markovo-1" was carried out in the vicinity of the village of Sunaly Troitsk district Chelyabinsk region in a cereal-grass biocenosis. The village is connected by dirt roads and highways with neighboring settlements. The distance to the district center (Troitsk) is 28 km, to the center of the rural settlement (Drobyshevo village) - 8 km. The coordinates of the center of the village of Sunaly are - 54°14' North latitude and 61°45' East latitude.

According to geobotanical zoning the territory of peasant farm "Markovo-1" is located in the southern forest-steppe zone. The territory of the farm is located between the Ural Mountains and the West Siberian Lowland, the nearest heights are 211 and 213 m.

The climate of the zone is sharply continental with dry hot summers and long cold winters. The warmest month is June, and the coldest is January. The lowest temperature is observed in January (-43.7 °C), the highest in July (+40.2 °C). The sum of effective temperatures for the period with temperatures above +10 °C is 2000-2200 °C, the duration of this period is 125-145 days. This level of heat supply occurs on May 5th-8th, is over on September 19th but however in the second and even in the third decades of May cold weather returns are not uncommon. These phenomena combined with early autumn frosts limit the duration of the frost-free period to 100-120 days. The period with a temperature above +15 °C lasts 80-90 days.

Winter is long it usually lasts 5.5-6 months. Snow cover is established in the first half of November, it persists until the second decade of April. The height of the snow cover in open areas is 20-30 cm, in protected areas it is higher for about 10 cm and in some places - for 20 cm. Strong winds are observed in February-March. Soils freeze to 80-90 cm.

Water reserves in the snow before the start of snowmelt are on average 115-135 mm in a meter layer they are often insufficient. It is known that high reserves of productive moisture for sowing spring crops are an important factor in guaranteed germination. Due to these reserves agricultural crops tolerate the air drought in May and June [9,10,11].

Spring is short (1-1.5 months) it usually cold with winds, late frosts (the average date of spring frosts is May 14 th, the earliest is April 19 th, the latest is June 6 th). The transition of daily temperatures through 0 °C falls on April 10 th. Summer lasts 3.5 months, it is hot, with little precipitation.

Autumn with early frosts, begins in September, lasts 2-2.5 months. The first half of autumn is rainy, the second half is dry with clear cold days. The number of frost-free days is 120-125 (maximum 157). The first autumn frosts occur in the third decade of September and stop at the end of May.

The average annual absolute humidity is recorded in June-August (minimum 51.7%), in August (maximum 61%). The number of hours of sunshine is 2,218 (according to other sources - 2,249) per year. The number of days without sun is 57.
Precipitation falls unevenly, 350-400 mm of precipitation falls per year, 175-240 mm during the growing season. The hydrothermal coefficient (HTC) varies from 0.8 to 1.0.

Strong winds also have an adverse effect on the development of plants. The greatest number of days with a strong wind is observed in May during the sowing of the main crops which contributes to an increase in evaporation, faster drying of the arable layer [12,13,14,15]. The winds of the north-east and south-west directions prevail.

The soils of the farm are represented by leached and ordinary chernozems. Leached chernozems are the best arable soils. They are characterized by a relatively powerful humus horizon - up to 60 cm, 7% humus content, weakly acidic reaction of the soil solution medium, favorable for most crops. According to the granulometric composition, these are medium-humus, medium-loamy soils.

The content of phosphorus available to plants in leached chernozems is as a rule insufficient to obtain high yields. The nitrogen supply of plants depends on the processes of mineralization of nitrogenous compounds of soils. They are active on fallows, so a lot of mineral nitrogen, mainly nitrate nitrogen, available to plants accumulates in the soil. After other precursors the supply of this element in the chernozems leached for sowing crops is sufficient.

Ordinary chernozems unlike leached ones are characterized by the content of calcium carbonates in the lower part of the humus horizon and often by an increased content of CaCO₃ in the B₂ horizon. Calcium carbonates preserve soil nutrients and make them difficult for plants to access. Sodium exchange in ordinary saline chernozems worsens the water-physical properties. In terms of humus and nutrients ordinary chernozems are not inferior to leached chernozems [16,17,18,19]. The humus content in horizon A at its capacity of 30-40 cm ranges from 4.9-9.8%. The above writingsuggests that the arable soils of the southern forest-steppe zone of the farm have a high potential fertility which makes it possible to obtain a good biomass of plants which contributes to an increase in the number of insects.

The natural vegetation of the studied zone is represented by meadow, cereal-legume and grass-type plant communities. The vegetation cover is characterized by the alternation of small aspen-birch forests and steppe vegetation in open areas that grow on the above-mentioned soils most of which are plowed up for crops.

The herbage is dominated by Meadow Timothy (Phlum pratense L.), Meadow bluegrass (Poa pratensis L.), Festucae (Festuca valesiaca), Meadow fescue (Festuca pratensis Huds), Creeping wheatgrass (Elytrígia répens), Bitter wormwood (Artemisia absinthium L.), Sage (Salvia nemorosa), Lessing’s Feather grass (Stipa lessingiana), Tenacious bedstraw (Galium aparine L), etc.

By the nature of the land relief the territory of the farm is in general a slightly undulating plain where slightly elevated spaces are replaced by closed lowlands and lakes.

Atlantic air masses bring precipitation to the territory and in winter the warmth. The warmed-up air penetrating from Central Asia is the main reason for the establishment of hot dry weather in the first half of summer. During the winter season the formation of powerful anticyclones in the depths of the Asian continent causes cold sunny windless weather. Less often the cause of sudden air cooling is the air masses coming from the Kara Sea.

Thus the southern forest-steppe soil-climatic zone is characterized by a relatively large amount of heat and a lack of moisture this is also actual for the territory of the analyzed peasant farm "Markovo-1".

In summer period of 2021 a high ambient temperature was observed in the studied area; the average daytime summer air temperature was in the range of 18-22°C and during the day it reached up to 30-35 °C; precipitation was below normal, the summer was hot and dry. Evaporation during the summer period exceeded the level of precipitation (Table 1,2,3).

Specialization of peasant farm "Markovo-1" is a production of plant-growing products. The predominant crops are cereals. Among them the leading place is occupied by wheat and barley which are used mainly in the feed balance.
Table 1. Dynamics of monthly and annual precipitation amounts, mm (Troitsk weather station data).

| Year | Jun | Feb | March | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | For the year |
|------|-----|-----|-------|-----|-----|------|------|-----|------|-----|-----|-----|-------------|
| 2019 | 14  | 29  | 28    | 37  | 12  | 52   | 65   | 34  | 43   | 49  | 14  | 22  | 398         |
| 2020 | 15  | 26  | 25    | 27  | 24  | 11   | 54   | 45  | 76   | 25  | 18  | 9   | 354         |
| 2021 | 38  | 34  | 13    | 2   | 13  | 22   | 48   | 9   | -    | -   | -   | -   |             |

Table 2. Dynamics of maximum daily precipitation amounts, mm (Troitsk weather station data).

| Year | Jun | Feb | March | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | For the year |
|------|-----|-----|-------|-----|-----|------|------|-----|------|-----|-----|-----|-------------|
| 2019 | 4   | 13  | 8     | 10  | 6   | 23   | 43   | 12  | 12   | 17  | 7   | 8   | 43          |
| 2020 | 4   | 7   | 10    | 8   | 11  | 4    | 31   | 20  | 30   | 7   | 8   | 5   | 31          |
| 2021 | 11  | 6   | 4     | 0.6 | 4   | 9    | 20   | 5   | -    | -   | -   | -   |             |

Table 3. Dynamics of average monthly and annual air temperature, °C (Troitsk weather station data).

| Year | Jun | Feb | March | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | For the year |
|------|-----|-----|-------|-----|-----|------|------|-----|------|-----|-----|-----|-------------|
| 2019 | -15.8 | -13.5 | -2.6 | 4.9 | 15.2 | 18.1 | 21.3 | 18.0 | 9.8  | 6.4 | -7.5 | -9.3 | 3.8         |
| 2020 | -7.8  | -7.1  | -0.1  | 6.9 | 16.5 | 17.6 | 23.3 | 19.5 | 11.9 | 5.3 | -5.5 | -12.0 | 5.7        |
| 2021 | -16.1 | -15.2 | -7.1  | 6.7 | 19.5 | 20.4 | 20.8 | 21.7 | -    | -   | -    | -    |             |

The structure of the acreage that is the percentage of individual crops in the total area of sowing of the analyzed farm is shown in Table 4.

Table 4. Structure of acreage, hectares.

| Crop    | Acreage, ha | Yield, c/ha |
|---------|-------------|-------------|
| Sunflower | 280         | 8           |
| Wheat    | 170         | 8           |
| Barley   | 86          | 7           |
| Flax     | 15          | 6           |
| Total    | 551         | -           |

In 2021 the summer was hot and dry, the temperature in July reached 30°C and above. There was practically no precipitation. Climatic conditions have become the main limiting factor that has a significant impact on crop yields.

During the survey of entomofauna on the territory of peasant farm "Markovo-1" 19 herpetobiont species were identified in the biocenosis which are represented by 9 families. Among the presented species basically all belonged to the order Coleopterans or Beetles (Coleoptera) except for one species - the steppe ant - this is the order Hymenopterans, the Family of Ants (Formicidae).

During the research we identified 51 species of hortobionts that belonged to 8 orders and 25 families. Entomofauna was represented by the following orders: Dragonflies (Odonata), Coleopterans (Coleoptera), Dipterans (Diptera), True Hemipterans or bugs (Hemiptera), Neuropterans (Neuroptera), Lepidopterans (Lepidoptera), Orthopterans (Orthoptera), Hymenopterans (Hymenoptera).

Thus, we identified 421 herpetobionts and 482 hortobionts in the cereal-grass biocenosis of the farm. A significant number of insects of the order Coleopterans (Coleoptera) which belonged to 16 families and 32 species were found in the analyzed territory. The largest number of species were
representatives of the family of Ground beetles (Carabidae) and Lamellate beetles (Scarabaeidae) (5-6 species).

The family of Ground beetles (Carabidae) was represented by the species - the Cicindela hybrid Linnaeus whose number was 135 specimens, and the family of Lamellate Beetles (Scarabaeidae) - the species - the housefly (Musca domestica Linnaeus) - 18 specimens.

The number of other families of this order was not so significant (1-3 species).

Insects of the Lepidoptera order were represented by 6 families and 15 species. Thus the family of Golubyanka (Lycaenidae) had seven species among which the dominant species was the Golubyanka Icarus (Polyommatus Icarus) numbering 7 specimens.

As a result of field surveys of the biocenosis among the entomofauna of the farm we also identified insects harmful to field crops as because of their vital activity crop yields and product quality sharply decrease.

In this regard at the next stage of our research phytosanitary control of agrocenoses was carried out it is one of the elements of the integrated plant protection system which is of great practical importance. It is known from the literature that in order to protect the environment and agrocenoses economic harm thresholds (ENT) are used to control insect pests. ENT is the population density or the degree of development of a harmful organism when it is economically feasible to apply protective measures (GOST 21507 - 2013: Plant protection. Terms and definitions) [20].

According to the results of the survey of the territory of the farm several types of insect pests the representatives of different orders and families were identified in the discovered herpetobionts and hortobionts. For example among the insects of the order real Hemiptera or Bugs (Hemiptera), the family of Shield Bugs (Pentatomidae) there was a species –Corn Bug (Eurygaster integriceps) whose number was 38 copies. The economic threshold of its harmfulness in the tillering phase on spring wheat is 0.5-1.5 bugs per 1m², 1-2 larvae per 1 m² or 10 strokes of the net, in the grain filling phase - 0.5 larvae per 1 m² or 10 strokes of the net in drought. Mass flight occurs at an average daily air temperature of 12-14°C, and the maximum reaches at 18-20°C. At an average daily temperature of 22°C, embryonic development lasts 6-10 days.

Larvae and bugs cause great harm by feeding on grain. If the grain is damaged, its weight and germination decreases and baking qualities deteriorate. Gluten under the influence of the enzymes of the saliva of the Corn Bug loses elasticity does not resist stretching.

The order Lepidoptera was represented by the family of Scoops (Noctuidae), a species of Winter Scoops (Agrotis segetum Den.et Schiff.) and the Firefly family (Pyralidae), a species of Meadow Moth (Pyralidae). Winter Scoop (Agrotis segetum Den.et Schiff.) met up to 5 specimens. The economic threshold of its harmfulness in the germination phase on cereals is 5-8 caterpillars per 1 m², on sunflower in the phase of 3-5 leaves - 0.5-1 caterpillar per 1 m² and in the phase of 6-8 leaves - 3-5 caterpillars per 1 m². Crops are damaged by caterpillars that destroy sown seeds and seedlings in the soil, gnaw plants at the soil level and eat leaves, gnawed leaves are sometimes dragged into the soil by caterpillars.

The meadow moth (Pyralidae) was found up to 50 specimens. The economic threshold of harmfulness on sunflower in the phase of 4-6 leaves is 10 caterpillars per 1 m² and in the flowering phase is 20 caterpillars per 1 m², on flax the first generation is 5 caterpillars per 1 m² and the second generation is 8-10 caterpillars per 1 m². Imago departure occurs at average daily temperatures of + 15°C and mass flight - at +19°C. Depending on the climatic conditions, the flight is stretched and lasts 1-2 months. The maximum fertility of females occurs when the caterpillars are fed on plants and the air temperature is + 22- + 25°C, the relative humidity is 80-100%, the length of the daylight is at least 14 hours. Embryonic development lasts from 2 to 15 days at an optimal temperature of +28 °C. The meadow moth is a wide polyphage, the main harm is caused by caterpillars. The caterpillars of younger ages are on the leaves under a thin spider web skeletonize the leaves leaving only veins, and the caterpillars of older ages roughly eat the leaves which leads to a decrease in yield and deterioration of product quality.
Among the insects of the order Coleoptera there were insect pests from the family of Weevils (Curculionidae) and are represented by a species - Beetroot Weevil (Bothynoderes punctiventris Germar) in the amount of 18 copies. The economic threshold of harmfulness on sunflower in the germination phase is -2 beetles per 1 m². Favourable temperature for development is +20-+28 °C, the minimum temperature for development is +10°C. The embryo develops in 18-19 days at a temperature of +20-28 °C.

Beetroot weevil is an extensive polyphage. It is especially dangerous at the stage of germination - 1-2 pairs of real leaves of culture. Beetles harm by gnawing the edges of young leaves, cotyledons, sunflower growth point and larvae - they feed on plant roots.

The species of a small seedClick Beetle (Agriotes sputator Linnaeus) belonging to the family of Click Beetles (Elateridae) is found only once.

4. Conclusions
1. During the survey of entomofauna on the territory of peasant farm "Markovo-1", 19 herpetobiont species were identified in the biocenosis, which are represented by 9 families (421 herpetobionts and 482 hortobionts).
2. 51 species of hortobionts belonging to 8 orders and 25 families were identified. Entomofauna was represented by the following orders: Dragonflies (Odonata), Coleoptera (Coleoptera), Diptera (Diptera), True Hemiptera or bugs (Hemiptera), Neuropterans (Neuroptera), Lepidoptera (Lepidoptera), Orthopterans (Orthoptera), Hymenopterans (Hymenoptera). Insects of the order Coleoptera belonged to 16 families and 32 species. Insects of the Lepidoptera order were represented by 6 families and 15 species.
3. The largest number of species were the representatives of the family of Ground beetles (Carabidae) and Lamellate beetles (Scarabaeidae) (5-6 species). The number of other families of this order was not so significant (1-3 species).
4. When carrying out phytosanitary control of agrocenosis the economic thresholds of insect harmfulness are determined. According to the results of the survey of the territory of the farm several species of insect pests the representatives of different orders and families have been identified from the discovered herpetobionts and hortobionts - these are True Hemipterans or Bugs (Hemiptera), the family of Shield Bugs (Pentatomidae), the species – Corn Bug (Eurygaster integriceps); order Lepidopterans (Lepidoptera), family - Scoops (Noctuidae), species - Winter Scoops (Agrotis segetum Den.et Schiff.) and the family - Fireflies (Pyralidae), the species - Meadow Moth (Pyralidae). Family of Weevils (Curculionidae), beetroot weevil species (Bothynoderes punctiventris Germar). The species is a small Click Beetle (Agriotes sputator Linnaeus) belonging to the family of Click Beetles (Elateridae) is found only once.
5. In peasant farm "Markovo-1" such crops as: spring wheat, peas, barley, sunflower, flax are cultivated. Under existing natural climatic conditions insects from the following orders are most dangerous for these cultivated plants: true Hemipterans or bugs (Hemiptera), the family of Shield Bugs (Pentatomidae) and Coleoptera (Coleoptera), families of Dareling Beetles (Tenebrionidae), Weevils (Curculionidae) whose numbers exceeded the economic threshold of harmfulness.

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