Breed affiliation features of honey bees (Apis mellifera) in the Novgorod region

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Abstract. The article discusses the problem of biodiversity conservation, on the example of honey bees (Apis mellifera) in the Novgorod region of Russia. The work examines the local bees breed affiliation. The regional population of the Central Russian (Central European) breed has been indigenous to this territory. The author analyzes the natural conditions of the region in which it was formed and to which it is well adapted. Due to the anthropogenic factor and appearance of man-bred new breeds, the local population began to disappear, giving way to crossbred bees. The study finds out the breed genes prevailing in their modern population and whether the aboriginal Central Russian bees survived in the region. We indicate the morphometric breed features of the bees in the region, find the differences between the bees of various regions, analyze the reasons of these differences. It becomes obvious that pure-bred Central Russian bees practically did not survive. The bees of the Carpathian (Apis mellifera carpathica) and Krainsky (Apis mellifera carnica) and local Central Russian (Apis mellifera mellifera) breed had the greatest influence on the formation of the modern honeybee population in the region. Unfortunately, this situation can be considered as an example of natural biodiversity reduction, which threatens local biocenoses, especially given the important role of honey bees in them.

1. Introduction
On the planet, there are about 30 natural breeds (races) of honey bees (Apis mellifera), formed in their habitats. The birthplace of the honey bee as a biological species is Africa, from where it gradually populated all the continents. At first, this happened naturally. Bees multiplied under favorable conditions and populated new territories. Thus they settled, including the European continent. The border of their natural habitat passed just in the north of the Novgorod region, and these bees will be discussed here. Over the centuries of evolution, bees localized in their natural habitats in certain natural and climatic conditions and acquired their breed characteristics. Most of their natural breeds thus formed in Africa and Europe. Later on, the spread of honey bees around the world was influenced by human activities. People brought bees to America, Australia, and some parts of Asia where they had not previously lived. It should be noted that the imported bees subsequently had a great influence on the ecology and biodiversity of the new territories [1–8].

For a long time, the breeds of bees had not been of a great importance to people. In the 19th century, the development of beekeeping began both as a separate branch of agriculture and as a science. This development continued particularly intensely after the Second World War. Beekeepers-practitioners sought to acquire and import more productive and peaceful breeds, scientists worked on crossbreeding in order to breed bees that are optimal for beekeeping according to their economic characteristics. At
this stage, they did not think about preserving local populations of bees. As a result, since the 60s of the twentieth century, many natural native breeds of bees have lost their unique characteristics and have been mongrelized by other bee breeds as a result of mass uncontrolled reproduction [1, 9–12].

What do we have now? On the one hand, there are several breeds of bees that are used for human activities, intensively bred and distributed. These are either breeding lines of natural bee breeds (*Apis mellifera carnica, Apis mellifera caucasica, Apis mellifera carpathica, Apis mellifera ligustica*), or new breeds obtained by interbreeding (Buckfast). On the other hand, the gene pool of many local breeds has been lost, which affects the ecology and biodiversity of many regions, where these bees were an integral part of biocenoses. The bees of the Central European breed, including the populations of Central Russian bees, particularly suffered from these processes. The problem is that now, without human participation, any thoroughbred bees, with uncontrolled reproduction, quite quickly, after several generations, lose their useful economic traits (productivity, winter hardiness, peacefulness, etc.) and turn into populations with a wide unpredictable spread of hereditary information. As a rule, these mongrelized bees are very aggressive, rich in swarms, have poor disease and cold resistance wherein the last characteristic is especially important for the region we are studying. [3, 13–16].

As we have already indicated, one of the breeds most affected by human exposure was the Central European bee breed (*Apis mellifera meliffera*). The studied territory of the Novgorod region was historically inhabited precisely by it, or rather by one of its populations, usually called Central Russian. Let us further consider in what conditions historically the formation of the local bee population took place and to what conditions it, respectively, is most adapted [1–3, 11].

The Novgorod region is located in the north-west of the Russian Federation, on the territory of the East European Plain. The region stretches 385 km from west to east, and 278 from north to south. The region has an important geographical position, it is located between the largest cities of Russia – Moscow and St. Petersburg. Through its territory there are automobile and railway transport routes connecting the two cities. Despite the relatively small size, a rather large variety of topography, landscapes and local climates is observed in the region [17–20].

In the center of the region there is a large lake Ilmen, around which there is a swampy Priilmenskaya lowland. A large number of rivers flow into Ilmen, only one flows out – the Volkov. To the east, the ground level rises and gradually passes into the Valdai Upland. The Valdai Upland is rightly considered the pearl of the North-West of Russia. The relief, vegetation and, to a lesser extent, the climate of the western and northwestern territories of the region (where the Valdai Upland just begins) are quite different (considering the geographical proximity of the location) from the Priilmen Lowland. On the territory of the Valdai Upland, hilly terrain with a large number of lakes predominates [17, 18].

The climate of the region is greatly influenced by the Baltic Sea, with its moderate amount of heat and an excess moisture. The region is characterized by a mixture of different types of climates. As a rule, summer is short, not hot and rainy. Autumn is long with variable weather, often cool. Winter is quite mild, with occasional severe frosts and frequent thaws. Spring is usually cold and prolonged. An important detail for beekeeping - almost all year round strong winds are observed in the region, mainly west and northwest [17–18, 20].

The warmest (average annual temperature 4.5 °C) are the southwestern and western regions of the region. The average temperature of July, the warmest month, is +16 – +18°C. In the east and northeast, the region is on average colder by 2°. The region is characterized by a large annual amplitude of temperature fluctuations, it is 25–30°. Annual precipitation, like temperature, is gradually changing from south-west to north-east, increasing from 600mm to 800mm. Snow cover lies 4–5 months. In the east and northeast, its thickness on average over the years is twice as large and, accordingly, it lies longer [17–18, 20].

In the region, forests predominate, occupying 86% of the area. Moreover, in the past 60 years, the forest area has increased by 15–20%. This is due to the afforestation of former farmland that is no more used by people. Currently, most of the forest area (more than 60%) is occupied by deciduous forests. The proportion of coniferous forests is increasing in the east and northeast. Every year, there is a little
increase in ripe and overripe deciduous stands, mainly from aspen. This fact causes some environmental concern [21–25].

In general, to summarize, the territory of the region can be divided into two parts according to the features of relief, climate and vegetation. The border runs through the regional center – the city of Veliky Novgorod and runs from the northwest to the southeast. In the south-west of the region, the climate is milder, with higher temperatures, less rainfall and less winter snow cover. There is a smaller percentage of forest and deciduous forests prevail. In the northeast and east it is colder, with more rainfall, and a longer winter with great snow cover. A large percentage of the territory is covered by forest, in which conifers predominate.

Thus, the local population of Central Russian bees formed in specific climatic and melliferous conditions. Cool rainy summers, winters with large temperature drops and long springs. The melliferous conditions, especially given the summer weather, also suggest difficulties for bees. As a rule, honey collection is unstable, almost never strong, and ends early. Nevertheless, local bees adapted to such conditions and for centuries provided people with beekeeping products. It is worth recalling that in the Middle Ages, Veliky Novgorod was the leader in Europe in the honey and wax trade [25].

The objective of the research was to determine the morphometric characteristics of the region's bees, to find out the genes of which breeds prevail in the modern bee population, and to find out whether the aboriginal Central Russian bees survived in the region.

2. Materials and methods

The species of bees can be determined by various methods, including a number of morphometric characteristics. These features include the proboscis length, the length and width of the third and fourth tergites, the length and width of the third sternite, discoidal shift, cubital index, color, etc. Some behavioral characteristics, such as aggressiveness and comb capping, are also used to determine the breed.

The most common determination of breed characteristics is a combination of two parameters: the proboscis length and cubital index. The determination according to these morphometric characters is simple, but at the same time highly reliable. These parameters we used in our work. The proboscis length and the cubital index were studied according to the standard method using optical means, computer equipment, and special computing programs. When determining the breed and population of bees, we relied on the data of Krivtsova N. I., Goryacheva I. I., and Borodachev A. V. (2011). The results are presented in table 1 [1].

| Breed, type        | Length of proboscis, mm | Cubital index, % |
|--------------------|-------------------------|-----------------|
| Central Russian    | 6.2                     | 62.3            |
| Carpathian         | 6.6                     | 43.1            |
| Caucasian          | 6.9                     | 51.2            |
| Prioksky           | 6.7                     | 56.4            |
| Oryol              | 6.3                     | 60.2            |
| Tatar              | 6.3                     | 60.6            |
| Krasnopolyansky    | 7.0                     | 52.4            |

In the table there are no data on the Krainsky breed (Carnica), as it has approximately the same indicators as the Carpathian breed. Moreover, many researchers do not distinguish between them, considering them to be one breed.

In the work, we were primarily interested in the Central Russian bee breed. Due to its wide range, it has formed many populations that differ slightly in characteristics. According to the same authors, the proboscis length of different populations of the Central Russian breed varies between 6.20–6.34 mm, and the cubital index is 54–63%.
When determining the breed affiliation, beekeepers-practitioners often use the following visual signs to assess the bee colonies and individual bees: peacefulness or aggressiveness, the speed of spring development, intensity of autumn build-up, winter resistance, size and color of bees, behavioral patterns, and comb capping. We did not systematize these evaluation criteria, although they were taken into account in the work. The complexity of the visual assessment is that even within the same apiary there are always families with a different set of properties. The exceptions are when in an apiary all families are kept with thoroughbred queens, but even then the signs scattering also takes place. Nevertheless, we took into account these signs and criteria of belonging to a particular breed as indirect and additional. For example, such a sign as comb capping (“dry” or “wet”) can very accurately show the presence or absence of genes of Grey mountain Caucasian bees. Aggressiveness, on the contrary, does not always indicate the Central Russian breed. Relatively peaceful Central Russian bees are found; and at the same time, crosses, especially after the second generation, of Carpathian and Krainsky bees can show high aggression.

For research, bees were selected from four districts of the Novgorod region: Valdai, Pestovsky, Novgorod and Starorussky (figure 1). Flight bees were selected during the honey season, so they were about the same age and from different apiaries, as far as possible. The features of beekeeping in these areas were also taken into account. So, in Novgorod and Starorussky beekeeping is more developed, there are large apiaries and many amateur beekeepers. In addition, as described earlier, these areas have a milder, warmer climate with less rainfall than in the eastern regions, which include Valdai and Pestovsky. In the Valdai and Pestovsky districts there are less apiaries and, accordingly, bees.

Figure 1. Localities of collecting the bees specimens for examination.

3. Results
Before discussing the results, it is necessary to take a short historical excursion on the development of beekeeping in the Novgorod region. The native breed of bees in the region is the local population of Central Russian bees (Apis mellifera mellifera). Earlier we described the conditions in which it was formed. We should remember that this area has not very favorable conditions for breeding bee families.
In fact, it was precisely on the territory of the modern Novgorod region earlier, until the 20th century, where passed the northern border of the honey bee distribution as a biological species. Nevertheless, beekeeping in the territory of the modern region was highly developed. The local population was distinguished in difficult climatic and honey harvesting conditions by high productivity and winter resistance. At the same time, it stood out with pronounced aggressiveness. First of all, it was this that caused the beginning of the southern bees delivery to the territory of the region, and incidentally, to the entire European part of Russia.

This process began most intensively since the 60s of the 20th century. First, queens of the Grey mountain Caucasian breed began to arrive, they were distinguished by their exceptional peacefulness. The first or second generation of hybrids also showed themselves, as a rule, from the best side. They were peaceful, not prone to swarming, but after two or three generations, beekeepers began to notice that cross-bees lose all their positive qualities, become aggressive, swarmy and unproductive.

From the 70s of the 20th century, the massive importation of Carpathian bees began, and an even stronger blow was dealt to the gene pool of local bees. After the collapse of the Soviet Union, the uncontrolled delivery of other bee breeds continued. The Grey mountain Caucasus has almost ceased to be imported, but Carpathians and Karniks began to arrive in mass. This process is currently ongoing. Unfortunately, often under the guise of thoroughbred lines of Carpathians and Karniks, outbred bees from the south, absolutely not adapted to the local conditions, are entering the region.

The results obtained in the study of morphometric characters of bees in the Novgorod region are presented in Table 2.

| District   | Length of proboscis, mm | Cubital index, % |
|------------|-------------------------|------------------|
| Novgorod   | 6.5±0.10                | 45.3±1.6         |
| Starorussky| 6.4±0.12                | 46.4±2.6         |
| Valday     | 6.3±0.07                | 48.8±1.8         |
| Pestovsky  | 6.3±0.15                | 53.4±1.97        |
| Average    | 6.37                    | 48.5             |

The first indicator presented in the table is the proboscis length. The average value in the examined bees is 6.37 mm. This is the average value between the Central Russian breed and the Carpathian, but still closer to the Central Russian.

The cubital index is a more important indicator than the previous one, the difference between the breeds is more pronounced in it. In the bees of the region, it ranges from 45.3% to 53.4%. The average cubital index value of the studied bees in the Novgorod region is 48.5%. The highest is 53.4% for bees in the Pestovsky district, the lowest is for bees in the Novgorod district – 45.3%. Comparing the results with the indicators of the bees standards shown in Table 1, we can draw some conclusions. Bees of the region on average clearly do not fit the standard of Central Russian bees. The cubital index is average between the Central Russian and Carpathian breed, they are closest to the index of the Grey mountain Caucasian breed. At the same time, there is a rather large scatter of indicators between bees from different areas, which suggests that according to the breed characteristics, these bees, albeit slightly, but differ.

4. Discussion
Basing on the results obtained and taking into account the indirect information, we assume that the Grey Caucasian mountain breed (*Apis mellifera caucasica*) does not practically influence the region’s bees, despite its active introduction in the 20th century. The cubital index of the examined bees is close to this breed, but one may notice that, in principle, the cubital index of Caucasians in itself is average between all breeds. In addition, it is logical that the influence of Caucasian bees should be expressed in an increase of the proboscis length, but we do not observe this. According to the external and behavioral characteristics, the bees of the region are not similar to the Grey mountain Caucasians, whose behavior...
and appearance are very characteristic and distinguish them from other breeds. The Caucasian bees are characterized by a "wet" comb cupping; it is practically not found in the bee colonies of the region. Nevertheless, we assume the presence of a slight influence of Caucasian bees, since, firstly, their importation into the European part of Russia was massive in the past, and secondly, amateur beekeepers periodically bring queens from the Caucasus. Beekeepers who have large and medium apiaries do not deal with the Caucasian bee.

The influence of the Carpathian (Apis mellifera carpathica) and Krainsky (Apis mellifera carnica) breeds is much more pronounced. This is evidenced (Table 2) by a shift in the proboscis length towards a slight increase and a significant decrease in the cubital index. The cubital index of the region's bees is especially noteworthy. According to his indicator, the region's bees are, on average, closer to the Carpathian and Krainsky breed, and not to the Central Russian. We also note the indirect behavioral characteristics of the local bees in which they are similar to these bee races. This is a relative peacefulness, the body color and the "dry" comb cupping. We can assume that at present, the main role in the "rush of blood" to the local bees is played by the Krainsky breed, as every year the local beekeepers use queens of this particular breed due to their positive economic characteristics.

There is a difference in the cubital index between bees from different regions. This heterogeneity illustrates the effect of imported bees. As in Novgorod and Starorussky districts there are more large and medium apiaries, the beekeepers are more active there, they buy Carpathian and Krainsky queens in large quantities. As a result, in these areas there is a high density of apiaries, on which the Carpathian-Krainsky drones predominate, which causes a significant mongrelism of bees, even those apiaries whose beekeepers breed the local bee race.

In the Valdai and Pestovsky districts, the conditions for beekeeping are more difficult, there is a lower density of apiaries, many amateur beekeepers prefer to breed local Central Russian bees. As a result of this, the degree of bees proximity to the Carpathian and Krainsky breeds is less in these districts. This is especially true of bees in the most northern Pestovsky district, they are the most close to the Central Russian bees and retained their gene pool, although they underwent a significant mongrelism.

We can assume that in relatively isolated apiaries in the eastern and northeastern parts of the region, bees from the local population of the Central Russian breed survived. But the beekeepers of the region continue to import bees of other breeds in mass every year. Therefore, from each year, the possibility of preserving the gene pool of the local bee population decreases. This affects the overall biocological situation. For centuries, local bees have been an integral part of biocenoses, being the most important pollinators and participants in trophic chains of many organisms, and whether they can be replaced by bees of southern breeds, and subsequently by their crosses – is an open question.

5. Conclusion

Summing up, on the basis of the results obtained, we can say that in the territories of the studied districts there is a mixed crossbred population of bees, which includes characteristics of different breeds. Especially strongly visible is the influence of the Carpathian and Krainsky breed. We have to admit that among the investigated bees there are no purebred Central Russian bees. It is possible that they were preserved in separate amateur apiaries located in isolation, but this statement requires additional research. The greatest probability of preserving the gene pool of local bees exists in the eastern and northeastern regions of the region.

If we predict the development of the situation for the future, we can assume that the influx of the Carpathian and Krainsky genes to the local bees will continue. After some time, a stable population of bees will be formed on the territory of the Novgorod region, which will be closer to these breeds in the characteristics, and not to the local Central Russian one. Unfortunately, this situation can be considered as an example of a reduction in the natural biodiversity, which threatens local biocenoses, especially given the important role of honey bees in them.
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