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A Biological Method of Ecological Assessment of Large Areas

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Abstract:

Currently in Siberia, the beekeeping industry is mainly based southward of the Trans-Siberian Railway. In these areas, the main part of agricultural production is concentrated; vegetables and fruit accumulate harmful substances from fertilizers, automobile exhaust gases and emissions of industrial enterprises. Northward of the Trans-Siberian Railway, there is a huge area of 50° up to 60° northern latitude of terrain. This territory is called the Vasyugan Swamp. There are no industrial enterprises, railways, highways in this vast territory, and there are almost no settlements at all.

The purpose of our research is to identify the territory that is ecologically safe for food production. To determine the environmental friendliness of the area, two indicators were taken, which are easily quantifiable in the terrain. Such indicators are bumblebees and honey bees. These two groups of insects are sensitive to environmental safety; therefore, their numbers are always monitored. A large amount of insects is a reliable indicator of the environmental friendliness of the terrain. Additional data were obtained for the observation of other insect species. The number of natural plant communities of the nectar-polliniferous orientation was determined by expeditionary inspection.

Applying the developed methodology for assessing the environmental friendliness of the terrain for habitation of bumblebees, the ecological safety of the Vasyuganye territory for habitation of bumblebees was determined from 25 ± 0,61 to 40 ± 0,45 pcs. per 100 m^2. At the same time, 100 km southward, bumblebees were not met or met in an amount not exceeding 10 ± 0,21 pcs. per 100 m^2. The ecological safety of Vasyuganye promotes mass reproduction of insect competitors of honey bees, found gathering nectar from all flowering plants. The representatives of the following orders were met in large numbers: *Hymenoptera, Diptera, Hemiptera, Lepidoptera, Coleoptera, Orthoptera.* In the north of Western Siberia, during expedition routes and terrain valuation around the apiary, more than 100 species of nectar-secreting plants were found, which could produce commercial honey and create industrial stationary apiaries.

Keywords: latitude and longitude of terrain, record of insects, pollutants of terrain, nectariferous plants, polliniferous plants.

INTRODUCTION

One of the main problems of the 21st century is the creation of a safe ecological environment for the production of vegetable and animal foods. In Western Siberia, the zone of active farming and farm animals breeding is concentrated to the south of the fiftieth degree of northern latitude. In this area, for the production of vegetable foods, in addition to the constant active processing of land for plant care, mineral fertilizers, pesticides, herbicides are used and agricultural burnings are annually carried out. Meadows are mowed to feed animals, pastures are trampled by cattle. In addition to this, the atmosphere is filled with exhaust gases from numerous automobile transport and motor vehicles working in fields and hayfields. Large cities have an enormous influence on atmosphere pollution and soil contamination: Omsk, Novokuznetsk, Barnaul, Novosibirsk, Berdsk, Barabinsk, and others. Industrial enterprises pollute the environment with hazardous wastes – lead, arsenic, sulfur, phosphorus, cadmium, asbestos. These harmful substances are assimilated by vegetables, fruit, berries, mushrooms, grain; they accumulate in meat and other livestock products. Such a dangerous ecological situation, not only in the south of Western Siberia, but also worldwide, is of concern for humanity in all countries. The production of environmentally friendly goods, such as vegetables, fruit, berries, meat, honey, and others, is therefore at the forefront of food production [1; 2].

When assessing the ecological safety of a specific territory, the air pollution by gases and contamination of food products are usually defined. These jobs require highly skilled professionals: chemists, doctors, and veterinarians. The laboratories with very expensive equipment and reagents are required. Note that all the tests are expensive. And also with such approach it is impossible to give an environmental assessment of a large territory. Such details are usually of local importance.

In view of this, it is necessary to develop a rapid assessment methodology for large areas when assessing the ecological condition of the terrain. In this article, we represent a solution to this problem.

The second issue of concern to the people of all countries is the desire to identify territories with a pristine environment, with a view of producing environmentally friendly foods on this land. Foodstuffs produced in an ecologically safe area are classified as organic products, not to mention their value. Expensive eco-friendly products do not frighten off consumers with their high price, but, on the contrary, attract them by cleanliness and safety.

It should be noted that in Western Siberia there is the most extensive environmentally safe area in the world. It is located in the north above the fiftieth degree of northern latitude and from west to east from 73° up to 86° eastern longitude. This region is located from the right bank of the Irtysh River to the left bank of the Ob River; its length is 573 km long and 320 km to the north. This ecologically clean area is not only the treasure of a number of constituent entities of the Russian Federation – the Omsk, Novosibirsk, and Tomsk Regions, but also of the entire country [3]. In this area, it is possible to create ecologically safe beekeeping. In this case, the population of the Russian Federation will be fully provided with food, and the drug industry – with precious crude drugs. In addition to meeting the needs of its own population, this territory will export ecologically safe bee products.

This area must be preserved and used wisely.

The territory of Western Siberia, located to the north of 50° northern latitude and 73-86° eastern longitude, attracts by the fact that in this region, covered with swamps and land occupied by vegetation, there are no cities, settlements and villages; only small settlements are occasionally found. All human settlements are connected with the district centers only by country roads used only by animal-drawn vehicles, and for most of the year, these roads are impassable even for animal-drawn transport (periods of spring and autumn muddy seasons). Thus, the negative human impact on the environment is completely excluded.

Wind pattern acts only in one direction; winds clean the atmosphere of cities from smog. In the opposite direction, the movement of air masses from the polluted atmosphere of cities is not observed. Given all of the above factors, it can be argued that the northern territory of Western Siberia is environmentally friendly. To draw a final conclusion, it was necessary to study in detail the flora and fauna, their mutual relations. After receiving the results of environmental research experiments, it will be necessary to carry out experiments to establish industrial stationary apiaries with a high marketable value of ecologically safe beekeeping products.

METHODS

It has long been known that the pioneer in the development of new living spaces is the beekeeping industry. Back in the tenth century, beginning with the development of forests in Central Russia, the first "honey hunters" appeared. They produced honey and wax. These products were the main export commodity in Rus. Rus traded honey and wax, and furs held the third place.

The purpose of our study consisted in the search for a terrain suitable for keeping industrial apiaries for the production of ecologically safe beekeeping products.

Work on the study of vegetation was carried out by expeditionary surveys in the northern part of the Novosibirsk Region, as well as the Tomsk Region (Narymsky Krai) – the territory of the Vasyugan swamps (Vasyuganye). During the expedition surveys, we determined, which species of nectariferous and polliniferous plants grew in the form of trees, shrubs, half-shrubs, perennial herbaceous plants, biennial and annual ones; whether they secreted nectar and provided insects with pollen or not. We estimated, which species of honey plants did not grow northward of 50° northern latitudes, and which species grew well, but did not secrete nectar, and which species in this area produced nectar and pollen, i.e. studied the biological features of flowering plants. The secretion of nectar was determined primarily visually [4-6]. But the most important assessment of the suitability of plants was determined by visiting the flowers with insects, taking into account the number of their families and species that attract insects. We defined the speed of the insect to collect nectar and pollen [4].

Usually, veterinary and other laboratories, where they analyze food for the presence of harmful substances, are involved in assessing the terrain for environmental safety. We have used this technique and we have seen that it is impossible to give an objective assessment quickly and in a large territory, since it is highly labor-intensive and too expansive.

It should be noted that such expensive evaluation of products does not provide a comprehensive overview of how this affects the fauna of the given terrain.

We assumed that if the terrain is environmentally safe, therefore, this should affect the increase in the number of species of the animal world, in particular, insects. Therefore, this method of determining the environmental friendliness of the area for ordinary beekeepers and specialists of other industries for which it is necessary to assess environmental safety before embarking on the creation of an agricultural food production sector, seems to be the most objective and acceptable.

The class of "insects" in the number of species exceeds all other classes of the animal world. In general, all species of this class are associated with plants and cannot exist without them. But most species only parasitize on plants, for example, the order Lepidoptera. Currently, only butterflies (Lepidoptera) amount to more than 140,000 species, and all of them, using plants as a fodder base, inflict enormous devastation on the plant world: a gypsy moth (*Lymantria dispar* L.) destroys in a year up to 1.5 million hectares of forest. Small butterflies of sod webworm (*Pyrausta sticticalis* L.) feed on nectar and proliferate. The grubs of sod webworm cause devastation in the plant world. In the Novosibirsk Region, this happens periodically; the grubs of sod webworm destroy all vegetation just as much as the family "grasshoppers" (Acrididae). No less are the "merits" of sulphur butterflies (Pieridae): thorn butterfly (*Aporia crataegi* L.), cabbage white butterfly (*Pieris Brassicae* L.), small tortoiseshell (*Aglais urticae* L.) from the family "Brush-footed butterflies" (Nymphalidae), etc. [5].

But in the class of "insects" there are two families that not only do not harm plants, but, conversely, plants cannot live without them. These are Apidae (true bees) and Bombidae (bumblebees). These two families in the process of co-evolution have created a close relationship with the plant world. They do not exchange genetic information, but are closely related as species-partners, requiring each other. The result of co-evolution is the mutual adaptation of bees

and bumblebees with flowering plants. And if they have a connection with other groups, for example, gymnosperms, or wind-pollinated plants (alder, birch, aspen, plantain, rye, etc.), then this phenomenon is secondary.

Visiting flowers, butterflies, blood-sucking insects, flies, wasps, beetles and a number of others feed on nectar and pollen; they do not bring benefits to plants, but on the contrary, they often injure flowers. For example, the beetles of the Cetonia family (Potosia Muls.) "plow out" stamens and ovaries in the flower, making the plants fruitless. Just the same way beetles handle with wheat, etc.

For 27 years, we annually observed the number of insects in the localities, southward and northward of the fiftieth degree of northern latitude. We noted the difference in the number of bloodsucking insects, butterflies and moths, beetles, etc. only visually. Farther southward, there were either very few of them or not any at all. However, northward the number of representatives of all the orders and families was exceptionally large.

We decided to measure the difference in the number of insects living southward of 50° north latitude and simultaneously of those living northward of 50° northern latitude. The representatives of two families which are necessary for the reproduction of floral plants were used as indicators; these are *Apis mellifera* L. and Bombidae.

Usually, to determine the number of insects, entomologists use a technique consisting of three points: 1) mowing with a standard entomological net for the purpose of counting the number of fauna; 2) visual collection of insects with an exhauster from individual plants in a tenfold repetition; 3) gathering of pupae, larvae, damages taking into account square sites with a side of 1 m.

We believe that this is not enough and decided to supplement this technique with an actual record of bees and bumblebees working on flowers to the south of 50° northern latitude and 100 km northward of 50° northern latitude of Western Siberia. To compare the work of insects objectively, a well-known Siberian plant (*Melilotus officinalis* L.) was taken. Records and observations have been carried out on the plots of the continuous cover of a sweet clover 1 m width and 100 m length, i.e. on the square of 100 m^2.

It is easy to count working bees, bumblebees, and other insects feeding on nectar and pollen on this site. [4; 7-14]

The observer goes along the strip and counts insects collecting nectar or pollen. After each passage, the number of registered bees, bumblebees and other insects is recorded in a fieldnote. The records were held three times a day – from 9.00 am to 10.00 am; from 12.00 am to 01.00 pm; from 5.00 pm to 6.00 pm. In case there were many insects, 10 passes were taken per hour, and when there were fewer ones, then 15 passes were taken. After each pass, the data received were processed by variance statistics method. The work was carried out simultaneously by two observers. One of them registered bees and bumblebees on the field of sweet clover, located to the south of 50° northern latitude, the other registered the data on the field, located at 100 km distance from 50° northern latitude strictly to the north. The observations were carried out for 2 years, during the mass flowering of a sweet clover.

Based on the difference in the established number of species and individuals, conclusions were drawn about the ecological safety of the zone.

The main elements of the insect's life environment (environmental factors) are: climate, soil, vegetation, other animals, and human beings. Heat and moisture are the main factors in climatic conditions; wind and light are of less importance. Every insect is limited in its spreading: 1) geographically, i.e. it lives in some countries and is entirely absent in others, occupying a certain area or habitat on the earth surface; 2) ecologically, i.e. it does not live everywhere within its habitat and takes only those areas where conditions necessary for its life can be found.

Alongside with recording the species of insects, it was necessary to define the plants' species which were able to secrete nectar and provide all numerous species and orders of insects with beebread. This main issue of the relationship between fauna and flora northward of 50° north latitude was solved this way: we defined by means of expeditionary routes the species of nectariferous and polliniferous plants and the species not secreting nectar. To carry out this work, 60 observers among the students of the Faculty of Biology and Technology of the Novosibirsk State Agrarian University were involved. The main researcher and performer of this work assigned each observer for one species of plant. The plant should be well developed and take fully the square of 1 m^2.

Simultaneously, the observers for 60 species registered for 3 days the work of honey bees, bumblebees, and all other types of insects that fed on nectar and pollen in the midst of mass flowering. It resulted in identifying the most productive plants and the number of competitors of honey bees. The observations were conducted for two years, every year three times a day from 9.00 am till 10.00 am; from 12.00 am till 1.00 pm and from 5.00 pm till 6.00 pm.

RESULTS

Numerous sources of scientific research report the fact of a widespread decrease in the number of bumblebees [3; 15-17]. The reason is the plowing of land, laylands, field boundaries, processing fields against pests and weeds. Processing fields against pests kills primarily useful insects: bumblebees (Bombidae), single bees, and parasitoid wasps (Ichneumonidea).

During our survey, two observers registered the number of bees and bumblebees working during the mass flowering of the yellow sweet clover (*Melilotus officinalis* L.), in the fields southward and northward of 50° northern latitude of Western Siberia two years running. The results of comparative records are summarized in Table 1.

Table 1. The number of bees and bumblebees working on flowers *Melilotus officinalis* L. (pieces per 100 m^2)

50 km to the south of 50° northern latitude of Western Siberia		100 km to the north of 50° northern latitude of Western Siberia	
bees	**bumblebees**	**bees**	**bumblebees**
From 9 am till 10 am			
155.00 ± 1.06	no	116.00 ± 1.96	37.00 ± 1.06
From 12 am till 1.00 pm			
171.00 ± 1.0	10.00 ± 0.21	126.00 ± 2.0	40.00 ± 0.45
From 5 pm till 6 pm			
145.00± 1.5	no	66.00 ± 1.18	25.00 ± 0.61

Analyzing the results of biennial observations (Table) for the number of bees and bumblebees, it can safely be concluded that a dangerous ecological situation has been created for bumblebees in the southern zone of active agriculture. There are many highways in this area with a 24-hour road traffic. The fields are powered by motor vehicles (tractors, combines, and trucks). The fields are treated with herbicides and insecticides. We rarely met a common carder bee (*Bombus agrorum* F.) in this zone, in built nests on the edge of the forest, woodlands, in the trash of old rotten stumps. A bumblebee builds a nest from moss, dry grass, leaves. It works well on red clover flowers. In one minute, it visits 26 flowers. The second type is a garden bumblebee (*Bombus hortorum* L.), which appears in early spring on the flowers of honeyberry (*Lonicera edulis* Turcz. ex Freyn). This species is also found on the flowers of red clover, where it visits 29 flowers in a minute. The third species is a white-tailed bumblebee (*Bombus lucorum* L.). This species is also called an operator; it gnaws a corolla's tube of a red clover flower at the bottom and sucks nectar through this hole. With this work, the bumblebee does not pollinate the clover, so bees use this method, extracting nectar. Agronomists often refer this species of bumblebees to pests [4].

This bumblebee can be found on the flowering fields of broad beans (*Vicia faba* L.). During the hot part of the day from 01.00 pm till 04.00 pm, you can hear how the bumblebee gnaws the bottom of the flower. Approach carefully following the sound and you will find this "worker". We have examined the flowers and found out the results of bumblebee-operator's work almost in all of them.

Northward of 50° northern latitude, the ecological situation is aggravated, in spite of severe climatic conditions (long frosty period – up to -55° C, and frequent cold nights in the summer, the temperature drops to 7-10 degrees). But the fact that nature in these latitudes has remained virgin not deformed by man proves that the zone is safe in general. The world of insects is thriving in a safe zone. In this zone, seven additional species of bumble bees: red-tailed bumblebee (*Bombus lapidarius* L.), tree bumblebee (*Bombus hypnorum* L.), great yellow bumblebee (*Bombus distinguendus* F.), short-haired bumblebee (*Bombus subterraneus* Est.), shrill carder bee (*Bombus sylvarum* l.), cuckoo bumblebee (*Bombus salstitialis* Pr.), moss carder bee (*Bombus muscorum* F.) have been found, except for three species of bumblebees that had been found in the warm southern, but rather dangerous environment.

The same is the diversity of species of butterflies and moths (Lepidoptera), beetles (Coleoptera), flies (Diptera), hymenopterans (Hymenoptera), true bags (Hemiptera), net-winged insects (Neuroptera), orthopterous insects (Orthoptera). From Hymenoptera there inhabits European hornet (*Vespa crabro* L.), wood wasp (*Vespula silvestris* Scop.), the family "Digger wasps" (Sphecidae). There are many insects of the order Diptera, suborder "Short-horned straight-seamed flies" (Brachycera-Orthorrhapha), families: Horse-flies (Tabanidae), Bee flies (Bombyliidae), Assassin flies (Asilidae); Short-horned circular-seamed flies' suborder (Brachycera-Cyclorrhapha) families: Hoverflies (Syrphidae), Botflies (Oestrinae), Louse flies (Hippoboscidae) (forest fly – *Hippoboscidae equina* L.) [9].

In addition to observations and records of the number of bumblebees in the southern and northern zones, we paid attention to the number of bloodsucking insects. Bloodsuckers are rare in the southern agricultural region of Western Siberia. People cannot live and work without protective clothing in the northern zone (Vasyuganye).

To assess the environmental situation, we, along with assistants, conducted records of insects visiting flowers for nectar and pollen feeding. The work was performed annually for 9 years.

While recording the types of vegetation in the area of Vasyuganye (100 km to the north of 50° northern latitude), 44 species of nectariferous plants were found. The nectar bearing capacity of each species was defined by the number of insects visiting flowers to eat nectar and pollen. These plants turned out to be the most attractive for insects. The record of insects' species, working specifically on each nectariferous plant, apart from these 44 plants, resulted in the discovery of further 70 plant species, which attracted insects but in lesser degree. Therefore, we can assume that 114 species of plants growing in the territory of Vasyuganye provide a large number of insects with their nectar. At the same time, 27 species of plants providing insects with pollen have also been discovered and registered. Let us name only the families: the birch family (Betulaceae), Lythraceae (Lythraceae), Apiaceae (Umbelliferae), the willow family (Salicaceae), Guttiferae (Hypericaceae), Poaceae (Gramineae), the dogwood family (Cornaceae), the hemp family (Cannabaceae), the buttercup family (Ranunculaceae), the figwort family (Scrophulariaceae), the plantain family (Plantaginaceae), Rosales (Rosaseae), Asteraceae (Compositae), the pine family (Pinaceae), the goosefoot family (Chenopodiadeae).

Our expeditionary surveys showed that 22 species of nectariferous and beebread-bearing plants were not found northward of 50° north latitude of Western Siberia as these species grew southward of this latitude. All these plants in the south of Western Siberia enable honey bees to bring 800-1000 grams of pollen load to the hive. Their absence in the area of Vasyuganye makes the nutrition of insects poor, so honey bees bring only 20-100 grams of pollen load to the hive a day. This gathering of pollen load provides bee colonies, but is not enough to obtain marketable products.

The second feature of the forage of beekeeping in Western Siberia, according to our data, is that there are plants that grow both in the south and in the north of Western Siberia. But they behave differently. In the south, they secrete nectar, and in the north they do not secrete it, so insects do not visit them. There are only seven of such plants: bird cherry (*Padus avium* Mill.), caragana tree, or a Siberian peashrub (*Caragana arborescens* Lam.), sally-bloom, or fireweed (*Epilobium angustifolium* L.), valerian (*Valeriana officinalis* L. sl), breaking buckthorn, or alder buckthorn (*Frangula alnus* Mill.), burnet bloodwort (*Sanguisorba officinalis* L.), Siberian mountain ash (*Sorbus sibirica* Hedl.).

Siberian peashrub among the nectariferous plants, in the south of Western Siberia, in the Barzas taiga, in Gornaya Shoria is a plant, which secretes nectar abundantly. Bees collected a record number of nectar – 16 kg 700 g a day from this plant [6]. Bees produce one of the world's finest flavors of honey from the nectar of Siberian peashrub. In the area of Vasyuganye, bees do not visit the flowers of Siberian peashrub, as this plant does not secrete nectar and pollen. It is a great loss for beekeeping of the north.

The second widely known nectariferous species is sally-bloom, or fireweed. This plant came to be known on the Kola Peninsula, far beyond the Arctic Circle, for secreting abundant nectar. The bees taken out by the beekeepers of the Moscow Timiryazev Agricultural Academy collected commercial fireweed honey up to 90 kg on average per a hive. This plant is widely found in the Urals, Western Siberia, Eastern Siberia, the Far East, and Sakhalin. It secretes especially abundant nectar in the expanses of Eastern Siberia. So, a bee family brought 24 kg of nectar a day on the apiary of A.I. Demko, in Bogotolsky District of the Krasnoyarsk Krai, on the border with Western Siberia. At the apiary consisting of 160 honey-bee colonies, each family collected 180 kg of willowherb honey.

In the Vasyuganye area, thickets of fireweed occupy large areas, but bees do not visit flowers and honey gathering is not observed. The abundant gathering of fireweed honey from the Arctic Circle of the Kola Peninsula (the Murmansk region) is associated with the warm current of the Gulf Stream. In the area of Vasyuganye, there is no warm current in the vicinity, and fireweed in a harsh climate has lost the ability to produce nectar.

Professor G.A. Avetisyan [18-19] and P.I. Martynova [20-21] stated that farther to the north, the more nectar was produced by the same species (fireweed). On this ground, they proposed to carry out migration of apiaries vertically, i.e. starting in southern Siberia to keep the apiary near the expanse of fireweed, and in the course of blossom fall to transport the apiary to the north, where this species just started to break into bloom. In this way, the apiary should be moved from the south to the north. Our observations showed that in the area of Western Siberia, the plants behave differently and the migration of apiaries from the south to the north following blossoming fireweed is meaningless. We just have to regret that such migration is impossible in Western Siberia.

DISCUSSION

The above-mentioned facts lead us to the conclusion that the huge region located northward of 50° northern latitude and 73-86° eastern longitude of Western Siberia is not rationally used, but this territory attracts attention by its virgin purity. The ecological cleanliness or security of the terrain is on a special account in each country. In such territory, food and raw materials produced for the pharmaceutical industry are invaluable. The mentioned region having the name "Vasyugan Swamps" or simply "Vasyuganye" has been little studied from the ecological and, especially from the practical point of view.

Taking into account the historical experience in the development of new territories – the central regions of Russia, where there are dense forests, beekeeping was first mastered by bee hunters. They produced honey, wax and fur. Rus traded honey and wax (the main export goods) and furs. After beekeeping, other branches of agriculture appeared. So it was in Siberia, in the Far East, in Australia, and in the Northern and Southern Americas. Until the bees appeared in Siberia in 1792, there were such industries as horse breeding, large-scale animal husbandry and sheep breeding. Only after the appearance of bees there emerged gardening, horticulture, buckwheat cultivation, cultivation of industrial crops such as sunflower, mustard, rapeseed, and flax; production of berries appeared.

By using numerous examples of development of new territories, we propose the same way to develop a region unique in terms of area sizes and environmental friendliness. So, according to our calculations, over 6,000 stationary apiaries can be established and placed in the territory of Vasyuganye.

CONCLUSION

Vasyganye, covering a territory of 573 km from west to east and 320 km to the north, has an exceptionally ecological purity. In this area, 114 species of nectariferous plants grow. These plants are not cultivated; they grow naturally. The numerous types of insects existing in this territory cannot collect annually secreted nectar; therefore, ten thousand tons of nectar remains unused every year.

The obtained results of studies and the first practical experiments on the keeping of honey bees in the stationary apiaries of Vasyuganye allow recommending by creating a beekeeping industry to receive tens of thousands of tons of environmentally friendly honey.

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