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EVALUATION OF THE INFLUENCE OF ANTHROPOGENIC FRAGMENTATION OF INTACT ECOSYSTEMS OF THE SOUTHERN TAIGA OF THE NIZHNY NOVGOROD REGION ON SPECIES DIVERSITY OF MODEL GROUPS OF LIVING ORGANISMS

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ABSTRACT

The influence of fragmentation on biodiversity of the Southern taiga forest ecosystems (the Trans-Volga part of Nizhny Novgorod region) is discussed. The correlation between species numbers and the area of forest fragments is analyzed. The "island" effects do not occur in the existing network of natural habitats in the Nizhny Novgorod Transvolga region.

Keywords: southern taiga, Nizhny Novgorod region, anthropogenic fragmentation of habitats, birds, ground beetles, higher plants.

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INTRODUCTION

The theory of dynamic equilibrium of island biogeography has received growing attention from academics for decades [1]. There are many research that studies the effect of habitat fragmentation on living organisms of various systematic groups [5, 7, 8, 10, 14, 15 etc.]. Such studies are of great practical importance for the conservation of biological diversity and the formation of regional and national levels network of natural habitats.

In the 1980-90s the state of biological diversity in the Nizhny Novgorod region was assessed as increasingly critical. The preservation of most types of natural ecosystems was negligible. The share of species that need special protection in the model groups of living organisms was about 30%. The main limiting factor for most rare species was the destruction of habitats [2]. The most important step on the way to overcoming the crisis was the establishment of Protected Areas (PA) that preserve intact ecosystems with a large set of rare species of living organisms.

The state of biological diversity in the southern taiga with nemoral elements of in the Nizhny Novgorod region was also critical. The intact areas of the southern taiga, preserved only by 2% of the former territory, need special protection. Currently, a significant part of these taiga fragments is located in protected areas. However, their number and area has remained unknown to be sufficient to conserve biodiversity and maintain ecological balance.

It is known that fragmentation of natural ecosystems leads to a reduction in species diversity. Therefore, the establishment of small protected areas isolated from each other can be ineffective for its conservation. However, in the Nizhny Novgorod region, the majority of protected fragments of old-growth forests are included in large forest areas. The manifestation of “island” effects under such conditions is not sufficiently studied.

It is advisable to establish the importance of protected areas of different sizes for the conservation of biodiversity, its possible role as sources of species distribution that are characteristic of late stages of succession of forest ecosystems. Inventory of the biota of the preserved taiga sites and its surroundings is necessary for this. Inventory of all systematic groups of living organisms requires long-term studies, so it is necessary to select a small number of model groups.

Establishment of patterns of conservation of the richness and diversity of species of living organisms, depending on the area and degree of isolation of protected areas of old-growth forests, will allow assessing the ecological effectiveness of the existing network of protected areas in the southern taiga coniferous forests. An effectively functioning ecological network will ensure conservation of biodiversity and sustainable development of the territory.

The research aimed at assessing the impact of anthropogenic fragmentation of old-growth southern taiga forests on the conservation of species richness and diversity of model groups of living organisms in the territory of the Nizhny Novgorod Transvolga region was started in 2008 [3]. The inventory studies were continued on a larger number of model areas to confirm the data received in 2009.

Brief description of the surveyed area

The territory of the north of the Nizhny Novgorod region lies within the subzonal strip of the southern taiga of the Eurasian taiga (coniferous evergreen forests) botanical-geographical area [12]. The zonal type - the Eurasian coniferous forests - includes forests dominated by *Picea abies* and *Abies sibirica*. Temperate broad-leaf and coniferous forests are also included here, since the coniferous species also have an edificatory role.

At present, all natural ecosystems have changed under the influence of human economic activity. Ecosystems are completely destroyed or radically transformed over a large area. Only 2.2% of the southern taiga coniferous forests have not changed. The primary vegetation of the floodplains was preserved only by 4.4% of its former area. 40% of bogs and less than 10% of pine forests remained in good condition [2]. Most natural old-growth forests are divided into small areas, the space between which is occupied by deciduous

(birch or aspen) or pine forests, as well as agricultural, industrial and residential areas. Areas of old-growth forests with an area of more than 1000 hectares are practically not preserved [4].

Open spaces of Nizhny Novgorod Transvolga region are cultivated lands or meadows (hayfields and pastures) of anthropogenic origin. Only forests and swamps belong to the natural communities of this territory. Initially, the continuous forest cover in the Nizhny Novgorod Transvolga region during settlement and development was cut into separate arrays and fragments by large areas of anthropogenic (agrocenoses) and natural-anthropogenic (meadows used as pastures and hayfields) ecosystems. Fragmentation of natural ecosystems was reinforced by anthropogenic infrastructure (road network and settlements). The riverbed of the Vetluga River can be considered as the only natural insulating barrier in the Northern Transvolga region. Assessment of fragmentation of natural ecosystems (forests and wetlands) of the Nizhny Novgorod Thansvolga region was carried out using GIS-software [3].

Methods of Research

There were selected 11 model sites of intact southern taiga coniferous forests located in Vetluzhsky, Varnavinsky, Tonkinsky, Sharangsky and Voskresensky districts of the Nizhny Novgorod region. The list and areas of the model sites are presented in Table 1. There are old-growth fir-spruce forests with nemoral elements, as well as fir-spruce and other types of spruce forests on all areas. The sites vary in area, degree of isolation, the presence and size of the watercourses, the severity of the parcel structure and anthropogenic disturbances of recent decades.

Table 1: Model sections of the southern taiga selected for field research

№	Model sites	District	Area of the unfragmented sites of natural ecosystems, km^2	The area of the old-growth southern taiga site, km^2
1	Forests of the Lapshanga forestry	Varnavinsky	285,18	19,70
2	Forest along the river Varvage	Varnavinsky	17,92	1,22
3	Tonkinsky Reserve (easternpart)	Tonkinsky	9,76	5,40
4	Tonkinsky Reserve (westernpart)	Tonkinsky	16,26	9,81
5	Forest on the River Shkleya in the Kilemar Reserve	Sharangsky	1967,64	58,53
6	Forest near the Mars village	Sharangsky	7,61	4,77
7	Forest near the former Permyaki village	Sharangsky	1,26	0,96
8	Forest near the former Lomna village	Tonkinsk	0,15	0,13
9	Forest near the former Kopani village	Sharangsky	0,71	0,34
10	Forest along the Yurong River in the Kilemar Reserve	Voskresensky	1967,64	14,67
11	Reserve "Klenovik"	Vetluzhsky	473,07	4,85

Birds, ground beetles (*Carabidae*) and vascular plants were selected as model groups of living organisms for inventory. All of them meet the requirements for model organisms: they are diverse, well-researched, easy to study, and can serve as indicators of ecosystem failure.

All the encountered bird species were recorded during the survey of model sites. The birds were recorded on temporary walking routes according to the standard method of recording birds by the voice of singing males and visually in a fixed recording area to establish the relative abundance [9].

Beetles gathered in all model sites between 1.05.09 and 4.08.09 according to the method of catching herpetobiont invertebrates by Barber's traps [11]. Barber's traps were plastic bottles with a capacity of 0.2 liters and a 65 mm inlet diameter. The traps were placed with the upper edge on the surface of the soil in lines of 25 pieces. The distance between the traps was 5 m. In total 22 lines of traps were established and 40885 trap-days were worked out.

Species composition of flora of vascular plants in the studied areas was revealed by the route method. Considered all the plant species encountered along the routes. Floristic lists on all model areas were made twice: at the first examination in the middle of June and at the repeated inspection in the end of July. The geographic coordinates of the places of growth of the species of vascular plants recorded in the Red Books of Russia and the Nizhny Novgorod region were noted using a GPS navigator.

The dependence of the number of species on the habitat area is expressed using the formula:

$$S=C*A^{z},$$

where S is the number of species, A is the area, and z and C are dimensionless parameters, the value of which should be selected for each particular set of data on the number of species and areas. The logarithmic transformation of this function leads to a linear connection. This allows us to calculate the value of z by analyzing the linear equation:

$$\log S = z*\log A + \text{constant}. \quad (1)$$

In this equation, z characterizes the slope of the direct graph of this function. The values of z vary depending on whether the characterized object is really an isolate or simply a sample [6].

In the coordinate field, the logarithm of the number of species (S) was plotted along the X axis, and the logarithm of the area of the forest plot (A) was plotted along the Y axis, points corresponding to the specific values of these values for the model objects of the southern taiga investigated. The least-squares method was used to plot the linear dependence of the points obtained. According to the graph, the equation of the function was obtained and the value of z was determined.

RESULTS AND ITS DISCUSSION

In total, during the study of model areas of southern taiga forests 76 species of birds were found, 8729 specimens of ground beetles belonging to 42 species were caught and 331 species of vascular plants were recorded. The number of species of birds, ground beetles and plants encountered in each model site is shown in Table 2.

Table 2: Number of species of model living organisms recorded in model sites

№	Model sites	Number of species		
		birds	Ground beetles	plants
1	Forests of the Lapshanga forestry	47	19	168
2	Forest along the River Varvage	45	15	172
3	Tonkinsky Reserve (easternpart)	47	19	148
4	Tonkinsky Reserve (westernpart)	48	26	138
5	Forest on the River Shkleya in the Kilemar Reserve	51	23	194
6	Forest near the Mars village	46	24	127
7	Forest near the former Permyaki village	49	25	163
8	Forest near the former Lomna village	36	20	108
9	Forest near the former Kopani village	42	17	144
10	Forest along the Yurong River in the Kilemar Reserve	49	27	215
11	Reserve "Klenovik"	43	18	169

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The obtained dependences of the species number of each model group on the area of the unfragmented forests in general and the preserved intact taiga fragment are shown in Fig. 1-6. The values of the coefficient z were calculated as a result of the analysis of equation (1) (Table 3).

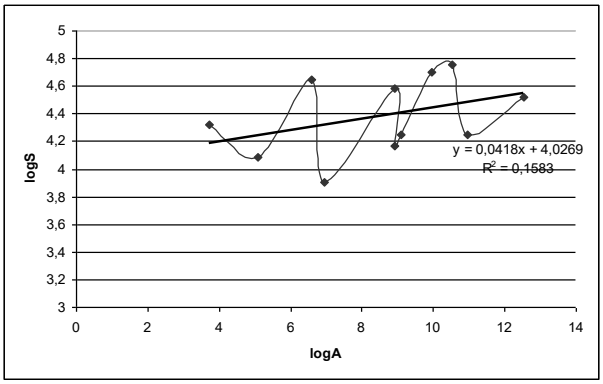

Figure 1: Dependence of the number of ground beetles on the area of the old-growth southern taiga

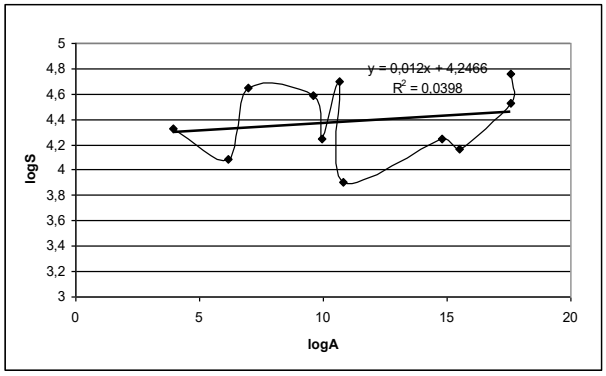

Figure 2: Dependence of the number of ground beetles on the unfragmented area of natural ecosystems

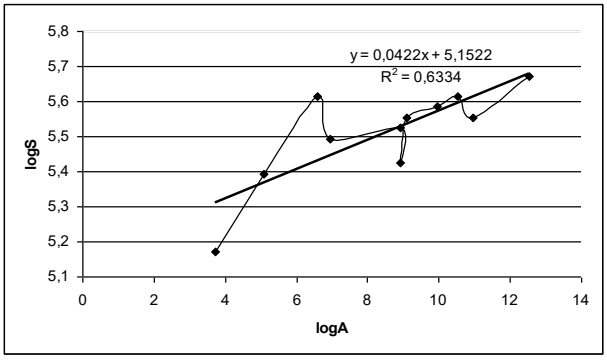

Figure 3: Dependence of the number of bird species on the area of the old-growth southern taiga

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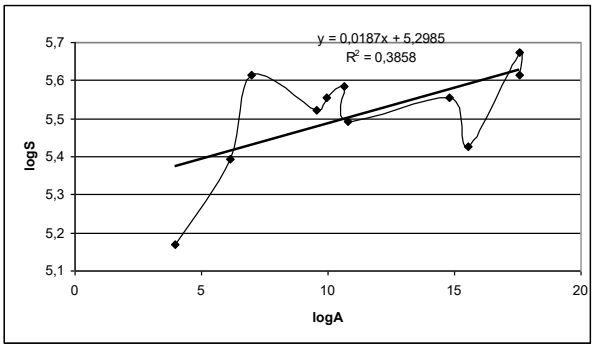

Figure 4: Dependence of the number of bird species on the unfragmented area of natural ecosystems

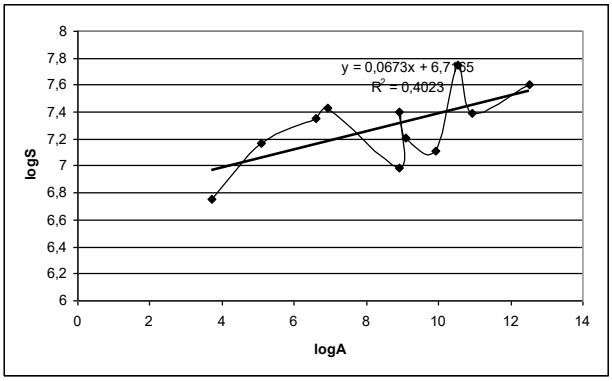

Figure 5: Dependence of the number of plant species on the area of the old-growth southern taiga

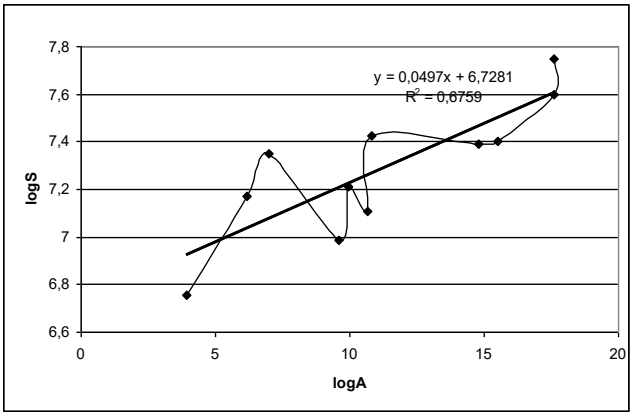

Figure 6: Dependence of the number of plant species on the unfragmented area of natural ecosystems

Table 3: The exponents of the coefficient Z in the equation of a linear function logS = zlogA + C

Model Group	of the area of the old-growth southern taiga	of the unfragmented area of natural ecosystems
Ground beetles	0,0418	0,012
Birds	0,0422	0,0187
Plants	0,0673	0,0497

The values of z vary depending on whether the characterized object is really an isolate or simply a sample. The range of values of z less than 0.17 is characteristic for samples, the range from 0.18 to 0.35 is characteristic for isolates [6].

The dependence of the number of species of living organisms on the area of the surviving fragment of habitats revealed by us corresponds to characteristic of samples. This confirms the assumption that there are no “island” effects in the conditions of the preserved natural network of the Nizhny Novgorod Transvolga region.

The protected areas with the largest remaining old-growth coniferous forests are the most important for the conservation of biological diversity in the Nizhny Novgorod Transvolga region. Such territories are inhabited by the largest number of rare wildlife species, as well as species characteristic of late stages of succession of forest ecosystems. A number of rare and endangered species is found only in the largest fragments of intact forests. The role of large protected areas as sources of conservation and settlement of such species can not be overemphasized. At the same time, large areas are separated from each other by tens of kilometers, which create insurmountable obstacles to the settlement of many wildlife organisms.

Under conditions of the preserved natural framework, which is typical for the north of the Nizhny Novgorod region, the influence of “island” effects on the species composition of model groups of wildlife organisms is absent. Therefore, a significant contribution to the conservation of rare wildlife species and their habitats is also made by protected areas of small size. In addition, in the intervals between large undisturbed massifs, small protected areas contribute significantly to the dispersal of rare species and characteristic for later stages of succession.

CONCLUSION

Research have confirmed the theoretical postulate of N.F. Reimers [13] that in the subzone of the southern taiga, the territorial ecological balance is maintained while preserving the natural ecosystems by at least 50% of the area. In the Nizhny Novgorod Transvolga region with a forest cover of more than 50%, natural ecosystems function as a natural framework of ecological stability, preventing the occurrence of island effects. Protected areas serve as refugia of rare and characteristic for the late stages of succession of wildlife. The prerequisite for the effective functioning of the network of protected areas is the protection of the largest remaining fragments of intact ecosystems that serve as habitats for the largest number of rare species of different size classes. In the Nizhny Novgorod region, compliance with this condition is largely ensured. The existing network of protected areas functions satisfactorily, although it needs to be expanded and strengthened.

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