Protection of the mainline territories of the Mountainous Crimea from technogenic physical factors

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Abstract. The structure of highways, their categories and features of laying, the scheme of high-voltage power lines in the Mountainous Crimea are considered. The assessment of the degree of isolation of forest areas, including specially protected natural areas, is given. The results of the study of the parameters of physical factors in the mainline territories – noise, lighting, electromagnetic field - are presented. The natural conditions and species composition of the animals of the Mountainous Crimea, the influence of the isolation of their habitats are analyzed. Recommendations are given on optimizing safe migration routes for animals across roads in the southwestern part of Crimea, considering the terrain.

1 Introduction

Road transport networks (RTN) are structures that are very closely connected with all components of the natural environment, these connections are primarily due to the ground location of roads, their linear nature and continuity. The specificity of the RTN impact as a whole consists in changing the structure of the territory and violating the ecological links between its individual parts. In particular, these linear engineering structures lead to landscape fragmentation and a decrease in the biological diversity of both the mainline territories and the entire region, in fact they are anthropogenic barriers [1-5].

2 Materials and Methods

The road network of the Mountainous Crimea is a communications system comprising two main highways of the rockade type, skirting this region from the north along the border with the steppe Crimea (Sevastopol - Simferopol - Belogorsk - Feodosia) and from the south along the Black Sea coast (Sevastopol - Yalta - Alushta - Sudak - Feodosia). Both highways are oriented in the "west-east" direction. They are connected by a number of roads oriented mainly in the north-south direction and crossing the mountainous and

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forested part of the territory of Crimea (Fig. 1).

The road network that has developed to date largely corresponds to the old and even ancient routes in this part of the peninsula. On the maps of the early - late nineteenth century [6-8], the roads of the Mountainous Crimea are shown with a foundation, in most sections almost coinciding with the modern one. The exception is roads that did not exist until the middle of the nineteenth century, for example, Sevastopol - Yalta, Sokolinoe - Yalta and some others. This coincidence is due to the relief and the requirements of the simplest and safest crossing of the mountain ranges of the main, inner and outer ridges along convenient passages. The modernization of roads carried out from the nineteenth century to the present has slightly changed their general directions. The surface, turns, slopes and other characteristics were improved.

The categories of roads in the Mountainous Crimea region range from IB (Tavrida highway) to IV (Bakhchisarai - Yalta and others), while only Tavrida and certain sections of the Simferopol - Yalta highway (category IB) are four-lane. Fences that prevent large animals from freely entering the roads are practically absent everywhere, except for the Tavrida section within the Mekenzievsky forestry within the administrative boundaries of the city of Sevastopol.

The roads Sevastopol - Yalta, Sevastopol - Kerch, Simferopol - Alushta, Stary Krym - Sudak and Stary Krym - Feodosia are accompanied by overhead lines with voltages of 110, 220 and 330 kV (Fig. 1). They are laid along the mainline territories through forests.

According to the above, the cumulative negative impact on the ecosystem of the Mountainous Crimea of roads and overhead lines is due to a number of physical factors:
- increased noise, which is characterized by unstable levels and maximum (peak) values, which are determined by the intensity and speed of movement, the composition of the traffic flow;
- excessive light at night from cars and in areas of artificial lighting of road sections;
- electromagnetic field of industrial frequency (50 Hz) from an overhead line with a voltage of 110 kV and higher;
- probability of an accident and injury to animals when they cross roads.

The criteria for assessing the harmful effects of physical factors of man-made origin are sanitary standards (MPL) for noise, lighting, and EMF parameters. For premises and territories in which human life is organized, the parameters of physical factors are regulated, with the exception of the maximum permissible values of illumination at night. There are no such norms for natural objects. This complicates the solution of the problem of protecting the wildlife of the Mountainous Crimea and other similar territories.

The purpose of the research of this work is to substantiate and define measures to protect animals from physical factors in the mainline territories in the Mountainous Crimea.

3 Research results and their analysis

The living conditions of animals near specific transport facilities are influenced by the "marginal zones" of landscapes with disturbed ecological systems, which are affected by the following physical factors:
- barrier factors (slopes, embankments, recesses, slopes, fences, screens, roadbed) that prevent the natural migration of species to their temporary and permanent habitats, gene pool exchange, reproduction, nutrition;
- anxiety factors (noise, light from moving traffic), frightening, disturbing animals and their habitat;
- factors that cause collisions with motor vehicles and deaths on the roads (direct risk factors for biota in addition to the risk from previous factors, "stretched" over time).

Based on the analysis of the above factors, the main large sections isolated from each
other by roads are identified on the territory of Crimea (Fig.1). These are central (1 and 2) and southwestern (3) parts of Sevastopol, central (4 and 5) and western (6, 7 and 8) parts on the territory of Crimea. Sites 4 and 5 are the least involved in economic activity and urbanized. Some of these fragments include specially protected natural territories of federal significance: the Yalta Mountain Forest State Nature Reserve, the Krymsky National Park.

Fig. 1. The scheme of the main roads and high-voltage power lines of the Mountainous Crimea

The territory located within the borders of Sevastopol in southwestern Crimea is more fragmented compared to Crimea. Figure 1 shows in detail the road network of this region and the scattered forest areas formed as a result of its laying. There are ten such sites, some of them also have protected areas.

All sites in the Sevastopol area are involved in economic activities to varying degrees (residential and recreational areas, agriculture, etc.). Site X is fully used for these purposes, and the Chernorechenskoye reservoir is located within its borders. Sections I - VI, VII and IX are less developed. The most extensive is the least developed section VII. It is almost completely occupied by forest and is bounded by the Bakhchisarai - Yalta road.

Thus, by now there has been a steady fragmentation of the mountainous and forest Crimea, limiting the habitats of animals, preventing their migration and being a potential cause of their death and accidents. To assess the impact of physical factors and develop measures to protect the mainline sections, we will limit to the territory within the administrative boundaries of the city with federal status Sevastopol.

The assessment of the parameters of physical factors was carried out on roads of three different categories within the Sevastopol region: Sevastopol - Kerch (Tavrida, IB), Sevastopol - Yalta (II), Oboronnoye village - Tankovoye village (IV). These roads can be considered representative of the entire Mountainous Crimea in terms of categories, traffic intensity and laying conditions.

In the course of route-expedition research in 2023, the authors conducted studies of noise parameters (Fig. 1, points 1,2,3), lighting (points 4,5), EMF (point 6). To evaluate the noise, the values of the following parameters were measured: equivalent sound levels, $L_{A\text{eq}}$, dBA, equivalent octave sound pressure levels, $L_{P\text{eq}}$, dB in the range of 31.5 - 8000 Hz.
(boundary frequencies 22 - 11200 Hz). These parameters were studied by analogy with those normalized for humans. Probably, for animals inhabiting the forests of the Mountainous Crimea, the values of sound pressure levels can also be determined at lower and higher frequencies. Nevertheless, due to the lack of criteria for comparison - sanitary standards, the above frequency range was adopted. Simultaneously with the measurements, the traffic intensity was calculated.

Considering the significantly different categories of roads, noise studies were carried out using two methods: on the Tavrida highway – at distances of 20-120 m in increments of 10 m from the axis of the nearest lane in the direction perpendicular to the road, on the other two – at points at a distance of 100 m. The measurement results at point 1 with an interval of 20 m are graphically presented in Fig. 2, a comparison of the results for three points at a distance of 100 m is shown in Figure 3. The spectra of the sanitary norm for residential areas in the daytime are optionally shown here [9].

The average traffic intensity during the measurement period was: point 1 – 1150 car/hour (carriage per hour) at a speed of about 100 km/hour; point 2 – 600 car/hour at a speed of about 70 km/hour; point 3 – 380 car/hour at a speed of about 60 km/hour.

Analysis of the measurement results shows that the highest levels of sound pressure are observed in the area of low and medium frequencies. In these ranges, the energy of sound waves is less attenuated with increasing distance from the source to the control point and the noise spreads over considerable distances. On the Tavrida highway, the noise significantly (up to 30 dB at a frequency of 1000 Hz) exceeds the norm for humans. It is noteworthy that the human auditory analyzer in this octave band also has maximum sensitivity, which means that the risk of negative effects increases.

![Fig. 2. Spectra of equivalent sound pressure levels on the Tavrida highway (point 1).](image-url)
The noise at the Tavrida highway slowly fades with distance for the reasons outlined above. Extrapolation of the values obtained at distances of 20-120 m over a long range suggests that the noise corresponding to the norm will reach no closer than 200-250 m. The values corresponding to background noise when it is perceived as sounds of the natural environment with almost indistinguishable traffic noise are obtained at a distance of about 500 m from the highway.

In the other two points (Fig. 3), the results are more favorable. Nevertheless, more in-depth studies of noise in the Mountainous Crimea are required, considering seasonal factors, species composition of vegetation, climatic conditions, relief and other conditions.

The assessment of illumination at points 4 and 5 (Fig. 2) was carried out at night with cloudless weather and moonlight. The site at point 4 is equipped with lamps, at point 5 the light sources are only car headlights. The illumination values on the side of the roadway were: point 4 (under the lamps) – 25-39 Lux; point 4 (between the lamps) – 13-16 Lux; point 5 – 7 - 12 Lux; point 5 (without cars) – 0-2 Lux.

The illumination values in the artificial lighting zone generally correspond to the norm for main roads – at least 30 Lux [10], nevertheless, all the results obtained are significantly higher than the natural background of up to 2 Lux, familiar to animals.

A series of measurements of EMF intensity at an industrial frequency of 50 Hz was carried out on a forest site near point 6 (Fig. 2). Here, three overhead power lines run parallel to the Tavrida highway, supplying Sevastopol and part of the Southern coast of Crimea: two 220 kV overhead lines and one 330 kV. They are laid parallel to each other along a clearing about 160 m wide. EMF intensity values were measured at a height of 2 m from the ground at 20 points with an interval of 5 m along a line perpendicular to the overhead line. The values obtained are in the range of 1070-6700 V/m. The spread is due to the distance from the wires to the measuring point, voltage (the maximum values were obtained under the 330 kV overhead line) and other factors. The only criterion for comparison in this case is the norm for the territory of populated areas of 1000 V/m [11]. It can be assumed that EMF with such intensity values is a factor that scares away animals and complicates their movement through forest areas with power lines. The natural background values obtained at a distance of about 300 m from the 220 kV overhead line closest to the forest were in the range of 0-10 V/m. Considering the measurement error, it can be assumed that EMF at a frequency of 50 Hz is practically absent in the natural forest environment.

The studied road transport networks fragment the natural cores of the regional
ecological framework of Sevastopol within the VI-X sections (Fig. 1). These are the largest in the region SNR "Baydarsky", NP "Protected area "Laspi Rocks", part of the territory of SNR "Cape Aya" and SNR "Laspi". The considered natural cores cover the Yailinsky mountain meadow and steppe landscapes, pine, beech and oak forest zonal landscapes of the southwestern part of the Mountainous Crimea, as well as the sub-Mediterranean complexes of the western part of the lower seaside belt of the southern macroslope of the Crimean Mountains [12-16].

The natural systems in question are open and, as a result, very vulnerable. The continuity of the ecological network system is achieved by creating ecotechnical interchanges at intersections with linear anthropogenic barriers. Such bio-crossings are eco-bridges - artificial road structures (bridge, pipe or tunnel type) that ensure safe crossing of the highway by fauna representatives [17, 18].

Rare and endangered species of wild animals listed in the Red Book of Sevastopol and Crimea were classified as the target species of fauna representatives that we considered when placing and arranging eco-houses. Among mammals, such species include red deer (Cervus elaphus), pygmy shrew (Sorex minutus), Crimean stone marten (Martes foina), small and large horseshoe bats (Rhinolophus hipposideros, ferrumequinum), notch-eared bat and lesser mouse-eared bat (Myotis emarginatus, blythii), European badger (Meles meles), Mediterranean water shrew (Neomys anomalus).

European roe deer (Capreolus capreolus), white-breasted hedgehog (Erinaceus roumanicus), bicolored white-toothed shrew (Crocidura leucodon), European hare (Lepus europaeus), squirrel (Sciurus vulgaris), fox (Vulpes vulpes), stone marten (beech marten) (Martes foina), weasel (Mustela nivalis), fox (Vulpes vulpes), stone marten (beech marten) (Martes foina), weasel (Mustela nivalis) are also widely represented among mammals within the considered Special Protected Natural Areas. If no measures are taken to overcome territorial fragmentation, the number of these species will decrease rapidly [19].

It is also worth noting that the appearance of wild animals on highways often leads to serious consequences for road users. According to expert estimates, the number of animal collisions in the total number of road accidents is at least 2%, and the death toll is 2-3 people per 100 collisions with animals, for which accidents are fatal in most cases [20-22]. The species that pose a danger to traffic in the study area include large ungulates – red deer (Cervus elaphus), European roe deer (Capreolus capreolus), European moufflon (Ovis orientalis), wild boar (Sus scrofa).

The locations of the ecoducts were determined based on the following: the formation of a network of crossings should link the main fragments of forests into a single area with access to vast and minimally urbanized areas of the Mountainous Crimea; slopes at the entrance and exit sites to ecoducts for large animals should not exceed 15 degrees [18]; eco-houses should be as far away as possible from settlements and other places where people and equipment congregate; approaches to eco-houses should be equipped with noise shields and barriers made of dense woody vegetation. Considering these reasons, during the engineering and environmental surveys on the territory within the administrative boundaries of the city with federal status Sevastopol Sevastopol, 6 locations of possible bio-crossings were identified (Fig. 1).

The choice of a design solution for the engineering arrangement of animal migration routes is usually carried out on the basis of a feasibility study of the route. Nevertheless, in the conditions of the already established road transport system of Sevastopol and Crimea, the arrangement of eco-parks should be carried out based on the species composition of animals, microclimate, soil structure and other natural features of isolated habitats, which will be the subject of further research.
4 Conclusion

To the greatest extent, the barrier effect of linear engineering structures is manifested in the conditions of mountainous and foothill terrain, which is already characterized by significant differentiation. Currently, fragmentation is not considered when designing the development of road transport networks and their elements. Accordingly, the development of measures to protect the mainline territories from man-made physical factors should be carried out based on the characteristics of the already established natural and economic subsystems.

Based on the research carried out, a specific solution has been proposed to protect the mainline territories of the Mountainous Crimea from man-made physical factors by arranging eco-parks at six locations within the main federal and regional highways of Sevastopol. The implementation of these proposals will ensure road safety, increase the population of wild animals, and reduce the number of animal exits on the roadway.

The approaches to solving the problem of overcoming fragmentation by linear engineering structures of natural biotopes presented in the work can be extrapolated to the entire territory of the mountainous Crimea.

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