The influence of the anthropogenic factor on the state of the natural-territorial complexes of the "Opuksky" reserve (Republic of Crimea) and the prospects for the development of ecological tourism

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Abstract. The present research is devoted to the assessment of the ecological conditions of the "Opuksky" reserve (Republic of Crimea, RF) under the conditions of increasing anthropogenic pressure. The development of ecological tourism on the territory of natural reserves is one of the vectors of development of the system of protected areas in Russia. However, this is associated with an increase in anthropogenic impact on these objects. To correctly account for the permissible anthropogenic pressures, strict monitoring measures are required to control environmental conditions. The work is based on the material obtained over three years (2017–2019) in the framework of scientific practices for students of St. Petersburg State University. As a result of the work, a map of the distribution of heavy metals in the soils of the reserve was compiled. The regularities of migration of pollutants in soils are described and the vulnerability to pollution is substantiated. The stages of anthropogenic digression of plant communities have been determined. The consequences of tourism development are assessed. Recommendations for the regulation of tourism are given.

1. Introduction

The state budgetary institution nature reserve "Opuksky" is one of the nature reserves with the strictest protection regime, corresponding to the concept "strict nature reserve (IUCN category Ia) or wilderness area (IUCN category Ib)" in the international classification. The main functions are biodiversity conservation and scientific research. The secondary, but no less important, tasks include the development of environmental education and eco-tourism. The reserve is located in the south of the Kerch Peninsula of the Republic of Crimea. Its area is more than 1.5 thousand hectares. The reserve was created to preserve and reproduce the steppe natural complexes of the flat Crimea and aqua complexes of the Black Sea. The territory of the reserve is included in the IBA list of territories important for the conservation of bird populations within Europe. The Opuk Cape Aquatic and Coastal Complex was included in the list of wetlands of international importance (Ramsar Convention) in 2004.
On the territory of the reserve, several main types of biotopes can be distinguished, within which ecological-faunistic complexes are formed: steppe, shrub, near-water, rocky. At least 90 species of terrestrial vertebrates were recorded in the study area. Of these, 55 are background, 28 are rare and protected species. The coastal area also has high biodiversity. In addition, a wide variety of avifauna is noted on the territory of the reserve, which is due to the variety of habitat conditions for birds represented by coastal-marine, wetland, rock-steppe complexes. At present, the nesting complex of birds is at least 60 species [1]. There are interesting geological objects on the territory - Mount Opuk, which is a carbonate massif bounded by steep ledges and dissected by deep tectonic cracks into separate blocks; salt lake Koyashskoe. In addition, the ruins of the ancient Greek city of Cimmerik (6th century BC - 4th century AD) are preserved on the territory of the reserve - the remains of a citadel, dozens of ancient wells and captages.

Convenient location, a large number of unique natural and historical sites make the reserve interesting for various types of tourism, scientific research; For many years, the territory of the reserve has been used as a testing ground for field geological studies for students of St. Petersburg State University.

The centralized use of the lake territory for tourism, the exploitation of the balneological resource is permissible even within the boundaries of the natural reserve, however, for rational exploitation, strict control of anthropogenic impact is required [2-4].

Nevertheless, today the tourist and recreational infrastructure on the territory of the reserve is poorly developed. Tourist and recreational activities are carried out in an organized and unorganized form. Ecological routes are organized in the form of one-day hiking trails of varying duration (there are 3 ecological trails and 1 sea route under development).

Tourist and recreational activity generates a significant load on natural landscapes. This activity is complex and varies significantly over time (season, micro-season). The main negative impacts are: impact on the soil cover, water bodies, vegetation, wildlife, changes in the sanitary state of the territory.

In recent years, an increase in the flow of tourists has been recorded, which can lead, first of all, to the degradation of the soil cover and plant communities on the territory and to a change in the geochemical characteristics of soils [5-7]. Therefore, the most important task is to monitor the state of the ecological state of the natural systems of the reserve and determine the permissible levels of anthropogenic impact.

It should be noted that the Concept for the Development of a System of Protected Areas of Federal Significance for the Period up to 2020 defines the development of ecological and educational activities of reserves and national parks on a national scale, the involvement of specially protected natural areas in the development of ecological tourism. It is the nature reserves that experience the greatest difficulties in the implementation of these tasks, since this type of nature reserves was originally created for the preservation of natural systems, and not for use. Therefore, a well-developed environmental tourism policy (clear organization of tourism activities and calculation of permissible exposure levels), and a full-fledged program of control and monitoring of the quality of the components of the natural environment is an important part of the reserve's work.

Determination of the types and degree of anthropogenic impact is the main component in the assessment of tourist and recreational activities in protected areas and makes it possible to develop an effective action plan for the protection of these territories. The assessment of the impact of tourist and recreational activities should be carried out in a comprehensive manner and consider several parameters of the natural environment: the external appearance of the territory - litter, the state of the herb-shrub layer, the state of the soil, etc.

2. Materials and methods
In 2017–2019 Within the framework of monitoring work jointly with St. Petersburg State University and the administration of the reserve, studies were carried out on the state of soils and plant communities of the reserve. 105 surface soil samples were taken, 4 soil pits were laid and described.
Sampling of surface samples was carried out in accordance with GOST 17.4.4.02-2017 by the route method. The samples were analyzed by two methods - atomic emission spectrometry of inductively coupled plasma (ICP-AES) on the basis of the resource center of St. The content of heavy metals was estimated (Pb, Zn, Ni, Cu, Co, Cd, Cr, Fe, As, Mn).

In the process of geobotanical descriptions, the factors of differentiation of the territory were identified, its morphological structure and interrelation of components, the degree of anthropogenic degradation of natural-territorial complexes were clarified.

The landscape profiles were constructed so that they intersect the greatest number of landscape settings and hiking trails. At each point of the profile, work was carried out with forms of geobotanical descriptions.

Observations were carried out along the profile continuously, and when the plant communities changed, observation points (sample plots) were set, where all the components of natural-territorial complexes were described in detail: characteristics of the development of the territory, littering, relief, soil characteristics, moisture conditions, characteristics of the species composition of the grass-dwarf shrub layer. On the territory, 20 sites related to the tourist and excursion area were described, of which the first test site was selected as a conditionally background. The first profile passed from the shore of Lake Koyashskoye sublatitudinally through the western slope of Mount Opuk and ended at its top (test plots (PP) from 1 to 10). The total length of the first profile is 1540 m. The second profile began at the top of Mount Opuk (eastern end of the upper plateau, near the quarries) and continued along the route of the ecological trail in a southern direction to the sea. The last point of the profile was located on the coast, near an antique well (PP 2-10). The length of the second profile is 1590 m (figure 1).

![Figure 1. The network of roads and paths of the reserve (on the left - profile 1 PP 3, on the right - profile 2 PP 4).](image)

3. Results

Analysis of soil samples for heavy metals showed that the content of none of the studied heavy metals did not exceed the standard values. The values of the contents of cadmium, arsenic and cobalt did not exceed the detection limits of the methods in all samples (for cadmium it was 1 ppm, for arsenic and cobalt - 10 ppm). The rest of the metals are confidently diagnosed. To assess the geochemical background, we have chosen the median as an indicator that does not depend on “outliers”, that is, irregular maximum values of the sample [8].

The results of the analysis were compared with a similar work in this region, in which the soil of settlements was analyzed [9-11]. The low values of the content of heavy metals in the soils of the reserve in comparison with the soils of residential areas indicate that the soils of the reserve are relatively clean.
It can also be noted that the content of chromium and nickel in the soils of the reserve is slightly lower than the average level for Crimea (median values of the sample are 67, 33 ppm), zinc and copper are almost two times less (71, 25 ppm). But the lead content in the study area (the median was 40 mg / kg), on the contrary, turned out to be increased (27 mg / kg in the residential areas of the Republic of Crimea).

Each element is characterized by a normal distribution. Emissions are observed only in zinc and lead distributions. They correspond to observation points associated with stops of ecological routes (spring and abandoned quarry). The normal distribution is not typical for natural ecosystems; therefore, it can be assumed that the territory studied by us was or is influenced by an anthropogenic factor. Geochemical conditions in the study area are fairly uniform. As the map shows (figure 2), relief does not play a major role in the migration and accumulation of elements. The parent rock of soils (limestone) is the same throughout the Opuk Mountain and in its vicinity.

In this regard, we assume that it is anthropogenic sources that make the main contribution to the contrast of the areal distribution of heavy metals. As you can see from the map, relatively high values of K * s are located on the territory of the former settlements of Novy Koyash and Chekur-Koyash and in the area of dense road network.

It is important that all the objects of economic activity indicated on the map (the map shows objects from 1953), except for the spring, have not been functioning for more than fifty years. The landscape does not bear any traces of anthropogenic impact. However, the consequences of human activity are still being diagnosed.

As a result of geobotanical descriptions, we found that the main indicator indicators of the state of the NTC of the "Opuksky" reserve are the above-ground and grass cover. Geobotanical description of the territory was carried out along two profiles.

Geobotanical studies were carried out with the description of plant communities, determination of their state and the degree of anthropogenic degression [12], as well as identification of the Red Data Book species in the territory.

Analysis of the conditions of the first profile showed high biodiversity at all ten sites (up to 25 species), and the type of plant communities corresponds to the growing conditions. Thus, the coastal coastline of the eastern side of the Koyashskoe salt lake is characterized by a goniolimon-sveda-wheatgrass community on salt marshes with lake nutrition. The leveled surfaces are represented by the wheatgrass-soflora community. The slopes (20-35 degrees), on which the soil is represented by petrozem on limestones, is loamy with fragments of limestone, characterized by a saline-zopnik (Red Book species of Bellevalia speciosa has been found), thyme-yarrow, flax-cmine, oak-katranovo communities. The summit is characterized by a cornflower-resinous community. The grass cover is represented by 12 species, the indicator species are the Crimean stock-rose \textit{Alcea taurica}, the common Dubrovnik \textit{Teucrium chamaedrys}. The Red Book species were revealed: \textit{Bellevalia the Magnificent} - \textit{Bellevalia speciose}, \textit{Iris Dwarf} - \textit{Iris pumila}.

The first profile was chosen in such a way as to cross in several places the routes of ecological paths, as well as the roads laid on the territory of the reserve even before its formation and still used today. The state of plant communities strongly reacts to these anthropogenic objects. Thus, the projective cover of herbaceous plants and mosses on profile 1 varies widely from 100% to 30-40% in the immediate vicinity of the roads (5-10 meters). The sites located near the roads are characterized as moderately degraded. Also, at such points, the spread of weed species is observed (solar cornflower \textit{Centaurea solstitialis}, santonica wormwood \textit{Artemisia santonica}, fluffy wormwood \textit{Stachys pubescens}, \textit{Elytrigia maeotica}) up to 30% of the total number, there is no litter in open places, trampled and broken by the mineral part of the soil by motor transport.

It is also worth noting that the greatest contrast of conditions is typical for sections of paths and roads on slopes, where the total project coverage decreases from 80-100% to 40% near paths (so-called 1.6-1.7) within the same observation site. This kind of transformation of the landscape and its individual components develops in connection with unorganized tourism.
The most degraded site is PP 1-10 located on the upper plateau of Mount Opuk. This kind of degradation is associated with the fact that the landscape has been changed by man very significantly. There are four caponiers 100x80 m² in size.

The plant communities of profile 2 are highly diverse. The landscape position of this site in the form of leveled plateaus descending in steps to the sea is favorable for the development of more fertile soils, such as dark humus residual calcareous soil on carbonates, textured calcareous chernozem on carbonates. On this site, wheatgrass-zopnikovoe, gullyavnikov-hormolavnikovoe, rose-cutter (Red Data Book species: flat-leaved kermek *Limonium platyphyllum* (s.)), Thousand-leaved-kartamusovoye, partly ephedra, and leo-cornflower communities on flattened cornflower, partly ephedra, tsinanchum-harmal communities; the slope to the sea - with a tsinanhum-harmalous community, and the edge of the coast in front of the beach is characterized by a mustard-ephedra community (a species from the Red Data Book has been identified - rough *Crambe asper*) The general condition of the vegetation cover is good.

The total project coverage does not fall below 80%, mostly close to 100%, even near roads. The grass cover is represented by 13–20 species.

4. Discussion

To compare the state of plant communities in connection with human exposure, scales of stages of recreational degression are used. The stage of degradation, to which the community belongs, is determined by a number of indicators, such as: the state of vegetation, projective cover, the presence of weed species, etc. Buzmakov [12].

Based on the results of the assessment of plant communities, it was found that the anthropogenic load is distributed non-uniformly (figure 2). The most transformed site (moderately degraded steppe communities according to S.A. Buzmakov) is the top of Mount Opuk (two points), since this site has been associated with human activities for two thousand years and has been greatly changed (the remains of a fortress and an ancient settlement of Kimmerik, four caponiers roads created in the 20th century). Slightly degraded sites include 4 and 6 test sites of the first profile, located on the slope and near the roads, as well as sites 1, 3 and 9 of the second profile, mainly confined to roads. Due to the vigorous activity of man, including the tourist flow, in the changed areas the number of species characteristic of this territory is reduced and replaced by weeds, and the projective cover is reduced.

Thus, two factors can be distinguished that determine the state of the natural-territorial complex. On the one hand, this is the position in the relief - areas located on slopes and characterized by undeveloped soils are less stable and more sensitive to anthropogenic impact. The second factor is actually anthropogenic, since it is in the zone of influence of roads and, to a lesser extent, paths that degradation of natural-territorial complexes manifests itself. Note that in the course of the study, pathways were studied. Observations have shown that the area is oversaturated with trails that do not belong to official ecological routes due to unorganized tourism. According to calculations made using the ArcGIS program, the length of legal paths is 11 km, illegal - 14 km.

5. Conclusion

During the research, the contents of heavy metals and metalloids (As, Co, Cr, Cu, Ni, Pb, Zn, Fe, Mn) in the soils of the Opuksky reserve were determined and background values were calculated taking into account the historical characteristics of the territory. It was found that the content of all heavy metals does not exceed the MPC. When comparing the obtained values with the gross concentrations of the studied elements in the soils of the residential areas of the Republic of Crimea, it was found that the content of all metals in the soils on the territory of the reserve is 1.5-2 times lower than in the soils of the settlements of the region, with the exception of lead. The lead content in the study area (median 40 ppm), on the contrary, turned out to be higher than the average content in the soils of the residential areas of the Republic of Crimea (28 ppm).
When determining the background values of heavy metals, one should take into account anthropogenic activity in the background territory for at least the last 50 years, excluding such areas from the calculations. This is due to the extremely low mobility of trace elements in soils associated with carbonate parent rocks.

It was revealed that the transformations of the vegetation cover are manifested in connection with the road and path network, and the level of digression depends on the position in the relief. Slope areas are more susceptible to change, and the communities of leveled stations practically do not respond to the anthropogenic factor at the current level of impact.

When developing ecological tourism on the territory of the reserve, it is recommended to take into account the situation in the relief of individual excursion sites. The use of a modern trail network is permissible with strict control of the number of visitors and the mode of movement along the route. The movement of tourist groups along the slopes of the route must be limited or equipped with decks that minimize anthropogenic impact on the soil cover and vegetation communities.

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