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Article

Comprehensive study of the Tobias Creek valley following the development of the Krasnaya Polyana mountain resort

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Abstract. The impact of environmental management on water quality carried out in the Tobias Creek watershed area and that of geological processes occurring in the given geoecosystems have been studied. The survey based on a basin approach was performed at a watercourse located in a mountainous tourist area under recreational pressure, the latter has been significantly increasing recently due to increasing domestic tourism. The types of hazardous exogenous geological processes affecting the natural environment (including water sources) and economic activities have been identified: linear and planar erosion, landslides, creep, and mudflows. The “hotel complex” and “ski slopes combined with hiking tourist routes” had the greatest negative impact on the natural environment out of the eleven types of territorial environmental management identified by experts. The ecosystem components “flora” and “soil” were subject to the greatest anthropogenic impact. The environmental conditions deteriorated gradually from the creek source to its mouth as followed by bioindication and biotesting. A comparison of geological and anthropogenic factors and the processes occurring in the catchment area within the defined ecological zones allowed us to conclude that biological parameters reflecting processes in the aquatic ecosystems may be used as indicators of the state of the natural environment.

Keywords: geoecosystems, geological structure, hazardous geological processes, deprivation of terrestrial phytocenoses, environmental management, technogenesis, aquatic biocoenosis, bioindication, biotesting, zoning

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Научная статья

Комплексное исследование долины ручья Тобиаса в связи с развитием горного курорта «Красная поляна»

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Аннотация. Представлено исследование влияния природопользования, осуществляемого на водосборных площадях водотока, а также воздействия геологических процессов, происходящих в геозкосистемах водоема и его бассейна, на качество воды. Исследование основано на бассейновом подходе и проведено на водотоке, который расположен в горной туристской местности и находится под рекреационной нагрузкой, значительно возрастающей в современных условиях увеличения внутреннего туризма. Определены типы опасных экзогенных геологических процессов, которые оказывают влияние на природную, в том числе водную, среду и хозяйственную деятельность: оползни, сели; линейная и плоскостная эрозия; крип; обвально-осыпные процессы. Из одиннадцати выявленных экспертным путем видов территориального природопользования наибольшим воздействием на природную среду обладают «гостиничный комплекс» и «горнолыжные трассы, совмещенные с пешими туристскими маршрутами»; наибольшему антропогенному воздействию подвергаются элементы «флора» и «земля». Результаты биоиндикационного исследования и биотестирования указывают на ухудшение экологических условий от истока водотока к устью. Сопоставление геологических и антропогенных факторов и процессов площади водосбора с выявленными экологическими зонами водотока позволило сделать вывод о том, что биологические параметры, отражающие процессы в гидроэкосистемах водотока, могут применяться в качестве индикаторов состояния природной среды его бассейна.

Ключевые слова: геозкосистемы, геологическое строение, опасные геологические процессы, депривации наземных фитоценозов, природопользование, техногенез, гидробиоценоз, биоиндикация, биотестирование, зонирование

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Introduction

The properties of natural waters are formed as a result of complex processes in the catchment area and in the reservoir:

1) physicochemical weathering of elements; their interactions, filtration, migration, adsorption, and desorption; atmospheric deposition and evaporation from the surface;

2) biological, biochemical, microbiological, and biofiltration processes.

Therefore, water quality may be described as “properties formed in the process of chemical, physical and biological processes, both in the reservoir and in the catchment area; favorable water quality in a particular reservoir meets the requirements of preserving the health of the most sensitive organisms and the reproduction of species adapted in the process of evolutionary development to exist in the conditions of this reservoir” (Alimov, 2000). The basin approach allows taking into account the complex influence of various factors on the properties of natural waters; it is a set of techniques in geographical and environmental studies, based on the idea of the geographical continuity, where water flow acts as the main integrating factor (Snakin, 2000).

The anthropogenic factor, together with natural geochemical and biological processes, influences the changes in the environmental state of water bodies due to the entry and further transformation of toxic substances, eutrophication, acidification and other anthropogenically-induced processes. Most pronounced examples are remote high-mountain and arctic ecosystems exposed to technogenic impacts (Gudkova et al., 2021; Moiseenko et al., 2012).

During the lifespan, organisms use water as a resource and a habitat, so actively influence its properties; in some cases, they play a decisive role, so water may be considered as a biologically inert body (Moiseenko et al., 2012). Here, we focus on the analysis of biotic parameters characterizing the toxic effects and eutrophication of the aquatic environment, species richness, stability, and evenness of biological communities confined to certain geobiotopes characteristic of the study area, which are the main parameters of the aquatic environment state. Comprehensive indicators, reflecting the prevailing multifactorial external influences on the environment and reliably separating natural (background) aquatic biocenoses from degrading ones, have been determined and tested earlier in order to identify the quantitative parameters of biological systems under specific climatic and geographical conditions of the study area (Gorbunova, 2017; Gudkova and Gorbunova, 2018).

The production of a tourism product is based on the use of recreational and tourist natural capital; it is accompanied by a complex negative impact on the natural environment. The predicted increase in the consequences of overtourism for domestic natural recreational centers, caused by the increasing reorientation of external outbound tourism to internal routes and the short-sighted use of natural capital, carries the risk of destroying the natural resource basis for the development of tourism as a promising and socially significant sector of the state economy (Matova and Shagarov, 2021). In this regard, it is relevant

to choose the Tobias Creek basin, which flows through the territory of one of the most popular resorts in the mountain cluster of the resort city of Sochi, Krasnaya Polyana mountain resort, as a study area.

Total length of the Tobias Creek is 5 km; its source is located at an absolute elevation of about 2000 m above sea level (a.s.l.); the watercourse flows into the Mzymta River at about 530 m a.s.l.

The study aims to develop and to test a method for rapid assessment of the state of geoecosystems of natural watercourses and their drainage basin in the conditions of intensive development of mountain resorts in the south of Russia using comprehensive bioindicators as a tool for integrated water resources management (IWRM) using the example of a comprehensive study of the valley of the Tobias Creek.

The study comprised several tasks: (1) to identify natural and anthropogenic factors affecting the ecosystem of the Tobias Creek valley; (2) to highlight the areas of the Tobias Creek valley with different biotope types using comprehensive bioindicators; (3) to investigate the geological and anthropogenic processes occurring in the catchment area and posing a potential threat to the environmental and economic safety of the functioning of the tourism industry of the mountain resort; (4) to analyze the impact of basin environmental management on the natural environment; (5) to compare the selected sections of Tobias Creek valley with different biotope types with the drainage area zones characterized by general signs of the ecological well-being of ecosystems (Dmitriev et al., 2016), as well as by similar intensity of environmental management.

The scientific novelty of the work lies in the use of a systematic approach in the studying and analyzing the dynamics of geoecological and biological processes at the area characterized by a pronounced tourist specialization and thus resulting in the gradual degradation of the qualitative and functional composition of biological communities, reducing their stability and leading to the subsequent irreversible changes in the entire ecosystem.

Materials and methods

A comprehensive survey of the catchment area of the Tobias Creek was carried out in 2020–2022, the samples were obtained in three main areas: (1) the upper reaches, about 2000 m a.s.l., (2) mid-stream, about 990 m a.s.l., and (3) the mouth zone of the creek just upstream its confluence with the Mzymta River, about 550 m a.s.l., Esto-Sadok village (Fig. 1). Biological samples were taken to analyze the qualitative and quantitative composition of macrozoobenthos and periphyton, as well as natural water samples for biotesting using unicellular green algae *Chlorella vulgaris* Beijer as the main test object. In all areas, the samples were taken in similar biotopes to exclude the influence of the substrate type on the species composition of aquatic organisms. Sampling and taxonomic identification were performed according to the standard methods (Abakumov, 1983; Oprelidelitel'..., 1997–2000).

The study of the geological structure and hazardous geological processes was based on archival materials presented on courtesy by the Antistikhia Center of the Ministry of Emergency Situations of Russian Federation, the Southern Regional Center for State Monitoring of the Subsoil Condition, and Kubangeology State Unitary Enterprise.

The information on territorial environmental management was collected using geographic information systems: 2GIS, Google Earth, Public Cadastral Map of the Russian Federation, OpenStreetMap, OpenTopoMap. In addition, information about natural resource users and the nature of their activities in the public domains on the Internet was used. An expert assessment of the impact of human economic and consumer activities on the natural environment of the study area was performed using a modified Leopold matrix.

A reconnaissance assessment of the species composition of land vegetation was also performed, as well as the assessment of the natural resistance of vegetation to impact factors (recreational, technogenic, biogenic) and the assessment using landscape taxation scales developed for the territory of Sochi by the Research Institute of Mountain Forestry and Forest Ecology (Korol et al., 1999).

Bioindication methods applied are based on analysis of the species composition of benthos and periphyton, since these communities provide reliable information about ongoing or repeated impacts on the aquatic environment (Gorbunova, 2017). Based on the data obtained, biotic indicators have been calculated, which are indicators of biodiversity, stability and evenness of the structure of the biological community of macroinvertebrates: QMCI (Quantitative Macroinvertebrate Community Index) as an indicator of the tolerance of the aquatic community to environmental¹ eutrophication (Bennett et al., 2004;

¹ Factsheet: Benthic macroinvertebrates. LAWA Land, Air, Water Aotearoa. 24 September 2023. Electronic resource. URL: <https://www.lawa.org.nz/learn/factsheets/benthic-macroinvertebrates/> (accessed 10/02/2023).

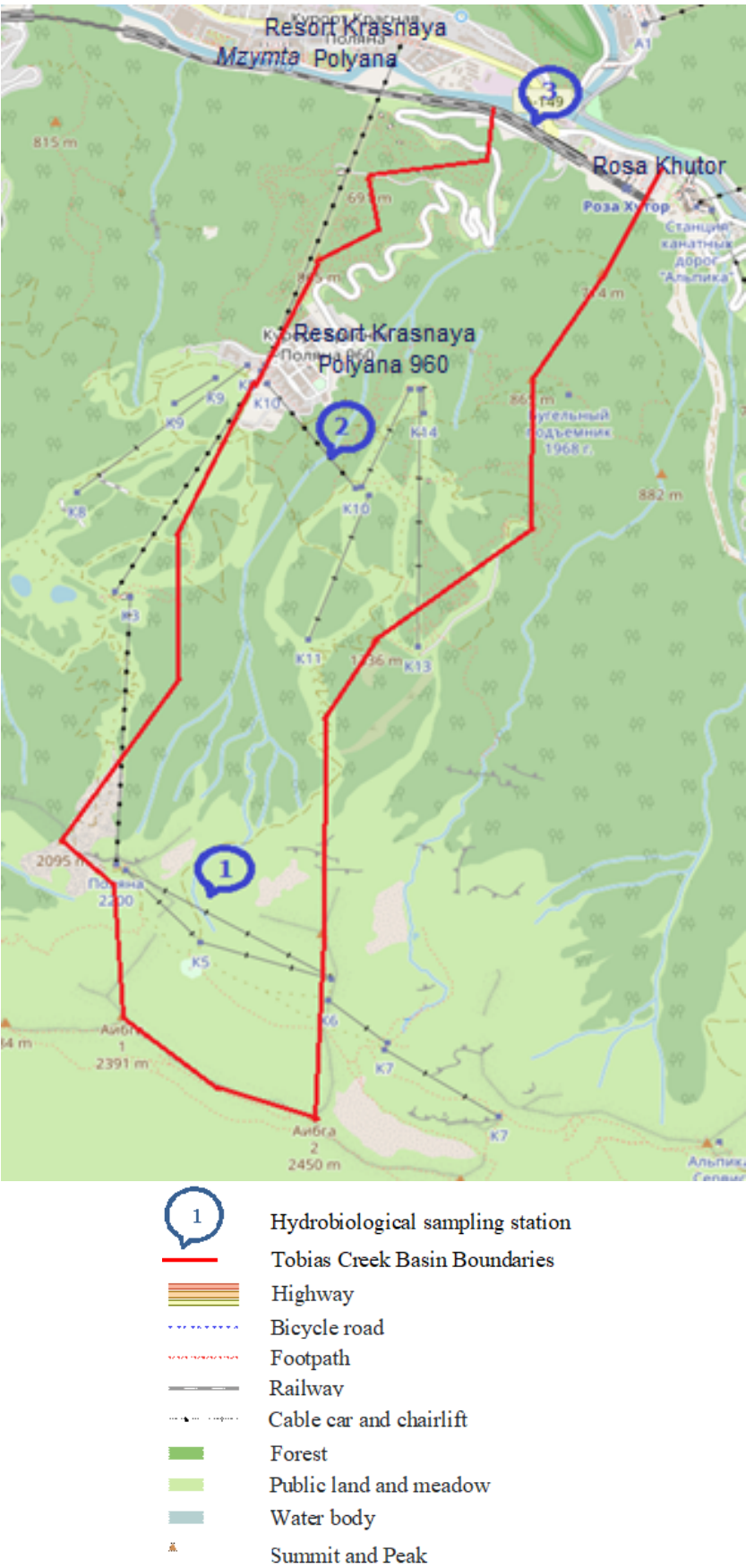


Fig. 1. Sampling site map. The northern slope of Mount Aibga in the Tobias Creek basin (scheme based on OpenStreetMap).

Collier, 2014; Gorbunova, 2017; Olomukoro and Dirisu, 2014), Margalef and Shannon indices as indicators of species diversity, and Berger–Parker and Simpson indices as the ones for assessing the degree of dominance of individual species (Rosenberg and Ryansky, 2005).

Acute (72 hours) and chronic (7 days) water toxicity tests were also performed using microalgae *Clorella vulgaris* according to accepted guidelines (Methodicheskoe rukovodstvo..., 1991; Rukovodstvo..., 2002;) and taking into account the most recent results of biotesting methods using green unicellular algae (Tyutkova and Grigoriev, 2014).

Results and discussion

Geological characteristics of the study area

Rocks of Lower Jurassic (J_1) and Quaternary (Q_{IV}) ages predominate in the study area, located on the northern slope of the Aibga Ridge. The most ancient rocks that come to the surface are deposits of the Jurassic system. Outcrops of bedrock, which are covered by proluvial-deluvial deposits almost everywhere, are found in steep ledges and undercuts of highway slopes.

Technogenic deposits, formed as a result of economic development of the territory during construction work-cutting, leveling, construction of highways, etc., are widespread in the area. They are represented by coarse clastic formations of building materials, remains of concrete, reinforcement, etc.

The hydrogeological conditions of this territory are characterized by the distribution of seasonal high water, groundwater of colluvial landslide and landslide deposits, and closely related groundwater of the fractured zone of the bedrock surface. The temporary (seasonal) layer of perched water is developed in the cover clay deposits of deluvial-landslide genesis down to the 1.5–2.5 m depth. The perched water is fed by precipitation and is formed in a loose near-surface layer, subject to alternating seasonal drying and wetting. Dense loamy varieties serve as the aquiclude for the perched water. Seasonal fluctuations in the water level are insignificant (about 0.5 m) due to good hydraulic connection with the Mzymta River. Groundwater of deluvial-landslide deposits are confined to clay deposits; they are distributed very unevenly due to the different compaction of sediments and the relief dissection. The most water-rich areas are associated with depressions, where local closed layers come up more or less consistently. Areas located at higher altitudes may be dry.

In the study area, several types of dangerous exogenous geological processes have been identified, which may affect negatively the natural environment and economic activity: landslides, mudflows; linear and planar erosion; creep; landslide processes.

Analysis of the impact of basin environmental management on the natural environment

In the study area, 11 main types of territorial environmental management have been identified. For each of them, a modified Leopold matrix has been generated: the matrix rows display the impact on the parameters of the natural environment and some environmental dependencies, the columns, a key environmental aspect² of the referred type of environmental management. The impact strength of key environmental aspects on the natural environment has been assessed by an expert method by a 3-point scale: 1 – weak, 2 – medium, 3 – strong impact. Next, the territorial types of environmental management are summarized (Table 2).

The greatest impact on the natural environment of the study area is noted for two types of environmental management: “hotel complex” and “ski slopes combined with hiking tourist routes.” The elements “flora” (trees, as well as shrubs and herbs) and “earth” (soil) are subject to the greatest anthropogenic impact.

Identification of sections of a watercourse with similar characteristics of biogeocenosis

The analysis of the types of economic activities in the study area, the geological structure, and hazardous geological factors made it possible to divide the watercourse of the Tobias Creek into several areas.

² The environmental aspect is an element of an organization's activities, its products and services that can interact with the natural environment. An important environmental aspect is one that has or is likely to have a significant impact on the natural environment (International Standard ISO 14004:2004 (E)).

According to the classification suggested M.V. Chertoprud (Chertoprud, 2011), the biotopes of the Tobias Creek belong to the crenoepirithral, which is typical for fast-flowing, slope streams, and macrorheocrenes with a rocky bottom. In such watercourses, a biocenosis similar to ritral develops often, but it is characterized by low species composition. Here, mostly cold-water organisms of the oligosaprobic zone with high sensitivity to eutrophication are found: caddisflies of the genera *Rhyacophila*, *Glossoma*, *Potamophylax*, mayflies *Baetis rhodani* (Pictet, 1843), stoneflies of the genera *Nemoura*, *Leuctra*, and Diptera larvae (*Diamesa* sp. and *Criptochironomus* sp.).

In the mouth zone of the stream, the biotope type changes mainly due to significant eutrophication of the stream flow and its heavy siltation. In addition, in the mouth area, a noticeable change in the nature of the bottom substrate is noted: instead of the fragments of limestone, tuff, diabase, and mudstone observed in the upper reaches, solid construction waste (fragments of panels, bricks, tiles, etc.) predominate in these areas. The complex of these factors contributes to the replacement of the typical geobiocenosis of the oligosaprobic zone described above in the mouth area by psephoepirithral (a biotope with rocky and pebble soil, heavily silted, with abundant fouling of green filamentous algae and mucus, where diatom fouling is practically absent). Mayflies (*Baetis rhodani*) and caddis flies of the family Limnephilidae are the most adapted to such an environment. In addition, due to the formation of loose bottom silt, some burrowing forms characteristic of soft sediments appear. It is also noted that the water temperature remains relatively low even in the summer (June–September) in the upper and middle reaches of watercourse, but in the estuary zones it increases up to 19 °C. The latter increases the possibility of biotransformation reactions of dissolved impurities entering the watercourse bed and leading to secondary pollution of the environment (Chekmareva and Grigorieva, 2019; Stribling, 2011). The physical and hydrobiological characteristics of the studied areas of the stream are given in Table 2.

Shannon index values indicate a relatively high level of stability of biological communities in the upper reaches of the stream. This indicator in crenal biotopes is slightly reduced compared to that for ripal communities of watercourses of the same territory (the Laura, Achipse, and Assara rivers), obtained earlier (Gorbunova, 2019; Gudkova et al., 2018). Probably, this is a consequence of reduced species diversity in stream biocenoses in high-altitude zones. Samples from the upper reaches demonstrate a fairly high degree of evenness according to the values of the Simpson and Berger-Parker indices; the share of individual dominant species in the community is low here. In the samples obtained at the upper reaches, caddisflies are the dominant group of aquatic animals, with a small share of mayflies and stoneflies (*Leuctra* sp.) in the EPT population. The EPT species accounted for more than 50% of the total abundance of aquatic organisms during the entire study period. They are indicators of a clean (xeno- and oligosaprobic) environment; some of them are endemic to the Caucasus. The dominance of the EPT organisms results in the high values of the QMCI index in these areas, so these biocenoses may be characterized as extremely sensitive to organic pollution (Morse et al., 2007).

The QMCI index remains high (i.e., corresponding to the xeno-oligosaprobic zone) for the section of the middle reaches of the Tobias Creek. However, there are signs of a decrease in the stability and evenness of the biological community in this area, as indicated by a decrease in species diversity and an increase in the share of dominant species. In addition, the share of EPT organisms in the total abundance and species composition per sample decreased. These indicators may be considered early signs of stability disruption of aquatic biocenosis under the influence of external factors.

In the mouth area of the Tobias Creek, both stability level and evenness of the biocenoses of the watercourse decrease. In addition, high values of the Simpson and Berger-Parker indices indicate a significant increase in the share of individual groups of aquatic animals in the biocenosis (Shitikov and Zinchenko, 2013). Dipterans and gastropods, which are indicators of water contaminated with organic matter, are dominants in these areas. The share of the EPT organisms is reduced compared to other areas down to 33.1%. The QMCI index values classify this site as moderately polluted and corresponding to the β -mesosaprobic zone.

A significant decrease in both the abundance and species diversity of the EPT organisms during siltation of the bottom substrate in rivers has been noted earlier because of the changes in their habitat (inability to attach to rocky substrate) and the absence of the usual phytofouling (diatoms), which serve as the food basis for the next links in the trophic chain of the watercourse (Gorbunova, 2020; Gudkova et al., 2022). During present study, it is also found that the siltation degree of the rocky-pebble bottom

Table 2. Main physical and hydrobiological indicators in the studied samples of the Tobias Creek.

Water body and its area	Physical parameters					Biotic parameters						
	Temperature, °C	pH	Degree of siltation of the bottom substrate	Presence of fouling of bottom substrate	Rocks in the riverbed	Biotic IndexQMC1	Shannon index	Margalef index	Simpson index	Berger–Parker index	Share of EPT organisms, % of the total number of organisms	Share of EPT organisms, % of the total number of species in the sample
The upper course of the Tobias Creek, level 2010 m a.s.l. (Area no. 1)	4–6	8.3	1	Attached diatoms (brown fouling of the bottom substrate)	Siltstones, shales, pelitic tuffs	6.89	2.35	5.75	0.19	0.2	59.1	39.7
The middle course of the Tobias Creek, mark 993 m a.s.l. (Area no. 2)	7–10	8.2	2	Attached diatoms, minor fouling of green filamentous algae mainly on limestones	Fragments of limestone, tuff, diabase, mudstone	6.77	2.11	4.4	0.21	0.3	45.2	37.5
The lower course of the Tobias Creek, confluence with the Mzymta River (Area no. 3)	7–19	8	4	Abundant fouling of green filamentous algae, mucus, detritus deposits	Bank of the Mzymta River, presence of construction waste	5.44	1.98	3.67	0.31	0.37	33.1	22.5

substrate of the stream increases from the upper reaches to the mouth, while the share of the EPT organisms in the total abundance of aquatic organisms decreases.

In addition, during qualitative and quantitative processing of the samples, it is discovered that various organisms of the benthic macrozoobenthos community prefer different geological substrates. For example, some species of caddisflies (*Glossoma capitatum* Martynov, 1913, *Rhyacophila* sp.) prefer mudstones, tuffs, and diabase to limestone fragments. However, caddisflies of genera *Hydropsyche* sp. and *Limnephilus* sp. are not substrate-selective. Caddisflies practically do not colonize the artificial substrate (fragments of bricks, concrete, tiles, etc.). At the next stage of work, it is planned to conduct a statistical analysis of the dependence of the qualitative and quantitative composition of bottom biocenoses on the geological characteristics of the material of the bottom substrate of water bodies.

Biotesting of the natural waters of the Tobias Creek was carried out using unicellular algae *Chlorella vulgaris* Beijer. This method was applied considering eutrophication caused by anthropogenic activities as one of the main problems when analyzing the most significant factors affecting the aquatic environment of the study area (Gorbunova, 2017, 2020; Gudkova and Gorbunova, 2018; Gudkova et al., 2022). In the presence of thick silt deposits, organic matter entering the watercourse with domestic and storm water accumulates in the sediment, while with a clean rocky bottom substrate it is washed away during the flood season by a strong current. The accumulation of biogenic organic matter in sludge sediments and the process of its decomposition create conditions for secondary pollution, especially in the summer at fairly high temperatures in estuary zones, low water flows, and intensified anthropogenic load during the touristic high season. The results of experiments are presented in Table 3.

During the acute (24 hours) and subacute (72 hours) experiments, no significant deviations from the control are found in the studied samples, which is common for mountain-type watercourses. In the chronic experiment, the algae growth rate differs in the experimental and control groups. In the upper reaches of the stream, this indicator differs from the control by only 10.8%, showing no significant deviations; however, in the middle reaches and the mouth area of the stream, it is significantly high (37.5% and 47.6%, respectively). In all samples from the Tobias Creek, algae growth stimulation is observed compared to the control, which indicates the presence of biogenic impurities in them (Fedoseeva et al., 2020).

Earlier, we have noted that abundant siltation of the rocky bottom substrate of mountain-type watercourses causes the changes in the composition of phytofouling. In particular, abundant fouling of filamentous green algae appears; when dying and decomposing, they create a threat of secondary pollution with organic matter (Gorbunova, 2017, 2020; Gudkova and Gorbunova, 2018; Gudkova et al., 2022). In addition, fine silt deposits, which formation is facilitated by the exogenous geological and technogenic processes identified above, are capable of accumulating organic matter entering the watercourse. This may contribute to increased eutrophication in the bottom layer of water and, as a result, stimulates the growth of algae in the experimental vials compared to the control group.

The Tobias Creek basin according to the level of intensity of environmental management based on the hydrobiological characteristics of the watercourse

Three zones of the Tobias Creek basin were identified, differing in the nature of the impact of natural and anthropogenic factors.

The first section of the catchment area, confined to the upper reaches of the Tobias Creek (area no. 1), is characterized by a relatively weak degree of natural disturbance. Hiking (eco-trails laid mainly along the clearings of winter ski slopes), cable lifts, and some tourist service infrastructure (fast food points, toilets, tent camps, etc.) are among the anthropogenic factors. The biocenoses of the stream in this area correspond to the xeno-oligosaprobic zone with clean water and bottom substrate. The partly reduced biodiversity of macrozoobenthos biocenoses is explained by their belonging to crenopirithral biotopes. Its characteristic communities are adapted to minimal input of organic matter into their habitat and are mainly represented by grazers and predators (caddis flies and aquatic developmental stages of mayflies). No significant deviations from the control were found in biotesting experiments for this area.

The second section of the Tobias Creek basin (area no. 2) also refers to the crenopirithral biotope. The hotel cluster of the “Krasnaya Polyana”–“Polyana 960” resort and associated technical structures, entertainment and tourist infrastructure, cable car areas, numerous hiking trails and ski slopes have

Table 3. Biotesting of Tobias Creek water using unicellular algae *Chlorella vulgaris* B.

Sampling site	Deviation over 24 hours (acute experiment)	Reliability criterion for deviations at $p < 0.05$ ($n = 9$, $td = 2.12$)	Deviation over 72 hours (subacute experiment)	Reliability criterion for deviations at $p < 0.05$ ($n = 9$, $td = 2.12$)	Deviation over 7 days (chronic experience)	Reliability criterion for deviations at $p < 0.05$ ($n = 9$, $td = 2.12$)
1	5.8	−0.57	7.01	−0.88	10.8	−0.98
2	5.2	−0.64	11.8	−1.46	37.5	−2.79
3	7.8	−1.92	18.2	−2.09	47.6	−3.02

significant anthropogenic impact on the basin geoecosystems. Here, the water flow is regulated in some areas into collectors. Bioindicator characteristics point to a decrease in the stability level of aquatic biocenoses (Shannon index) and their evenness (Simpson and Berger-Parker indices). Compared to the area no. 1, a decrease in the abundance and species diversity of caddisflies and an increase in the share of dipteran larvae are both observed. The presence of nutrients in the water samples is supported by the biotesting. Presumably, the latter is the factor contributing to the development of green filamentous algae fouling observed.

The downstream zone of the Tobias Creek (area no. 3) belongs to the psephoepirithral due to the heavy siltation of the rocky-pebbly soil and due to the abundant fouling by green filamentous algae and mucus, which are not characteristic of the biotopes of mountain and foothill crenal. According to QMCI index (5.44), the watercourse corresponds to a β -mesosaprobic zone with a moderately polluted aquatic environment. The biocenosis of this area is characterized, on the one hand by high biodiversity, characteristic of mesotrophic watercourses, but, on the other hand, by low values of stability indicators and by a high degree of dominance of certain taxonomic groups, which altogether point to a decrease in the biocenosis evenness. The share of EPT organisms, which are the indicators of clean water, is significantly reduced both in abundance and species composition. Grazers and detritivores appear in the ecosystem, they are characteristic of eutrophicating water bodies. The results of biotesting indicate an increased content of biogenic organic matter in the watercourse. The anthropogenic impact in this zone is quite intense: tourist accommodation and catering facilities, roads and railways. Similar to the previous area, the stream in this zone is partially regulated into a collector.

The state of terrestrial ecosystems, in particular forests, affects the regime of mountain watercourses, the quality of their bottom substrates and water, and, therefore, it changes the habitats of endemic biocenoses. In order to confirm the hypothesis about the coincidence of the ecological zones of the watercourse and its basin, forest and landscape inventory has been carried out. The main tree composition of the studied area is represented by disordered and low-productive middle-aged deciduous plantations with extra-tiered evergreen vegetation, with participation at the level of parcels and individual ecosystems: hornbeam, aspen, alder, maple, oak, and beech. According to the type of hygrotone, it refers to fresh forest conditions. Visibility of the territory >80 m; the undergrowth density for the four survey sites is 3.4 thousand/ha. The ground cover is represented by *Smilax* sp., ferns, blackberries, cereals, burdock (with temperature damage to leaf blades), and sedges. Completeness is uneven and low (less than 0.7); canopy density is 0.8–1.0; the bonitet of individual trees throughout the zone varies in the range III–V. According to these parameters, the analyzed forest area does not have an environment-forming function, since it has a reduced natural resistance to any factors (recreational, technogenic, biogenic). The area of grassed meadows varies as $\approx 4 \times 5$, 2×2 , 3×3 , 2×6 meters; in general, they are resistant to trampling due to the presence of meadow herbaceous components.

Based on the above survey, the anthropogenic deprivation of terrestrial phytocenoses was assessed in forested areas located in the mouth zone of the Tobias Creek basin and those under the influence of intensive recreational and tourist activities (Table 4). The results obtained indicate the unsatisfactory state of plant biocenoses in the study area and their vulnerability to recreational loads.

Table 4. Assessment of the mouth zone of the Tobias Creek basin by landscape taxation.

Class	State	Site characteristics
Sanitary and hygienic assessment		
3	bad	Littering with dead wood, the presence of quarries and pits, windy areas, strong shading, extraneous noise, excessive moisture, dense thickets
Biological sustainability of plantings		
2–3	broken or lost	Loss of more than 2 m ³ /ha due to trees with a diameter equal to or greater than average
Recreational assessment		
3	bad	Movement is limited (difficult) in many directions. Large capital expenditures for improvement are required
Microclimate comfort		
4	good	Closed type, fullness 0.5–0.7
Oxygen productivity		
2	very bad	Plantings of deciduous trees, disorganized, with low and medium productivity, abundance not lower than 0.6
Technological assessment		
3	bad	Littering (fallen trees), 10–20 ind./ha
3	bad	Relief roughness (1–2 bends)
Natural comfort of the area		
2	very bad	Undergrowth abundance (3000–10000 ind./ha)
Resistance to recreational loads		
2	very bad	Fresh beech trees, chestnut trees, etc.

Conclusions

The study of the recreational and tourist area made it possible to zone the Tobias Creek basin. Three sections of the watercourse with different types of biotopes were identified based on biological analysis. The coincidence of the ecological zones of the stream and its basin, characterized by negative changes (deterioration) in environmental conditions from source to mouth, have been found when studying geological and anthropogenic factors and the processes in the catchment area. Consequently, biological parameters reflecting processes in aquatic ecosystems may be used as indicators of the state of the natural environment of a watershed.

The proposed system of hydrobiological indicators may be used as the main comprehensive and relatively inexpensive monitoring tool in a systemic integrated approach, which does not require special equipment and which may be applied widely in natural resource management in the catchment area. An integrated approach may be an effective tool for identifying cause-and-effect relationships in water resource management, since it provides timely information about natural, technogenic, and anthropogenic loads on a water body and its sections, making possible to predict the development of the state of the river and its basin in regard to the changing environmental conditions.

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