Creating an ecological trail as a means of formation an culture of the population and preserving rare, protected species of flora

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Abstract. The paper presents an ecological trail created in the area affected by enterprises of the Tobolsk Industrial Site (Tyumen region, Russia). This ecological trail is aimed at preserving old-growth forest areas, creating a vision of harmonious coexistence between a large petrochemical facility and the surrounding natural environment and, therefore, helping to preserve rare, protected and indicator species of the biota identified near the Tobolsk Industrial Site. As a result of the research conducted on the ecological trail, thirteen rare and protected species of flora were identified and preserved. These are: *Lobaria pulmonaria* L. Hoffm., *Phegopteris connectilis* (Michx.) Watt., *Cystopteris fragilis* (L.) Bernh., *Dryopteris filix-mas* (L.) Schott., *Tilia cordata* Mill., *Calluna vulgaris* (L.) Hull., *Allium microdictyon* Prokh., *Neottianthe cucullata* L. Schlechter., *Malaxis monophyllos* L., *Dactylorhiza maculata* (L.) Soo, *Neottia nidus-avis* (L.) Rich., *Cypripedium guttatum* Sw., *Listera ovata* (L.) R. Br. The area reserved for the ecological trail will be protected from deforestation and construction.

1. Introduction

The city of Tobolsk (Tyumen region, Russia) is located about 100 km south of the border between the southern and middle taiga. This location determines the special natural environment surrounding the town, which has a great diversity of flora and fauna. Due to geological features of the region, the production and processing of hydrocarbons by oil and gas companies have become the most important economic sectors. Hydrocarbons are processed at facilities of SIBUR, the largest Russian petrochemical company.

The production capabilities of SIBUR Tobolsk include a natural gas liquids (NGL) facility with a capacity of 6.8 million tonnes per year, a monomer manufacturing facility, and a polymer manufacturing facility for polypropylene production with a capacity of 500 thousand tonnes per year. Moreover, the largest petrochemical facility in Russia and Europe, ZapSibNeftekhim, is under construction at the Tobolsk Industrial Site. This project will allow the company to increase the output of polymers in Tobolsk to 2.5 million tonnes per year.

A modern industrial enterprise must be evaluated not only in terms of efficiency and productivity, but also in terms of its interaction with the local community and the natural environment.

In the context of the development of the oil and gas complex in Western Siberia, it is necessary to promote environmentally friendly projects that are currently being developed with the greatest possible preservation of the environment.
One of the proven and effective ways of making this interaction efficient is to create an ecological trail. The ecological trail is a specially equipped demonstration path running through various natural features [1].

Trails are a type of tourism infrastructure that influence vegetation and soil, which are essential for sustainable recreation practices [2]. Research routes may affect the abundance of epiphytic vegetation [3]. Protected areas have been established for a variety of purposes, but preserving wild nature is certainly one of the most important [4].

The ecological trail project was implemented by SIBUR together with the Tobolsk Complex Scientific Station, Ural Branch of the Russian Academy of Sciences, with the support of the Tobolsk Town Administration, Tyumen Region, Russia. Research projects are essential to understand ecological change and the effectiveness of management activities [5]. In so doing, we hope to open up new research and practices that consider possibilities for environmental education to act in consort with other initiatives [6].

The aim is to create conditions for the formation of a worldview about the possibility of harmonious coexistence of a modern industrial complex with its natural environment through the organization of an ecological trail as one of the effective forms of environmental education and enlightenment of the population.

Education is one of the multiple services that ecosystems and landscapes provide to societies. Despite its importance to formal and informal learning and nature-based, cognitive tourism, it is hardly taken into account in the various quantification approaches of ecosystem services [7].

The ecological trail passes through mixed, deciduous and taiga forests; it is located 1.5 km from the Tobolsk Industrial Site. Such a neighborhood makes it possible to monitor the environment in the immediate vicinity of production facilities.

Due to the need to preserve the pristine natural environment, rare and protected species of flora in the immediate vicinity of the industrial facility, which has been operating for more than thirty years and continues to actively construct and develop, the creation of ecological trails is a relevant and important activity.

2. Materials and methods
The ecological trail was designed based on standard techniques. The description of vegetation was carried out during the growing seasons according to the methodological approaches and methods, which were accepted in phytocoenology and widely used in geobotanical studies [8,9]. Stations of the ecological trail and places of detection of rare and protected species recorded with GPS-navigator «Garmin». Coordinates of the entrance group N 58.1731, E 68.2842. The ecological trail was located 1.5 km from the Tobolsk construction site. Thus, it is a monitoring area, which can control the environment. The results of the ecological trail project include developed routes and tours, marked stop stations and designed stands. The ecological trail is routed according to its purpose so that the routes represent different areas of the natural environment. The essential conditions for locating the ecological trail include its accessibility for tourists, attractive landscapes, information richness, as well as the preservation of rare and protected species of flora identified in the area of the ecological trail [9].

3. Results and discussion
Routes of the ecological trail are located in urban forests, 1.5 km north of the ZapSibNeftekhim construction site and the existing facilities of the SIBUR industrial site. In total, these routes are 4 km long and occupy 70 ha.

The ecological trail consists of three routes, each of which passes through different types of forests found in the study area. An entrance unit decorated as a gate with information stands serves as a starting point for all routes. Near the entrance unit, there is a monitoring site with information stands dedicated to environmental monitoring on the ecological trail and in Tobolsk city (figure 1).
Figure 1. Tourists on the ecological trail in the city of Tobolsk

Based on the monitoring site, rapid tests for soil, water and air pollutants are conducted for visitors. Most of chemical tests are conducted in the presence of visitors. Visual assessment of water (snow) provide data on its quality: color, odor, suspended solids content, the presence of an oily film on the surface. Qualitative tests of water from various sources can identify the presence of such chemical compounds as chlorides, sulfates, iron, ammonia, lead, copper, phenol, and unsaturated hydrocarbons. Using a rapid water test kit, it is possible to determine the pH value, permanganate index, hardness, manganese, nitrates, and nitrites.

The ecological trail is routed so that visitors can not only pass through sections of pristine taiga with its living environments, deciduous and mixed forests, but also get acquainted with unique wildlife features: ancient lindens and pines, rare species of plants, fungi and lichens, fancy polypores and burls on trees.

During the guided tours, guides give some explanations. They provide visitors with necessary information about natural and other attractions on the ecological trail, get them acquainted with the rules of conduct at its individual sites, and ensure that these rules are complied with.

According to the general concept of the ecological trail, the names of the routes reflect the goals of this project.

1 – Circular route Petrochemistry and Wildlife: Ecology of the Neighborhood (2.0 km long). Its primary objective is to show the condition of the environment in the immediate vicinity of the petrochemical facility through bioindicator species: lichens, mosses, vascular plants, and some species of animals living on the ecological trail. Another objective of the route is to debunk the most common “environmental myths” about the negative industrial impact on the natural environment. The route includes seven stop stations equipped with systems of information stands for the following groups: indicator plants, lichens, insects, soil microarthropods, and animal paths. The route is used for seasonal sightseeing tours.

2 – Circular route The Image of the Siberian Taiga (1.0 km long). Visitors can get an insight into the diversity of biota, which is typical of the southern taiga subzone. The objective of the route is to raise environmental awareness and promote environmental education. The route includes eight stop stations equipped with systems of information stands for various flora and fauna groups:

3 – Circular route The Pearls of Tobolsk Flora (1.0 km long). This route focuses on rare and protected species listed in the Red Book of the Tyumen Region. Moreover, it provides some information on medicinal, edible and poisonous species of plants and fungi. The objective of this route is to demonstrate the richness of the plant world near Tobolsk, in which the floral diversity is 25–30% richer than that in other regions of Western Siberia. The route includes five stop stations equipped with systems of information stands for various plant groups:

Another feature of the trail is unique taiga forests. The age of the pine growing on the ecological trail is 250 years. By communing with nature, visitors to the ecological trail improve their powers of
observation, curiosity, logical thinking, the ability to analyze, compare and generalize, and can foresee and predict the effects of human activities.

Students receive field training on the ecological trail. Students not only increase their knowledge of natural science, but also get an insight into the relationship between humans and the environment. They learn to comprehensively evaluate the results of their research and to predict environmental consequences of human activities. Information stands, tours, talks, workshops and master classes have a certain impact on the minds of people, raise their environmental awareness, and make them think about their behavior and attitude to nature. As a result, of the research conducted on the ecological trail, rare and protected species of the flora were identified.

*Lobaria pulmonaria* L. Hoffm. A very large foliose lichen. Status: category II. Species with declining population. Listed in the Red Book of Russia. The thallus is 30–50 cm in diameter. It forms round or indefinitely shaped rosettes and loosely attached to the substrate. The blades are rather thick, gristly, deeply carved, and dichotomous branching. It is a foliose lichen growing mainly on trees (epiphyte). It mostly grows on deciduous trees, although it can also be found on conifers [6-9]. Sometimes it grows even on stones and rocks. In general, the lichen needs a substrate only for attachment (figure 2). Ferns are abundant in the grass-shrub layer. The species richness and abundance of ferns on the routes are determined by the humidity of the habitat, but, in general, pteridophytes are weakly represented in the diversity of the ecological trail. These are *Phegopteris connectilis* (Michx.) Watt. Category III – rare species; *Cystopteris fragilis* (L.) Bernh. Category III – rare species; *Dryopteris filix-mas* (L.) Schott. Category II – species with declining population [9,10].

![Figure 2. Lobaria pulmonaria L. Hoffm.](image)

The ecological trail has taiga sections with *Tilia cordata* Mill. This tree species is common in Europe, but in the Siberia it can be found only in the Tyumen Region and partially in the Khanty-Mansiysk Autonomous Okrug. *Tilia cordata* Mill. Category III – rare species [9,10]. The trees can grow to 30 m in height. In the understory, they can be found in bushlike form. The leaves are petiolate, round-heart-shaped, serrate along the edge, acuminate, 3–9 cm long, bearded with reddish hairs in corners of veins. The inflorescence is composed of cymes combining 2–4 flowers. *Tilia cordata* Mill. is considered a relict species for southern taiga forests of Western Siberia. It was widespread in warmer geological periods and significantly reduced its range in cold periods. At present, *Tilia cordata* Mill. thrives and reproduces well in the polydominant taiga.

Another interesting rare plant can be found in pine forests on the ecological trail: *Calluna vulgaris* (L.) Hull. Category III – rare species. It is an evergreen shrub of 15–50 cm tall, with woody, ascending and branching stems. The leaves are opposite, sessile, pressed, boat-shaped, small (1.7–2.3 mm long), sagittate at the base. The flowers are reclined or drooping, form almost one-sided tufts ending in leafy tops. The flowering season of heather lasts from July to late September. Dried heather flowers do not fall, giving the impression that the plant blooms until late autumn [9,10].
*Allium microdictyon* Prokh can also be found in the forest. It is a plant up to 70 cm tall, with a stem half covered with leaf sheaths. The bulbs are conical and cylindrical, with a diameter of up to one and a half centimeters. There can be from one to several bulbs on an oblique rhizome. The leaves are smooth, lanceolate or oblong-elliptical, flat with a well-defined blade, 10 to 20 cm long and 8 cm wide, tapering into a long (3–7 cm) stalk. The inflorescence at the end of the stem is shaped as a thick spherical umbrella. The flowers are borne on equal pedicels, which are two to three times longer than the perianth.

**Status**: category 3 [9,10]. It is a rare species that can be found on the western boundary of the distribution area. Species with disjunctive distribution. It is listed in red books of Tyumen (2004) and Sverdlovsk (2008) regions as category 2 (figure 3).

![Image of Allium microdictyon Prokh](image)

**Figure 3. Allium microdictyon Prokh.**

The ecological trail makes it possible to preserve the existing level of biodiversity, including rare, protected and indicator species of living organisms, even in the face of the fast industrial development of the region.

Among the interesting rare and protected species found on the ecological trail, orchids are notable. In terms of size and color of their flowers, Siberian orchids are much more modest than their tropical relatives. Some of them are quite inconspicuous, with small flowers. However, even these species often have extraordinarily elegant flowers (table 1).

**Table 1. Red book listed orchids occurring on the ecological trail.**

| No. | Type                                               | Category                              |
|-----|----------------------------------------------------|---------------------------------------|
| 1   | *Neottianthe cucullata* L. Schlechter             | III – rare species                    |
| 2   | *Malaxis monophyllos* L.                          | II – species with declining population|
| 3   | *Dactylorhiza maculata* (L.) Soo                   | II – species with declining population|
| 4   | *Neottia nidus-avis* (L.) Rich.                   | II – species with declining population|
| 5   | *Cypripedium guttatum* Sw.                        | III – rare species                    |
| 6   | *Listera ovata* (L.) R. Br.                       | II – species with declining population|

*Neottianthe cucullata* L. Schlechter is a perennial herbaceous plant. Tuber geophyte. The leaves are arranged alternately, small along the stem length, lanceolate, elliptical or ovoid. There are usually two leaves at the base of the plant. The flowers are pink with a shade of white or purple, collected in a racemose or spicate one-sided inflorescence. The fruit is a boll [9].

*Malaxis monophyllos* L. is a perennial herbaceous plant. Geophyte. Rhizome with a pseudobulb. The leaves are oval or elliptical, with a sharp or rounded tip. The flowers are small, yellow and green, collected in a racemose inflorescence. The fruit is a brown or green boll [10,11].

*Dactylorhiza maculata* (L.) Soo is a perennial herbaceous plant. The tuber is palmate and flattened. The stem is upright, single, dense, about 8 mm thick at the base. The leaves are few, (2) 5-6 (8), reclined,
almost flat or conduplicate, large, dark green, with round purple spots. Up the stem, the shape of the leaves vary from oblong-lanceolate, blunt or acuminate to acuminate, linear or subulate-linear, often slightly sinuate. The flowers are collected in dense, multi-flowered spicate inflorescences. The fruit is a boll with numerous small seeds [11].

*Neottia nidus-avis* (L.) Rich. is a perennial herbaceous rhizome non-photosynthetic plant. Being a mycoterotroph, the plant receives organic matter from its associated fungi. A yellow-brown plant with an upright stem and a dense elongated inflorescence reaches 20–45 cm in height. Four to six cataphylls are pressed against the stem. The flowers are borne on short pedicels and smell like honey. *Neottia nidus-avis* blooms from May to July [10].

*Cypripedium guttatum* Sw. is a perennial herbaceous plant with a long rhizome. The rhizome is long, creeping, shaped as thin cord. The stem is 10–30 cm high, adenotrichous. There are two, rarely three leaves, not counting smaller bracts. The leaves are sessile, alternate, broadly elliptic, rarely pubescent in the bottom part, with a smooth edge. The flower is single, large, shaped like a shoe. The fruit is an elongated boll [10,11].

*Listera ovata* (L.) R. Br. is a perennial herbaceous plant with a short creeping rhizome. The stem has two wide opposite oval leaves, which are arranged almost horizontally. The stems end in elongated multi-flowered inflorescences. The flowers are small, yellowish-green. The fruit is a boll [10].

All orchids are listed in red books of many areas in which they occur. According to the sustainable development concept, which involves the rational use of natural resources for the benefit of current and future generations, this ongoing project demonstrates that the region can support the intensive industrial development without significant damage to the environment, while preserving the existing level of biodiversity, including rare, protected and indicator species of living organisms.

**Conclusion**

As a result of the research conducted on the ecological trail, thirteen rare and protected species of flora were identified and preserved: *Lobaria pulmonaria* L. Hoffm., *Phegopteris connectilis* (Michx.) Watt., *Cystopteris fragilis* (L.) Bernh., *Dryopteris filix-mas* (L.) Schott., *Tilia cordata* Mill., *Calluna vulgaris* (L.) Hull., *Allium microdictyon* Prokh., *Neottianthe cucullata* L. Schlechter., *Malaxis monophyllos* L., *Dactylorhiza maculata* (L.) Soo, *Neottia nidus-avis* (L.) Rich., *Cypripedium guttatum* Sw., *Listera ovata* (L.) R. Br.

At the operational stage of the ecological trail project, the environmental efficiency involves communicating the research results to the expert community and the general public. These efforts help to prevent the negative environmental impact of industrial enterprises, to develop a more responsible attitude of the Russian petrochemical company SIBUR to the environmental impact of its production facilities and, therefore, to preserve the pristine natural environment with rare and protected species.

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