Methodological framework for assessment of anthropogenic impact on the biodiversity of soil-biotic communities of taiga and steppe ecosystems in the Baikal region

E P Bessolitsyna
Sochava Institute of Geography SB RAS, Irkutsk, Russia
E-mail: bessol@irigs.irk.ru

Abstract. Landscape-ecological analysis of soil invertebrate’s communities and their spatial distribution in the Baikal Region was carried out on the local (biogeocenotic), topological (facies) and regional levels. The paper considers Methodological Framework for Assessment of transformation of communities’ structure and biodiversity under the influence of natural: phytocenotic (peculiarities of vegetation), edaphical and climatic (hydrothermal regime of the soil) conditions and anthropogenic factors: the removal of the wood as a result of deforestation, fires, irrational use of pastures, technogenic pollution, recreation and others. Peculiarities of structures of invertebrate’s communities and their changes due to the climate change and anthropogenic impacts can serve as one of diagnostic criteria of soil conditions and can be used for estimation of an extent of landscape's transformation and for monitoring. In the spectrum of states of the taxonomic diversity of landscape units, three main categories of situations are distinguished: critical, conflict and relatively satisfactory. The main trend of changes in taxonomic diversity of invertebrate’s communities is a decrease in the species number in the gradient of an increase of climate aridity, and strengthening of the hypothermal character and anthropogenic pressure.

1. Introduction
The problem concerning the study and conservation of biological diversity, the relevance of which was marked by the United Nations Conference on Environment and Development, has one of the central positions in relation to global environmental changes and provision of environmental safety of humans and other living beings.

On the one hand, biological diversity conservation is closely associated with the activity on protection of natural resources and environment, carried out in the system of nature management. On the other hand, it is an independent, specific activity aimed at reducing the impact of the nature management process itself on the state of ecological systems.

Biodiversity as an object for conservation is not only a species composition of organisms with their quantitative parameters, but also a qualitative system of interrelationships between these organisms, which provides for the functional integrity of ecological systems. An effective strategy can be developed only on the basis of specific information about the state of biodiversity of individual regions, causes and trends of its changes, as well as about the distribution of objects within the territory.
Within the framework of the Convention, the policy of biodiversity conservation was described, a key position of which is to preserve not only the diversity of species itself, but also the natural habitat, where they were formed and acquired their own distinctive features.

2. Models and methods
The source of the actual material is the long-term studies of soil invertebrates population on the transect of field stations in the V.B. Sochava Institute of Geography SB RAS, located in the south of the Krasnoyarsk krai. A comparative analysis of the qualitative and quantitative characteristics of zoocenoses was carried out on a wide information basis, from the southern taiga of the Central Siberian plateau to the true steppes of the Minusinskaya depression. In the Baikal region, the study was carried out in four key areas, covering (in the landscape-zonal range) the main regional spectrum of geosystems: from the mountain taiga of the Leno-Angarskoe plateau to the forest-steppe landscapes of the Irkutsko-Cheremkhovskaya plain. This territory is characterized by a multicomponent phytocenosis, mosaicism and a wide variety of derivative communities that arise as a result of human activities.

The collection and processing of material were carried out in a uniform manner using both traditional and modern approaches and methods recommended for ecology-faunistic, soil-zoological, biogeocenological and landscape-ecological studies [1]. To determine the number and biomass of the inhabitants of soil and litter, 6-8 samples with a depth of 25-40 cm (depending on the limiting occurrence of invertebrates) were taken in each area in a checkerboard pattern on a 25x25 cm with a monolithic drill.

3. Results and Discussion
High biodiversity of the Baikal region is due to its geographical location and characteristics of the formation of the rift zone, which contributed to the formation of a unique landscape structure. The Baikal Natural Territory is one of the major physico-geographical "nodes" of the Eurasian continent. Here, the imposition of areas of representatives from different biogeographical zones is observed, which leads to a complication of the situation from the standpoint of the distribution of species and faunal complexes, and highlights the region against the neighboring territories. Increased biodiversity of the Pribaikalie, where, along with the taiga forests, there are steppe, wetland and alpine areas, is due to the passage of the northern and southern, eastern and western boundaries of the areas of many species of animals and plants. The peculiarity of the landscape-ecological conditions creates preconditions for local endemism and formation of unique natural sites with a large number of rare species.

The main reason for the impoverishment of communities and species extinction is increasing human impact on the environment. The main factors of anthropogenic disturbance of natural complexes are the impact of industrial enterprises, elimination of tree canopy as a result of felling, fires, overgrazing, plowing of meadows and copses, reclamation, unnormalized use of fertilizers and pesticides, recreational load, and many others, as well as collecting and intense gathering of rare and the most beautiful species. All this leads to the conversion, reduction, and sometimes complete degradation of habitats of animals, and even to the destruction of the least sustainable ecosystems. In most situations, the mechanism of anthropogenic transformations is a change in either hydrothermal regime, or physical and chemical properties of soil, that contribute to corresponding changes of biotic communities.

Impoverishment and trivialization of taxonomic and coenotic diversity of the animal population, and the outbreaks of mass reproduction of insects should be considered as indicators of negative processes in the landscape, i.e. changes in land cover towards its significant xeromorphization and degradation.

As a part of the policy of the environment and natural resources protection, activity on biodiversity conservation is aimed at resource conservation, the mechanism of which should include the following:

- Inventory of biodiversity at the taxonomic and ecosystem levels;
• Identification and assessment of the state of the most valuable, rare and endangered biodiversity objects;
• Classification and systematization of biodiversity objects, and spatial interpretation;
• Predictive assessment of trends of changes.

Biodiversity is in a complex functional relation to the characteristics of an ecosystem, its dimension and stability, and dynamic structure – biota and abiotic environment, representing a whole. An indication of the diversity of species is considered to be the correlation between the number of species and their specific value (numbers, biomass, productivity, frequency of occurrence, etc.) or the ratio of the number of species per unit area [2].

To develop a strategy for the biodiversity conservation of terrestrial ecosystems, bringing together two major biotic units, namely, flora and fauna, an integrated system approach is necessary. One of these approaches can be landscape-ecological or ecosystem one, which according to its content and methodology includes the most important elements of this strategy: from allocation of areas with increased biotic diversity, their inventory, typology and mapping to the development of methods and criteria for assessing the state of biodiversity and monitoring organization.

Landscape-ecological concept of biodiversity conservation involves science-based forms of human activity aimed at the conservation and reproduction of social and ecological functions of a landscape and its biotic potential by limiting the negative impact on the basis of the regulation and standardization of individual forms of economic activity, as well as at the optimization and further development of the system of protected territories.

Key elements in the concept under consideration are:
• identification of the most promising areas in terms of the uniqueness and value of biological and coenotic diversity;
• analysis of the spectrum of natural and anthropogenic factors affecting biotic communities;
• assessment of the current state and trends of changes of biodiversity at the species, coenotic and landscape levels under certain types and forms of human activity;
• determination of the objectives and variants of use of the territory (optimization of existing and potential types of economic activity with a priority for biodiversity conservation);
• development of restrictions for different kinds of impacts on biotic complexes, and environmental and resource-saving measures;
• monitoring of the state of biodiversity and socio-economic and environmental consequences of the anthropogenic impact.

The structure of population, biodiversity and the state of populations of soil invertebrates are the most convenient for biodiagnostics [2, etc.]. The feasibility of using these indicators to assess the state of the communities’ diversity of natural and natural-technical systems is determined by the variety of life forms, relatively high abundance, close ties with the soil and sufficiently fast response to changes in environmental conditions. Compared with the inhabitants of mineral soil horizons, gerpetobionts (litter complex) experience direct and indirect effects of anthropogenic loads to a large extent, and can be used to assess the toxicity of the technogenic impact.

The status of individual components of an elementary ecosystem, as well as the degree of change in diversity of biotic communities, can be expressed by different indicators, namely: diversity coefficients, the size of biomass and abundance of individual taxa, their occurrence, indices of similarity of compared objects, and by rating scales, where the deviation of the indication or estimated trait from the background/maximum characteristics is expressed as a percentage or points.

The study into the dynamics of soil mesopopulation under the influence of anthropogenic factors showed that good results for assessing the state of the natural environment are obtained through the use of a comprehensive comparative-geographical approach. When monitoring in the areas of human impact, particular attention should be given to the criteria that characterize the degradation processes of biogeocenoses, namely: in vegetation cover – phytocoenotic rebuilding of communities, and decrease in productivity; and in soil-and-biotic group – restructuring of zoocenoses, destabilization of
the population level of the background species, reduction of taxonomic diversity, and reduction of
biological activity of soil.

Depending on the resistance of animals and their response to the impact of anthropogenic factors,
both sensitive (responding positively or negatively) and indifferent taxa that do not have the indication
value for a given type of exposure can be distinguished among them.

The following criteria for the degree of transformation of natural complexes and biodiversity state
assessment are used as the main ones:

- Changes in species composition and community structure by comparing the taxonomic
diversity of natural and disturbed counterparts or according to the gradient of exposure;
- The ratio of dominant life forms and functional-trophic groups of invertebrates;
- Changes in productivity under the influence of environmental factors.

The most common is a five-point scale, where the first category is a deviation of no more than 20%
(high diversity), the second one corresponds to the deviation of 21 to 40% (relatively high), the third
category is an average with a deviation of 41 to 60% (mean value of diversity), the fourth one is a
deviation from 61 to 80% (low diversity), and the fifth category is a deviation in the range of 81 to
100% (very low taxonomic diversity).

For systemization of states and cartographic representation of the obtained data matrix lattices were
used, which were constructed taking into account the typological features of elementary ecosystems
(and, therefore, biogeocenoses), the number of taxa, recorded in a landscape unit, their occurrence,
and the total abundance and biomass of invertebrates. This approach allows us to estimate the state
of taxonomic diversity of a particular biogeocenose (or landscape unit). Well-ordered spectrum of states
is a source of information to create a map of the spatial differentiation of taxonomic diversity.

In the spectrum of states of the taxonomic diversity of landscape units, three main categories of
situations are distinguished: critical, conflict and relatively satisfactory (table 1).

The first category includes natural complexes with a high – 4th and 5th – degree of disturbance, and
with an almost irreversibly transformed structure, where the state of the environment affects adversely
the life of biotic communities. The second category includes reversibly disturbed (3rd degree) natural
complexes, where the environmental situation is very dynamic, and the increase in load leads to sharp
deterioration of the biota state and to ecological conflicts. Improvement of the situation and recovery
of the normal functioning and reproduction of renewable resources are possible by regulating the adverse impacts and by enforcement of environmental protection measures.

| Scale   | Categories of situations |
|---------|--------------------------|
| in points | in %    |
| 5       | 81-100    | Critical          |
| 4       | 61-80     | Conflict          |
| 3       | 41-60     |                   |
| 2       | 21-40     | Relatively satisfactory |
| 1       | <20       |                   |

A relatively satisfactory situation is characterized by a weak (I and II degree) of disturbance of
biotic communities, balanced trophic structure, a certain stability of functioning, and resistance to the
effects of anthropogenic factors.

These criteria can be used to identify areas of anthropogenic transformation, i.e. for ecological
zoning of territories, involving strengthening of environmental protection regime within the ingredient
of exposure from the most stable landscape structures to more sensitive and less stable ones, as well as
the control and regulation of the negative impact from the periphery to a protected object.
An important methodological aspect of the assessment and conservation of biodiversity is an idea about the levels of the spatial dimension of ecosystems. Regularities that take place in the system of general relationships and interdependence within the habitat are not identical in their spatial- and temporal scales. At the regional level, the structure of communities and quantitative characteristics depend largely on factors of the macro-geographical order, namely: natural zoning, and altitudinal belts, which are manifested in the change of climate, vegetation, soil and topography. In territories small in area, the main factors that determine the structure of biotic communities, their sensitivity to various forms of impact, and the specificity of anthropogenic dynamics, are the location of a biogeocoenosis in the landscape and hydrothermal conditions.

4. Conclusion
Changes in biodiversity can be tracked at two levels: at the species level, when there is a reduction in the number of species through some loss of individual species and taxonomic groups, and at the ecosystem level, when under the influence of anthropogenic factors leveling of differences between individual biogeocoenoses (eco- and geosystems) and complete degradation of some of them are observed. The probability of manifestation of adverse effects increases in accordance with the growth of the degree of impact, regarding the ecological parameters of the environment.

Peculiarities of structures of invertebrate’s communities and their changes due to the climate change and anthropogenic impacts can serve as one of diagnostic criteria of soil conditions and can be used for estimation of an extent of landscape’s transformation and for monitoring.

Landscape-ecological approach ensures the preservation of habitat-forming and regulatory functions of an ecosystem, and increases objectivity of prediction of changes in biodiversity by taking into account the structural-and-dynamic characteristics of natural complexes and related categories of sensitivity, stability, ecological value and uniqueness. Using this approach on a mapping basis provides for typological and spatial certainty of evaluative and predictive definitions, and the possibility to trace the patterns of manifestation of the effects of climate change and various forms of the anthropogenic impact.

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