Assessment of Ecosystem State and Dynamics for Implementation of Ecosystem Approach In Management-Planning of Biosphere Reserves (case-study of Katunskiy Biosphere Reserve)

FINAL REPORT

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1. Background

According to the *Seville Strategy for Biosphere Reserves*, biosphere reserves should be utilized as models of land management and of approaches to sustainable development. The adaptive land management should consider the natural and human-induced dynamics of the ecosystems. The principles of such management were worked out in the frameworks of the *Ecosystem Approach*, which is recommended to be implemented in the biosphere reserve management.

Katunskiy Biosphere Reserve is located in the Russian part of transboundary Altai Mountains region in one of the 200 WWF's Global Ecoregions. In 1998 it was designated as the cluster of World Heritage Site "The Golden Mountains of Altai". It is situated within weakly-transformed by human activities environment, with traditional land use practices, rich resources for recreation and tourism, lots of culturally-significant and sacred sites. The area of Katunskiy Biosphere Reserve and its surroundings with glaciers and snowfields is a headwater basin for huge lowlands of Western Siberia. However, at present time, there are some negative trends of degradation of several natural resources – mainly, medicinal plants, grazing lands, recreational resources etc. because of over-exploitation. This may lead to wider degradation of ecological functions of this territory, including water supply, stability of slopes etc. All abovementioned require interdisciplinary practically-oriented researches for the development of management strategy and objectives according to the principles of the Ecosystem Approach.

This interdisciplinary study aims to assess the present state and the dynamics of ecosystems within Katunskiy Biosphere Reserve and its surroundings, and to build up an information system to support decision-making process during the preparation of the management-plan and daily management of Katunskiy Biosphere Reserve. The study will be based on the concept of ecosystem services, developed by the *Millennium Ecosystem Assessment*[1], which is, being

[1] Ecosystems and human well-being: a framework for assessment / Millennium Ecosystem Assessment ; authors, Joseph Alcamo [et al.] ; contributing authors, Elena M. Bennett [et al.]

antropocentrical, friendly and easy-to-understand for the managers and decision-makers. This also will help to reduce the gap between them and scientists.

This study contributes to the implementation of *Global Change and Mountain Regions Research Strategy*[2], which has been developed by global change scientists in strong collaboration with UNESCO MAB Program. Proposed study will focus on 4 key issues of the Research strategy, namely, Quantifying and Monitoring Land Use Change (2a), Understanding the Origins and Impacts of Land Use (2b), Biodiversity Management (6c), Valuation of Ecosystem Services (9d).

2. Aim and Objectives of the Study

The aim of the study is to assess the present state and the dynamics of ecosystems of Katunskiy Biosphere reserve in order to develop management strategy and objectives, based on ecosystem approach.

In order to reach this aim, following research objectives should be set up:

1. Inventory of ecosystems of Katunskiy Biosphere Reserve and its surroundings;
2. Inventory of land use of this area in dynamical context (present-day and historical land uses). Under this topic the studies on how different land uses affect the ecosystem services are also mentioned.
3. To define basic ecosystem services of this territory;
4. To develop a system of indicators that characterizes the state of ecosystem services and anthropogenic pressure onto it;
5. To collect appropriate data and to set up a database of the dynamics of abovementioned indicators (at least, characterizing three time periods – 1960s, 1990s and present day for each indicator, depending on data availability).
6. To figure out the trends of change of ecosystem services and to identify the drivers of change of ecosystem services.
7. To identify areas where degradation of ecosystem services takes place and special conservation measures need to be undertaken.
8. To build up an information system (on the platform of spatial database) as the support for decision-making.

[2] GLOCHAMORE Research Strategy.
http://www.mri.scnatweb.ch/dmdocuments/GLOCHAMORE_Research_Strategy_color.pdf

3. Methodology and Methods

The general scientific and ethical principles that guide the study are:

- Interdisciplinarity,
- Integration of indigenous knowledge by consultations with local "experts",
- Practically-oriented results of the study.

The general methodological approach, which will be used in this study, is worked out in the frameworks of the *Millenium Ecosystem Assessment* project. The state and dynamics of ecosystems of Katunskiy Biosphere Reserve will be assessed by means of the concept of ecosystem services, which are "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life" (Ecosystems and human well-being: a framework for assessment / Millennium Ecosystem Assessment ; authors, Joseph Alcamo [et al.] ; contributing authors, Elena M. Bennett [et al.]).

The inventory of ecosystems is conducted by using remotely-sensed data of middle resolution (Landsat 7 ETM+, resolution 15-30 meters) with ground truthing at several field sites and usage of available published materials. As a spatial basis Landsat image of middle resolution was used. For further understanding of the landscape structure of the region, available published materials were involved:

- Geobotanical map of Ust-Koksa Municipal District (by N. Kuminova)
- Geological Map of the investigated territory (by State geological service)
- Palaeogeographic map of the investigated territory (by V. Butvilovsly and N. Prekhtel)

The preliminary map of ecosystems was updated by field investigations in 5 key sites: Multa river basin, Zaychikha river basin, Kucherla river basin, Semyshykha river basin, Lake Tajmenje surroundings. For each of 5 key sites large-scaled landscape mapping was performed including detailed description of relief, soils, vegetation and current land-use. For major types of ecosystems the set of ecosystem services is identified.

For inventory of *current land use system*, the data from official land cadastre of Ust-Koksa municipal district were used. The data were incorporated into GIS, and the map of current land

use of the territory was completed. On the map, land ownership as well as land use types are represented.

Past land use system were investigated by analysis of the data from different sources: state archives, state land use cadastre, Ust-Koksa state committee on agriculture and publications. Several meetings with local experts were organized in May and June. Based on the information derived, two land use maps were completed for two time periods: 1960s and 1990s.

For understanding of environmental effects of different types of land use, following field studies were carried out in July and August, 2008:

1. Area of intensive collection of medicinal plants (Semyshykha site)
2. Area of grazing (Lake Tajmenje surroundings)
3. Area of recreation development (Multa and Kucherla sites)
4. Maral (deer) farm (Terecta field site)

These field works include the comparison of state of vegetation, soils, erosion processes within disturbed ecosystems and in standard undisturbed ones.

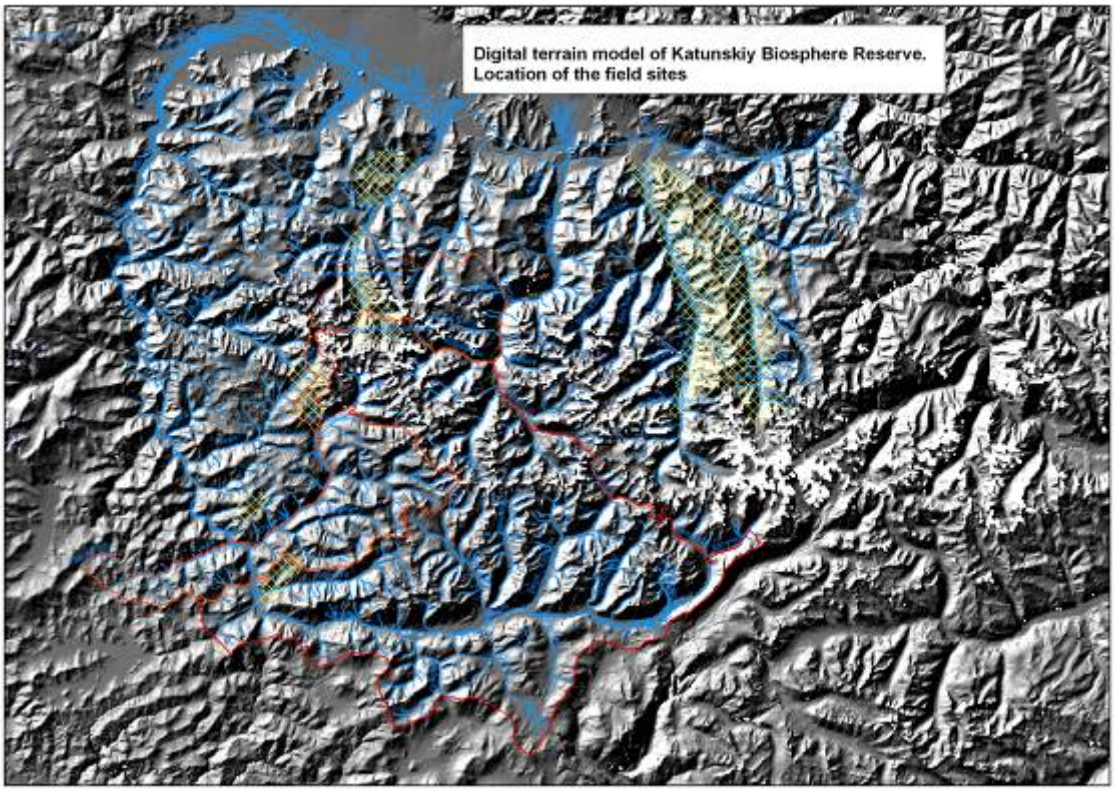

Fig. 1. DTM of Katunskiy biosphere reserve with the indication of the field study sites marked with yellow hatching

Based on the literature review and the data collected, the list of ecosystem services of Katunskiy Biosphere Reserve was developed. It includes number of provisioning, regulating, cultural and supporting services. For each type of ecosystem, the specific list of ecosystem services was derived. Then the analysis of how these services (mainly, provisioning) are used currently and in past land used systems. For defining the condition of ecosystem services specific indicators were applied. Several integral indicators are suggested for the evaluation of the conditions of pastoral and recreational resources. These indicators show the degree of pastoral/recreational digression of ecosystems and based on the complex of regionally-adapted indicators like biomass, species composition and abundance, soil density, development of erosion etc. This quantitative information allows to detect the degree of ecosystem disturbance and could be correlated with ecosystem resilience.

The state and trends of change of ecosystem services of Katunskiy Biosphere Reserve is presented in the form of matrix. The ecosystem services of the core zone have been analyzed separately from the services of buffer and transition zone to identify the role of the core area in conservation of ecosystem services of the whole BR territory. This matrix serves as a platform for identification management objectives of biosphere reserve in order to fulfil its basic functions: conservation and fostering sustainable use of natural resources.

4. Basic Results of the Project

4.1. Inventory of Ecosystems of Katunskiy Biosphere Reserve

Land cover of the investigated area is quite diverse and represented at the landscape map in the Annex 1. We have grouped all the ecosystems into several major classes representing their basic differences:

- glacial and nival ecosystems located at the summits of mountain ridges and covering 24% of the total area (62 % of the core zone)
- Subalpine and alpine meadows covering 31% of the whole biosphere reserve (26% of the core zone)
- Montane woods covering 42% of the whole area and 12% of the core zone
- Combination of woods and steppes in the lower parts of slopes covering 3% of the whole biosphere reserve area (no such type of ecosystems in the core zone)

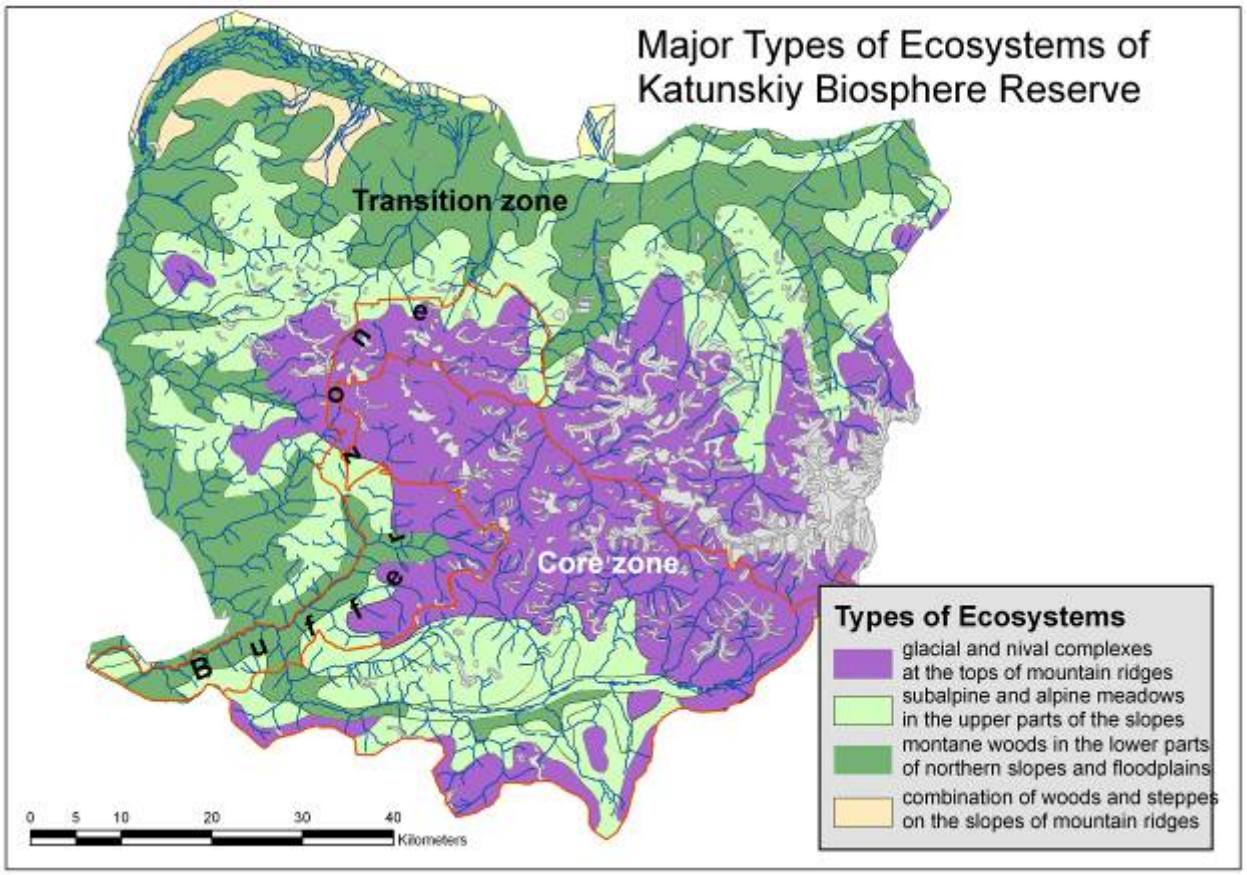

Fig. 2. Map of major types of ecosystems of Katunskiy Biosphere Reserve

Core zone is located in the southern part of the BR covering about 150 000 ha. It occupies transboundary position, bordering with Katon-Karagaiskiy National Park in Kazakhstan.

Altitudes of the core vary from 1400 to 3280 m above sea level. These high-mountainous ecosystems with glaciers and snow fields play an important role as water towers providing water supply for rivers of the whole BR. The major river of the Altai Mountains Katun originates from this area. There are 135 lakes in the core, mostly glacial moraine-dammed. One of the most significant centers of glaciation in the Altai with 148 glaciers is located in the core covering 79.8 km^2. Forests on the slopes of mountain ridges provide slope stability and control erosion. Core is natural habitat of 665 spp of higher vascular plants, 215 spp of mosses, 264 spp of fungi, 793 spp of lichens[3]. There are 20 spp of flora included into the Red data books of the Altai Republic and Russian Federation. Fauna of the core zone is presented by 56 spp of mammals including endangered Snow leopard inscribed into IUCN's Red Data Lists, 161 spp of birds, 3 spp of reptiles, 2 spp of amphibians and 8 spp of fish. The diversity of ecosystems includes mountain coniferous forests, subalpine and alpine meadows and shrubs, alpine tundra and glacial and nival complexes at the tops of the ridges.

Buffer zone surround core from north and covers the area of 57 000 ha. The altitudes of buffer zone are from 1450 to 3400 m a.s.l. This area includes mostly mountain coniferous woods (mountain *taiga*) in its western part and glacial and nival highlands in its central part. Large lakes Tajmenje and Middle Multinskoe of this zone are significant reservoirs of freshwater and attractive touristic sites. Mountain taiga is an important habitat of typical altaian mammals (ungulates – Musk deer, Maral (Red deer), Roe deer; and bears).

Transition zone covers about 400 thousand of hectares and located at the altitudes from 800 to 4506 meters above sea level. The highest peak of Siberia – Mt. Belukha – is located in the transition zone. This area is also one of the clusters of The Golden Mountains of Altai World Natural Heritage Site. There are 169 glaciers in Belukha massif covering 151 km^2. The biodiversity of transition zone is higher than in the core and represented by 750 spp of higher vascular plants including 38 endemics and 17 rare and endangered spp and 61 spp of mammals[4]. This territory is one of the basic habitats of Snow leopard, Musk deer, Ibex, Maral and Roe deer. At the same time, this is one of the most popular touristic sites in the Altai mountains.

4.2. Ecosystem Services of the Investigation Area

[3] Artemov I. et all. Flora and Vegetation of Katunskiy Reserve. Novosibirsk, 2001. [In Russian]
[4] Functional Zonation of the Nature Park "Belukha". A Scientific Report to the Ministry of Natural Resources of the Altai Republic. Katunskiy BR, 2007. [In Russian]

Based on the concept of ecosystem goods and services, the major ecosystem services of Katunskiy Biosphere Reserve were identified. According to (Ecosystems and human well-being: a framework for assessment / Millennium Ecosystem Assessment ; authors, Joseph Alcamo [et al.] ; contributing authors, Elena M. Bennett [et al.]), *an ecosystem* is a dynamic complex of plant, animal, and microorganism communities and the nonliving environment, interacting as a functional unit. Humans are an integral part of ecosystems. *Ecosystem services* are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth.

Basic ecosystem services were identified for different types of ecosystems within investigated area. In general, **provisioning services** of the territory include food (meat of animals, non-timber forest products, etc), fuel (wood), energy (alternative sources of energy – hydropower, wind energy etc.), fresh water, genetic resources, pharmaceutical resources (medicinal plants, animal derivatives - deer horns, bear bile etc.)

Regulating services of the area, which are the benefits obtained from the regulation of the ecosystem processes, include: climate and water regulation, erosion control, pollination, biological control etc.

Cultural services are non-material benefits people can obtain from ecosystems spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. For investigated area these services include resources for ecotourism and recreation, spiritual values, traditional knowledge systems, educational and aesthetic values. It is specific characteristic of the highlands of Katunskiy ridge and Mt. Belukha, which is a sacred site for different beliefs including local.

Supporting services are those that are necessary for the production of all other ecosystem services. It differs from other services by their indirect effect onto human being. However, maintaining these services is also vitally important since they provide primary production, soil formation etc.

The summary of all ecosystem services for different types of ecosystems of the investigated area is shown at the table below.

Table 1. Ecosystem services of Katunskiy Biosphere Reserve

Type of ecosystem	Provisioning services	Regulating services	Cultural services	Supporting services
Combination of woods and steppes on the slopes of mountain ridges	Honey Forage for cattle Medicinal plants Pastoral resources	Erosion control	Traditional knowledge Historical monuments Recreation	Soil formation
Montane woods in the lower parts of northern slopes of mountain ridges	Resources for hunting (meat of wild animals) Pharmaceuticals (medicinal plants, animal derivates) Honey Fuel wood Hydropower energy Non-timber forest products (cedar nuts) Fish Freshwater storage (lakes)	Flood and erosion control	Recreation Traditional knowledge	Carbon storage Soil formation Regional and local climate control Habitats of economically- and culturally significant species
Sublapine and alpine meadows in the upper parts of the mountain slopes	Medicinal plants Pastoral resources Wind energy	Erosion control		Soil formation Habitats of economically- and culturally significant species
Glacial and nival ecosystems at the upper parts of ridges	Freshwater storage (glaciers) Resources for hunting (meat of wild animals) Wind energy		Recreation Spiritual and sacred sites Aesthetic values Trophies of wild animals	Local and regional climate control Habitats of endangered species

4.3. Land Use Types and Its Environmental Impacts

<u>*Core zone.*</u> According to the legislation, no human activities are allowed within the core zone of Katunskiy Biosphere Reserve except for patrolling, researches and monitoring and limited scientific and eco-tourism. The land is state-owned, and the administration of the reserve is

responsible for the state and management of this area. However, before the establishment of the nature reserve, this area was actively used for grazing. Data from archives show that in the period of 1980-1990 at the area of 50 000 ha the grazing impact was caused by 10000 cows, 7500 horses and 11000 sheeps per year. Since no researches at the beginning of 1990s, the grazing impact was assessed by means of interviews with local herders and experts from the municipal Committee of agriculture as very strong caused significant changes in species composition, total abundance of grass and activization of erosion processes. Mainly subalpine ecosystems and meadows at the bottoms of the river valleys were affected. Field studies in 2008 show that nowadays the ecosystems has been fully restored during 17 years of strict protection.

The valley of Zaychikha river in the core zone of Katunskiy BR before the establishment of the protected area used for grazing. Earlier before 1950s there has been a village with about 200-300 inhabitants. Two houses left from the village are seen n the photo.

These grasslands in the core zone (upper Katun valley) were actively used for grazing in 1960-1990. During 15 years after the establishment of the reserve the vegetation cover has been recovered, and diversity of plants is about 15-20 spp per m^2.

<u>*Buffer zone.*</u> In buffer zone limited use of natural resources is allowed. There are following types of human activities:

- recreation and tourism,
- collection of medicinal plants and non-timber forest products (cedar nuts),
- hunting,
- fishing,
- apiculture,
- limited cattle grazing.

Recreation and tourism develops in the limited sites of the buffer zone, which includes Lake Tajmenje and Ozernaya river and Lake Middle Multinskoe. Due to limited number of recreants

(about 500-700 per year), the impact onto natural ecosystems is unsignificant and limited only to touristic trails.

Subalpine meadows in the western part of investigated area are natural habitats of medicinal plants (mainly, *Rhodiola rosea* and *Hedysarum theinum*). Both these plants are traditionally used by local people for medicinal purposes. Rhodiola rosea is rare plant included into the Red data book of Russian Federation, however, during 2000-2007 it was collected for industrial purposes. The total volume extracted from the buffer zone could be estimated as 2-3 tons of roots per year. In 2007-2008 with law enforcement this illegal process has been reduced. Field studies in 2008 showed that the restoration of the natural plant communities is in place, and in next 3-4 years the resources of the plants will increase up to natural volumes. The reason of this quick recovering is the specific way of collection when the small parts of roots stay in the soil and sprut as a new plant in the next vegetation season.

Traditional way of collection of Hedysarum theinum at Semyshikha field site

Restoration of Rhodiola rosea 2 years after intensive collection (Semyshikha field site)

Hunting is a traditional activity for local people also spread in the buffer zone. The main animals for hunting are fur mammals (sable, mink etc.) and ungulates (Musk deer, Maral (Siberian subspp of Red deer) and Roe deer, and bears. Hunting in the buffer zone is strictly controlled by State Hunting Control Service and limited up to 50-150 fur animals per year. Long-term monitoring results of the state of populations of these animals in the core and buffer zones show that this limited activity does not affect the state of populations in the core. The illegal hunting in the eastern part of transition zone cause greater impact onto wildlife population of the core area of the BR.

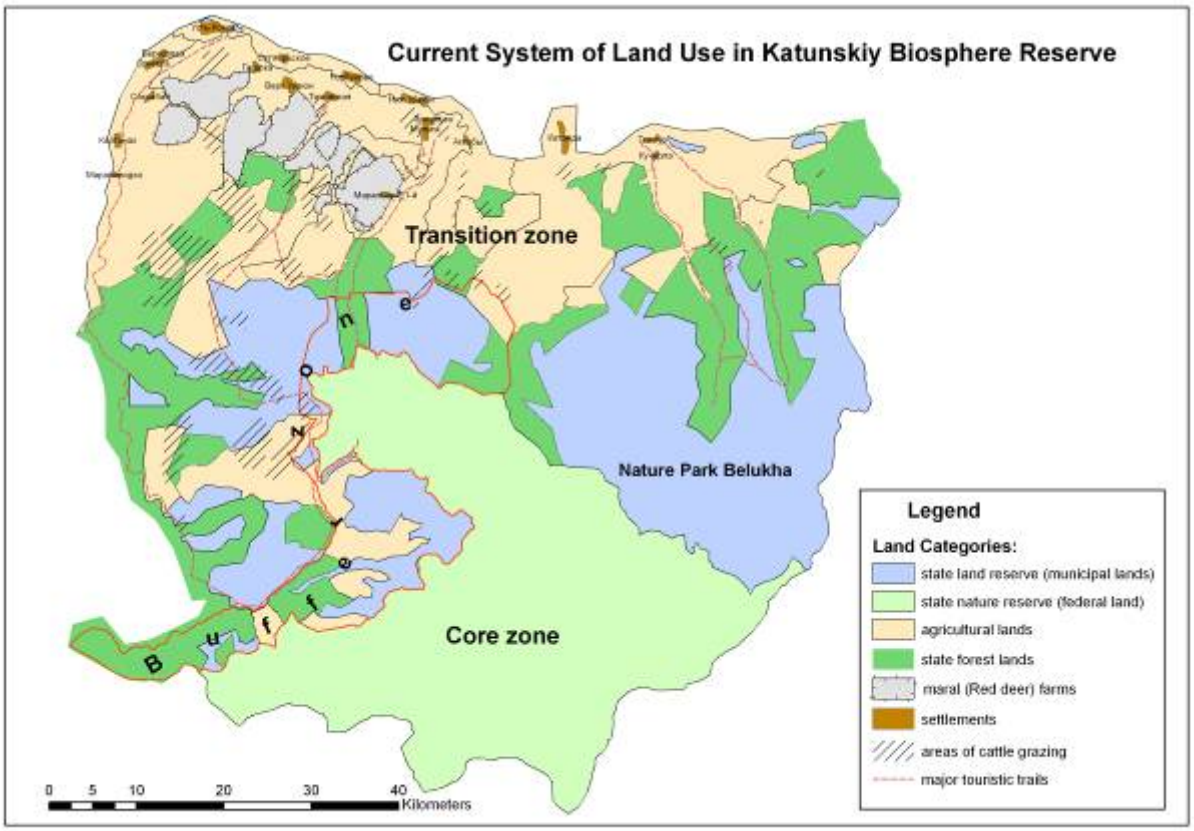

Fig. 3. Current structure of land use in Katunskiy Biosphere Reserve

Grazing impact on the natural ecosystems nowadays could also be assessed as low. After the collapse of the USSR with its planned economy followed by economical decline, the number of sheep has been significantly reduced, and the ecosystems were given a possibility to restore. Now in the buffer zone the grazing load could be estimated as 300-500 of sheeps, so this is twice less than 40 years before. Now chemicals are not used in the grazing lands, so according to the environmental impact assessment the state of grazing lands in the buffer zone is good.

Small apiary in the buffer zone of Katunskiy BR

The land of buffer zone is mainly state-owned and local authorities of Ust-Koksa administrative district and Federal Forestry Service manage these lands. However, several sites has been rented for a long-term by local people for development of private apiaries.

Transition zone. In the transition zone there are 10 permanent settlements with total population of ~ 4500 people are located. The land use types are more diverse here and include:

- forestry (harvesting fuel wood),
- maral (Red deer) farms,
- collection of non-timber products (medicinal plants, nuts, berries etc.),
- recreation and tourism,
- hunting,
- fishing,
- apiculture,
- cattle grazing,
- hay fields.

In this zone, the share of private-owned lands increases, because all the maral farms and other agricultural enterprises are privately-owned.

The basic environmental impact is caused by the ***maral farms***. These are large fenced areas where animals are reared in close to natural conditions. The basic product is maral antlers, which is exported to South Korea and China for pharmaceutical industry. The total number of animals in the farms of BR is 8800.

Maral farming is a traditional economy in the Central Altai. It was established in the region in 18 century. During this 300 years period maral farms evolved from small parks up to 30-40 ha with 10-20 deers to large economies of about 5000 ha with 500-2500 animals. In the development of maral farming three main stages could be identified:

1. Before the revolution and collectivization in 1920s farms were rather small and generally private economies. The number of farms was increasing.
2. During Soviet period the farms have become state-owned with planned economy. Maral farm have become a part of sovkhoz along with cattle breeding and agriculture. During this period stable development of economy took place. Local producers got the fixed costs for the production of maral farms from the government.
3. After perestroika in 1990s maral farms have become private companies again. Producers got direct access to international market, where the price of the farm production is much

higher that they got from the government in the soviet time. This led to rapid increase of the number and area of maral farms. The farming is developing in extensive way, and nowadays more than 80% of appropriate lands has already used by maral farms. New farms were established at the lands traditionally used by local dwellers for hunting, hay making and grazing of private cattle. Now it provides the income only for the farm personnel (8-10 persons of permanent stuff for a farm), which cause lots of conflicts between maral farmers and local people.

Typical landscapes with combination of steppes and woods favorable for maral farming

Animals in the farm before cutting off the anlkers. Photo: Reuters

The farm is divided into several parks used by sub-groups of animals in different seasons. Based on field investigation of the state of ecosystems of maral farm major changes in ecosystems were figured out. The changes include:

- changes in species composition and increasing the role of anthropochorusspecies in plant communities
- damage to shrubs and young trees
- sealing of upper soil horizons causing changes in air and moisture regime of soil and deterioration of plant growth conditions
- erosion processes along the main trails and fences

The changes in vegetation in maral farm (front) comparing to natural ecosystems (behind the fence) could clearly be seen.

Due to limited area and high number of animals, the damage to trees and shrubs in maral farm is much higher than in natural

habitats

The above indicators has been analyzed and united into the complex indicator of the pastoral digression which is the process of transformation of the natural ecosystems under the grazing impact. This process could be divided into several stages, showing the ability of ecosystems to restore after the grazing. The characteristics of the different stages are given in the table below.

Stage of pastoral digression	*Height of grass*	*Share of anthropochorus spp*	*Depth of sealed soil horizon, sm*	*Area of bare soil, %*
0	>100	0-2%	<5	0
I	50-100	2-5%	5-10	0-5%
II	30-50	5-10%	10-15	5-10%
III	15-30	10-20%	15-20	10-15%
IV	5-15	20-50%	20-25	15-20%
V	<5	>50%	>25	>20

The maps below (Fig. 4-5) show the structure and digression of ecosystems at Terecta maral farm.

Another important issue cause by maral farms is the disturbance to wildlife (large mammals) of the surrounding lands. The fenced farms covering huge areas block the natural migratory routes of ungulates and cause fragmentation of populations. However, until now this process is not well-investigated.

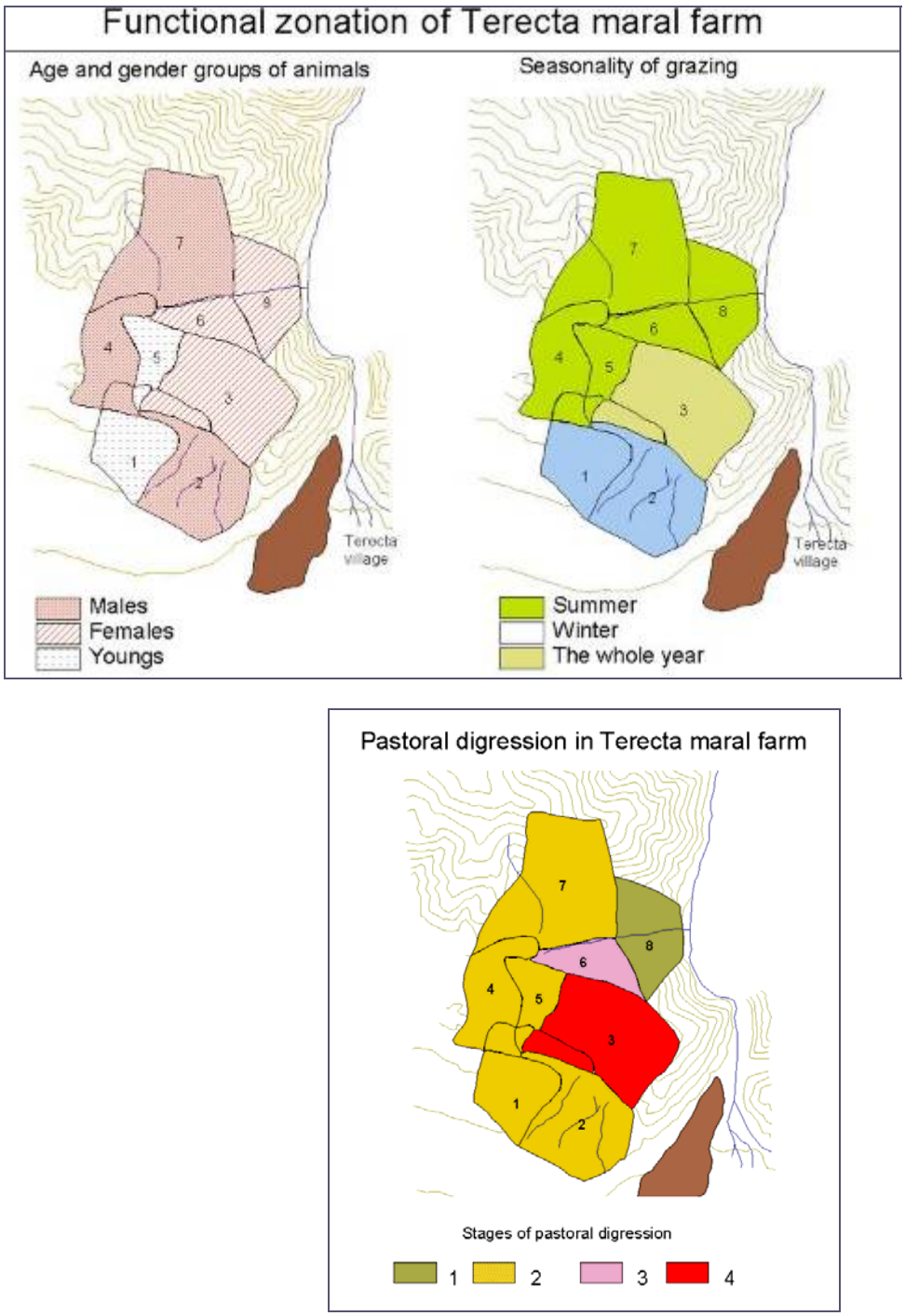

Fig. 4-5. Functional zonation and pastoral digression of the Terecta maral farm

In the transition zone Mt. Belukha – the highest peak of Siberia and the major ***recreational site*** of the Altai mountains is located. It attracts lots of tourists of different categories – starting from mountaineers to religious pilgrims following the doctrine of famous painter and philosopher Nicolas Roerich, who considered that Mt. Belukha is one of the ways to mystical Shambala. The major touristic sites are located in the eastern part of the transition zone in the Nature park Belukha and include Lakes Kucherlinskoe, Akkemskoe. In 2008 this area was visited by 9000 persons. Another popular touristic site is Lake Lower Multinskoe located in the central part of the transition zone visited in 2008 by 2000 persons.

Lakes Middle and Lower Multinskie in the Multa river valley. Lake Middle Multinskoe is located in the buffer zone of Katunskiy BR, Lake Lower Multinskoe – in the transition zone

M. Belukha, the highest peak of Altai and Siberia, located in the Nature park Belukha in the transition zone of Katunskiy BR

Unfortunately, basic trails are not sufficiently equipped with camps, and the system of control of recreational activity is not in place, so tourism causes negative impact onto the ecosystems, which could cause the degradation of recreational resources and loss of attractiveness of the area to tourists. Basic negative impact is the accumulation of garbage and degradation of trails.

To understand the impacts of tourism onto environment, detailed field studies were carried out in Multa river valley and in Belukha nature park. The impact is analyzed by the system of indicators including vegetation cover (species composition, abundance, presence of anthropochorus species, biomass of plant communities, state of trees), soil sealing and presence of erosion. All these indicators represent the recreational digression of the site, its stages representing the ability of ecosystems to recover, are described below.

1 stage – vegetation cover is not disturbed, in the forest ecosystems litter culd slightly disturbed but it is in place, no damage to young trees;
2 stage – trails are seen but not wider than 30-40 cm, no litter on trails, no damage to young trees;
3 stage – trails are clearly seen, no vegetation on trail, tree roots are naked on the trails, but no significant damage to young trees; on the camp sites changes in plant communities (share of anthropochorus spp up to 40%);
4 stage – damage to trees, transformation of grass communities to anthropochorus, erosion, at camp sites bare soil covers up to 40%;
5 stage – eroded trails, at the camp sites bare soil covers more than 40%, no reforestation.

When ecosystem transforms to 4-5 stages o digression, restoration process will take about 10-12 years and more, while for ecosystems in 1-2 stages of digression it will take 1-3 years to restore naturally without any pressure.

During this study the system of monitoring the state of trails and camp sites has been developed, and these physiognomic indicators could be easily used by non-professionals to carry out monitoring activities.

The results of this study show that the negative impact of tourism localized only to trails and camp site and doesn't affect the 95% of the whole area. Most of the trails and camping sites in the nature park Belukha are degraded to the 3 (from 5) stage of digression, and further increasing the number of visitors without equipment the camping sites and paving the trails will cause irreversible changes in natural ecosystems.

Plant community in the camping site (7а) comparing to the natural equivalent (7б).

Accumulation of garbage is typical problem caused by tourism development (coast of the Lake Kucherlinskoe in the Nature park Belukha)

Degradation of tourist rails caused by development of horse tourism. Valley of Multa river near Lake Lower Multinskoe

Grazing is also spread in the northern part of the transition zone. The total area of grazing lands is 45900 ha. It does not cause any significant changes in ecosystems due to low pressure. The total grazing load is 1700 cows, 2000 horses and 11000 sheeps.

Based on the data from state archives, the land use system for 1960s period was reconstructed. At that time all the lands were state-owned (sovkhozes) and planned economy was in place. Planning of the land use activities frequently did not considered ecological issues. Spacial pattern of land use was principally the same as now, the only difference between current and past land use systems is wider development of maral farms nowadays. With regard to the effects of the land use onto the environment, following key conclusions could be made:

- Larger pressure of grazing onto the ecosystems caused pollution and changes in vegetation communities. But with economic decline in 1990s, the pressure has been significantly reduced, thus giving the time for ecosystem restoration.
- During Soviet period maral farming was rather marginal, because the state was in charge of export trade and farmers used to get fixed and relatively low payment. Since 1990s, when maral farms became private JSCs, farmers got the direct access to the international market. It led to a great rise of these economies, which now occupy more than 80% of appropriate lands.
- The region was popular as a touristic destination for a long period, with more or less stable number of tourists (except for decline in 1990s), but in 2000s horse tourist started to develop actively, which led to the degradation of the basic trails.
- After the economic decline in 1990s lots of local people have very low income and unemployed. To provide money for the families, people actively and in most cases use natural resources (taking medicinal animal derivates – poaching on the Musk deer and Maral, collecting medicinal plants). During the Soviet period most people were involvel into agriculture, and level of poaching and illegal collection of medicinal plants was significantly lower.

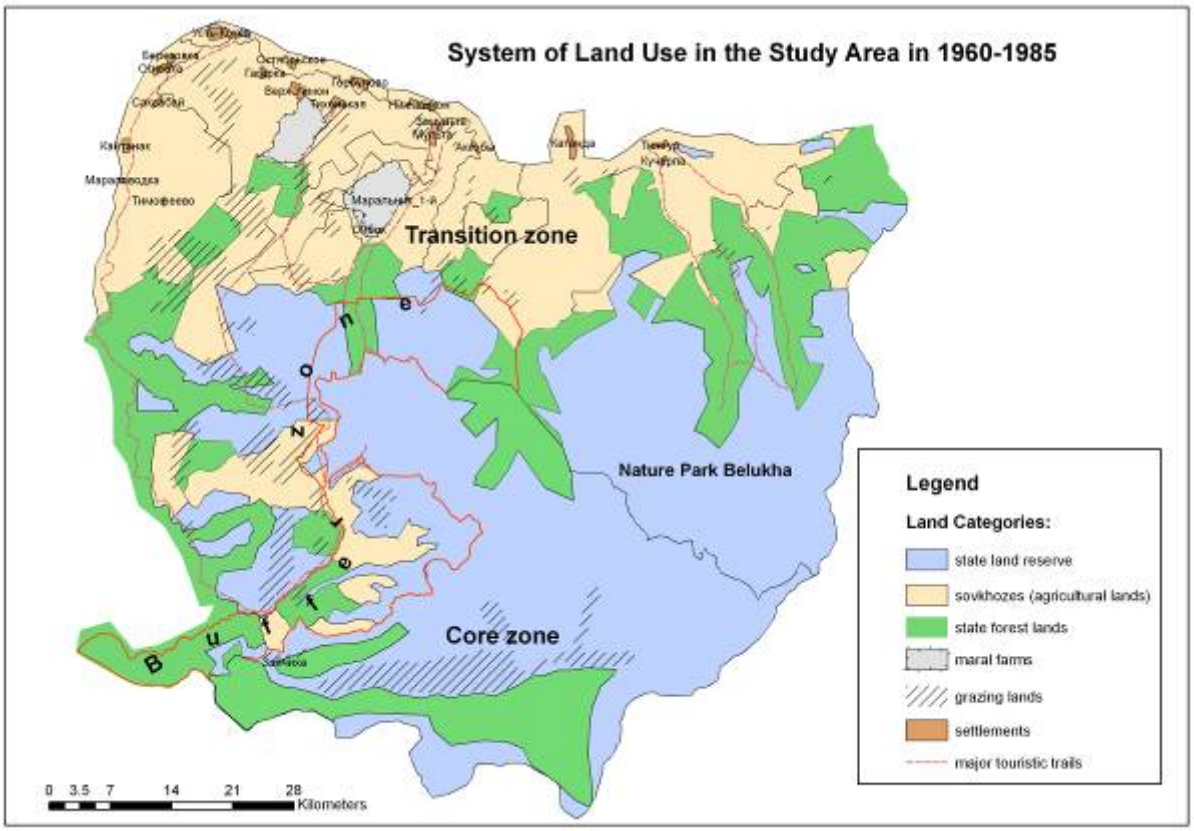

Fig. 6. Structure of land use of the territory of Katunskiy Biosphere Reserve in 1960-1985

4.4. State and Trends of Change of Ecosystem Services

Condition of ecosystem services, which are not used directly by human (like supporting and regulating services) could be assessed using standard indicators like area covered with woods (flood control), area covered with vegetation (erosion control), area covered with glaciers (climate control), fragmentation of habitats etc. Since the ecosystems of Katunskiy BR are not transformed by human activities (or at least transformed locally, in surroundings of village and within farms), we could expect that any changes of regulation and supporting services will be forced by natural factors (climate change mainly). It is demonstrated by the rise of upper treeline and forest line and degradation of glaciers in the area.

In general, the condition and dynamics of ecosystem services for different types of ecosystems and for areas with different conservation regimes (core and transition zones of the biosphere reserve) is presented in the tables below.

Table 2. Condition and trends of change of ecosystem services in the core zone of Katunskiy Biosphere Reserve

	Montane woods in the lower parts of northern slopes of mountain ridges	**Sublapine and alpine meadows in the upper parts of the mountain slopes**	**Glacial and nival ecosystems at the upper parts of ridges**
Provisioning Services			
Honey	→	↗	n/a
Forage for cattle	↗	↗	n/a
Medicinal plants	→	→	n/a
Fuel wood	↗	n/a	n/a
Resources for hunting (meat of wild animals)	↘	→	→
Pharmaceutical animal derivates	↘	→	n/a
Fish	→	n/a	n/a
Non-timber forest products (cedar nuts)	↗		
Freshwater storage (lakes)	→	n/a	n/a
Freshwater storage (glaciers)	n/a	n/a	↘
Hydropower energy	→	n/a	n/a
Wind energy	n/a	→	→
Regulating Services			
Flood control	→	n/a	n/a
Erosion control	→	↗	n/a
Cultural Services			
Recreation	→	→	→
Traditional knowledge	→	→	n/a
Aesthetic values	→	↗	→
Supporting Services			
Soil formation	→	↗	n/a
Carbon storage	→	→	n/a
Regional and local climate control	→	n/a	?
Habitats of economically- and culturally significant species	→	↗	n/a
Habitats of rare and endagered species	n/a	n/a	?

Condition of the ecosystem services:		**Trends of change of ecosystem services:**	
	very good	↘	Deterioration
	Good	→	Stable
	Average	↗	Improvement
	Bad	?	Not known

	Poor		

Table 3. Condition and trends of change of ecosystem services in the core zone of Katunskiy Biosphere Reserve

	Combination of woods and steppes on the slopes of mountain ridges	Montane woods in the lower parts of northern slopes of mountain ridges	Sublapine and alpine meadows in the upper parts of the mountain slopes	Glacial and nival ecosystems at the upper parts of ridges
Provisioning Services				
Honey	→	→	→	n/a
Forage for cattle	↘	→	→	n/a
Medicinal plants	→	→	↘	n/a
Fuel wood	→	→	n/a	n/a
Resources for hunting (meat of wild animals)	n/a	↘	↘	n/a
Pharmaceutical animal derivates	n/a	↘	n/a	n/a
Fish	→	→	n/a	n/a
Non-timber forest products (cedar nuts)	n/a	→	n/a	n/a
Freshwater storage (lakes)	n/a	→	n/a	n/a
Freshwater storage (glaciers)	n/a	n/a	n/a	4
Hydropower energy	n/a	→	n/a	n/a
Wind energy	n/a	n/a	?	?
Regulating Services				
Flood control	→	→	n/a	n/a
Erosion control	↘	→	→	n/a
Cultural Services				
Recreation	→	↘	↘	→
Traditional knowledge	→	→	→	n/a
Spiritual and sacred sites	n/a	n/a	→	→
Aesthetic values	→	→	→	→
Trophies of wild animals	n/a	↘	↘	n/a
Supporting Services				
Soil formation	→	→	→	→
Carbon storage	n/a	→	→	n/a
Regional and local climate control	n/a	→	n/a	?
Habitats of economically- and culturally significant species	→	→	→	n/a
Habitats of rare and endagered species	n/a	→	→	→
Condition of the ecosystem services:		**Trends of change of ecosystem services:**		

	very good	↘	Deterioration
	Good	→	Stable
	Average	↗	Improvement
	Bad	?	Not known
	Poor		

4.5. Drivers of change

In general, due to weak transformation of natural ecosystem by human activities, the changes of regional ecosystem services are mainly caused by natural or global factors. The most important among them is climate change.

Central Altai is characterized by the lowest rates of warming in the region, but, however, the observations from meteorological stations show the general trend of warming (Sukhova et al, 2005)[5]. The changes of mean January air temperature during last 40 years observed at the Ust-Koksa station are presented at Fig. 7. The most significant warming is observed in spring and winter seasons, while in summer this trend is not so clear. At the same time, the trend of warming is accompanied by slight increase of annual precipitation (see Fig. 8).

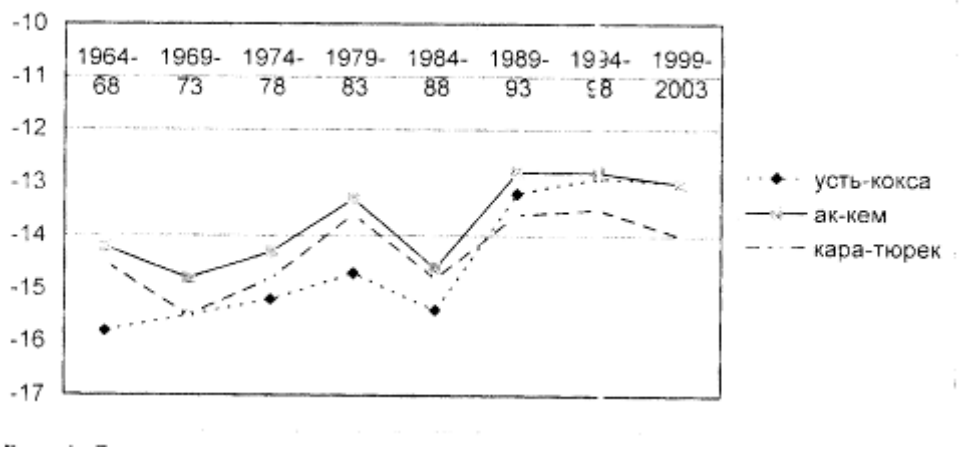

Fig. 7 Changes in mean January temperatures in Katunskiy BR (data from 3 weather stations)

[5] Sukhova M. Et al. Reconstruction, modern trends and possibl;e future scenarios of climate change. A case study of Katunskiy Ridge. In: Geoecology of the Altai-Sayan mountain region. Vol. 2. Gorno-Altaisk, 2005, pp 161-165. [In Russian]

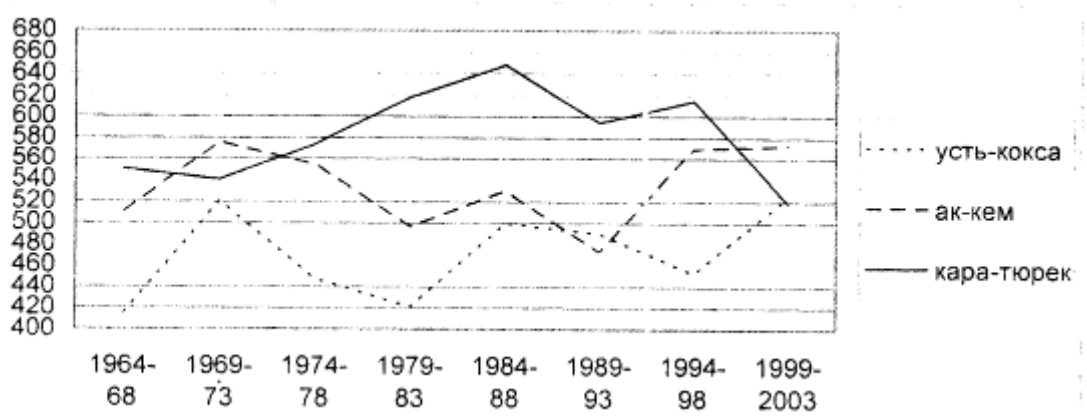

Fig. 8. Changes in precipitation in Katunskiy BR (data from 3 weather stations)

Until now there were no complex investigations of reaction of ecosystems as a whole to climate change; only several components of landscape were studied from this point of view. Lots of research efforts focused on the dynamics of glaciers as the most vulnerable to climate change natural formations. At the same time, glaciers play the important role in the water supply of the region, serving as the water towers. Galakhov and Mukhametov (2001)[6] provide a detailed study of glaciation of Katunskiy ridge, which includes all three zones of Katunskiy BR. According to this study, small kar glaciers have been significantly degraded for last 40 years. For instance, small Tomich glacier located in the Multa river basin on the border of core and buffer zones of Katunskiy BR, during 1973-1995 has been retreated by 61.9 m. Several small glaciers has disappeared during last 1970s. The rate of degradation of large glaciers is higher. In the table below the dynamics of glaciers area in the Belukha massif is presented.

Table 4. Changes of area of major glaciers in the Belukha massif (after Aref'ev, Mukhametov, 2006)[7]

Glacier	**Area, km^2**				**Reduction of area from mid-XIX to 1990s, %**
	Mid-XIX	**years**			
		1952	**1970**	**1980**	
Sapozhnikova	25,6	23,1	22,0	21,9	14,4
Rhodzevicha	19,6	17,2	-	16,9	12,0
Br. Tronovykh	15,9	-	13,4	13,3	16,4
Cherny	8,3	7,0	-	6,8	18,1
Geblera	15,7	13,7	13,6	13,5	14,0
B.Berelsky	15,0	-	-	12,6	16,0
M. Berelsky	13,4	11,1	10,6	10,5	21,6

Analysis of satellite images shows the total reduction of glaciated area in western part of Katunskiy ridge from 213 km^2 in 1975 г to 184 км^2 in 2000.

[6] Galakhov V., Mukhametov R. Glaciers of the Altai. Novosibirsk, 2001 [In Russian]
[7] Aref'ev V., Mukhametov R. On the glaciers of the Altai and The Sayan. Barnaul, 2006 [In Russian]

Lower and upper treelines are good indicators of environmental change. In (Mikhailov, Chistyakov, 1999)[8] the estimation of changes of these parameters for Katunskiy ridge is given. The results show that during the last glaciation at its maximum (about 18,000 years ago) the upper treeline was 620 meters higher than at present. Following the last cooling period (from the end of the 18th to mid 19th century) the upper treeline had shifted upward by 70 meters, and the lower treeline (the ecotone between forests and steppes) had shifted by 100 meters.

The modern trend of treeline dynamics in mountains is characterized by a continuous shift upward. Within mountain regions with modern glaciation this shift reaches 60-100 meters. For the Altai this altitudinal diapason is characterized by occurrence of three generation of trees, which form upper treeline. The lowest generation is 250 years old, the middle one is 120-150 years old, and the youngest one is 50-70 years old. This specific structure of upper treeline within glaciation areas shows the climate variability and concrete periods of changes. The dendrochronological data well correspond to glacier dynamics. Upper treeline in the Altai is almost unaffected by human activity and therefore its dynamics is a good indicator of environmental change.

Human activity

Human activities caused changes in ecosystem structure and functioning only at local level. For this case, primary factors are:

- development of agriculture as a basic priority for economic development of the territory
- low income of local people with significant share of incomes raised from kitchengardens and hunting,
- high market demand of medicinal plants and pharmaceutical animal derivates/

Major anthropogenic factors of changes of ecosystem services are shown in the table below.

[8] Mikhailov N., Chistyakov K. Stages of formation of landscape structure of Katunskiy ridge in the Holocene. In: Geograohy and Land Use of Siberia. Vol. 3. Barnaul, 1999, pp. 94-108

Table 5. Anthropogenic factors of changes of ecosystem services of the investigated area

Primary causes	**Factors of change**	**Observed changes in ecosystem services**	**Affected types of ecosystems**	**Afected BR zones**
development of agriculture as a basic priority for economic development of the territory	Organization of fenced maral farms	Blocking the migratory routes of wild ungulates, pastoral digression with significant changes and plant diversity loss at local level	Montane woods, combination of woods and steppes on the slopes of ridges	Transition zone
	Cattle grazing	Pastoral digression, loss of plant diversity at local level	Subalpine and alpine meadows	Transition zone
Low income of local people	Grazing of private cattle around the villages	Pastoral digression, including biodiversity loss and erosion	At local level in the surroundings of villages	Transition zone
	Hunting	Reducing the number of animals, some of which has become threatened (Musk deer).	Montane forests	Transition zone. The populations of animals in the core are also affected.
High market demand of medicinal plants and animal derivates	Collection of medicinal plants, poaching (Musk deer)	Rapid decrease of population of Musk deers in the BR, degradation of the resourses of medicinal plants	Лесные, луговые верхних поясов гор	Правобережье Катуни, зона сотрудничества «Теректа», охранная зона

4.6. Applications for management

The overall goal of biosphere reserve activities is conservation of landscape and biological diversity by means of strict protection, fostering sustainable land use practices and environmental education. To conserve the fragile environment of Katunskiy BR, major factors causing negative effects on mountain ecosystems should be reduced. BR itself can not deal with global drivers of change like climate change and illegal international market, but can provide management frameworks to deal with human activities in the BR territory.

In 2008 Katunskiy BR is developing a management-plan for 2009-2013[9]. The management plan includes activities in all three zones of the BR, which can be combined into several thematic programs: strict protection of core, monitoring and researches, environmental education,

[9] Management-plan of Katunskiy Biosphere Reserve for 2009-2013. Ust-Koksa, 2008

fostering sustainable use of natural resources and transboundary cooperation with adjoining national park in Kazakhstan.

Based on the results of this project management objectives and practical measures to reduce the negative effects onto the natural ecosystems were developed. An overview of these activities is presented in the Table 7. As explained above, the most affected by human development ecosystem services are resources for tourism and recreation, medicinal plants and animal derivates, resources for hunting and pastoral resources.

Table 7. Management activities for reducing negative impacts onto ecosystems of Katunskiy Biosphere Reserve

Negative impacts on the environment	**Proposed management activities**	**Affiliation to the thematic program of management-plan**
Poaching in the transition zone (nature park Belukha) and illegal collection of medicinal plants	Strict law enforcement by systematic patrolling the territory Creation of alternative sources of livelihoods for local people	Protection of the territory Fostering sustainable use of natural resources
Degradation of recreational resources in the transition zone	Equipment of trails and camping sites, Organization of cleaning expeditions (volunteers) Training local guides Regulation of visiting of the territory, Monitoring the state of trails and camping sites, Development and implementation of interpretation programs for visitors	Fostering sustainable use of natural resources Protection of the territory Monitoring and researches Environmental education
Overgrazing in the surroundings of villages	Creation of alternative sources of livelihoods	Fostering sustainable use of natural resources
Changes of supporting and regulating services caused by climate change	Promotion of alternative energy Raising public awareness on global changes Researches and monitoring	Fostering sustainable use of natural resources Environmental education Monitoring and researches

To reduce climate change impact in Katunskiy BR only mitigation measures could be developed. For the management-planning period these measures are represented by promotion of alternative energy suppliers (solar batteries) and raising public awareness of global climate change. Climate change and its effects on the ecosystems are also the basic focus of further researches and monitoring, to be completed by the BR staff and interested research institutions.

But to deal with human activities causing negative impact onto the ecosystem, management measures are developed for different types of land use. To address the degradation of recreational resources, which is in place in the Belukha Nature Park, following activities are suggested:

- equipment of basic tourist trails and camping sites,
- development of mechanism and provision recreational services by nature park administration,
- based on the researches conducted in 2008, the maximum number of visitors, which will not cause irreversible changes in ecosystems, could not exceed 9000 persons. The management objective is regulation of the number of visitors,
- development of interpretative programs for visitors of the park,

To reduce negative impact caused by maral farming onto the environment, the recommendations to the farmers were figured out and include:

- pasture rotation and regulation of pressure,
- implementation of livestock breeding,
- transfer the park fences every 10-12 years to prevent the erosion,
- development of ecotourism and medical resorts on the base of existing maral farms to make this economy less dependent on the global market fluctuations and to provide additional jobs for local people.

Proposed management objectives and activities are incorporated into the management-plan of Katunskiy Biosphere Reserve and into the Draft of Strategy on the Development and Management of the Golden Mountains of Altai World Heritage site, which is developed together with the Ministry of Natural Resources of the Altai Republic.

The results of the project are presented and discussed at different scientific and practical meetings, namely:

- International Workshop “Perspectives of integration of Katunskiy Biosphere Reserve into Socio-Economic Structure of the region” (7-9 August, 2008)
- Public Council of Nature Park Belukha (2 October, 2008)
- Regional Conference on Conservation of World Heritage in the Altai Republic and Meeting of Association of the Protected Areas of Altai-Sayan Ecoregion (Oct., 17-19, 2008)

- Annual meeting of Ust-Koksa Archive service (19 December, 2008)
- Final public hearings of the management plan of Katunskiy Biosphere Reserve (15 December, 2008)
- International Workshop “Research Strategy on Global Changes in Mountain Biosphere Reserves” (Nepal, Kathmandu, November, 20, 2008)

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