ISSN 1875-3728, Geography and Natural Resources, 2016, Vol. 37, No. 1, pp. 79-86. © Pleiades Publishing, Ltd., 2016.
Original Russian Text © Zh.T. Tilekova, M.T. Oshakbaev, A.P. Khaustov, 2016, published in Geografiya i Prirodnye Resursy, 2016, Vol. 37, No. 1, pp. 173-181.

GEOGRAPHY ABROAD

Assessing the Geoecological State of Ecosystems in the Balkhash Region

Zh. T. Tilekova[a], M. T. Oshakbaev[a] and A. P. Khaustov[b]

[a] *Kazakh National Technical University, Almaty, Kazakhstan*

[b] *Peoples' Friendship University of Russia, Moscow, Russia*

e-mail: tilek_zhanna@mail.ru

e-mail: o_mels@mail.ru

e-mail: akhaustov@yandex.ru

Received May 22, 2015

Abstract—We examine the current ecological problems of the Balkhash region. An assessment is made of the ecological status of the territory and water resources among which Lake Balkhash and the Ili, Karatal and Lepsy were assessed as the most severely polluted rivers. Lake Balkhash is represented not only as a fishery water body but also as the unique center of the region's ecological integrity. A rationale is provided for the need to carry out a geoecological monitoring as well as comprehensive measures for maintaining stability of the Lake Balkhash level, preventing the water bodies from pollution, the protection of the lakes' floodplains, the preservation of tugai forests and saxaul vegetation, and a monitoring of desertification processes. Based on studying and analyzing the spatiotemporal physical-geographical characteristics of the territory of the Balkhash region, we constructed a fragment of the geoecological regionalization map. A study into the spatial-regular distribution revealed the region's dominant plant communities. The main pollution sources have been identified: mining industries, housing and communal facilities, influences from settlements, and agrocenoses, specifically irrigated agriculture. As a result of our investigations, it was found that all landscapes of the region have been undergoing changes due to anthropogenic impacts to become anthropogenic modifications of natural landscapes. It was further found that irrational consumption and ill thought-out strategies for utilization of biological resources, coupled with an inadequate scientific regulation of anthropogenic impacts, continue to inflict damage to the region's bioresources.

DOI: 10.1134/S187537281601011X

Keywords: geoecological regionalization, geosystem, landscape, plant communities, pollution, environment.

FORMULATION OF THE PROBLEM

The number of species of plants and animals living in the geosystem serves as an important indicator of the degree of its natural state, and most clearly characterizes the level of ecological destabilization of the environment. Biodiversity conservation on our planet Earth constitutes a challenging issue to date. The green cover of the Earth is rapidly dwindling in the process of its rampant exploitation. So-called "crises" were observed in the past, implying extinction of some species of animals and plants. However, the rate of decline in biological diversity during those periods was disproportionately lower than the destruction rate of habitats (landscapes) to date.

Biodiversity losses in Kazakhstan continue due to a disturbance of the balance in natural ecosystems, the overexploitation of land and plant resources, changes in water regime of rivers, and to discharges of polluted irrigation waters into them as well as because of the invasion of alien plant and animal species into ecosystems. Extinction is particularly clearly pronounced in mountain, forest, desert, floodplain and coastal ecosystems, i.e. in different types of ecosystems. All the aforementioned problems are also, in full measure, true for the Balkhash region.

The contrasting natural conditions of this region were responsible for the faunal and floral diversity. The region is home to 345 species of terrestrial vertebrates living in the Ili river delta or in the adjacent Taukum and Saryesik-Atyrau Deserts, including mammal species, 300 bird species, 2 reptile species, and 3 amphibian species. Besides, about 20 fish species and several thousand invertebrate species can be found here [1].

In recent years, the ecological situation of the Balkhash region has deteriorated dramatically, which is associated not only with the stream flow control but also with the irrational economic activities. This has affected the status of the region's bioresources. Anthropogenic impacts on the biota are becoming so serious that they present the risk of wholly destroying the natural ecosystems, the primary units of biosphere. Therefore, an investigation devoted to assessing the geoecological state of the bioresources in the Balkhash region is of critical current importance.

OBJECTS AND METHODS

The Balkhash region lies in an extensive depression in the south-east of Kazakhstan. Its territory is represented by the plateau of the Northern Balkhash region, and by sand deserts of the Southern Balkhash region. The plateau plain averages 400–450 m in height and surrounds the Lake Balkhash basin. The Southern Balkhash region divides into the western and eastern parts. The Taukum and Moiynkum Deserts stretch along the left portion of the Ili basin, and the interfluve of the Ili and Karatal rivers is home to the Saryesik-Atyrau Deserts. The eastern part, between the Karatal and Aksu rivers, includes the Zhamanzhal and Lyukkum sands, and Aralkum lies between the lower reaches of the Aksu and Lepsa rivers. The area is characterized by an arid climate, and the Balkhash region is home to desert landscapes [2].

The region is endowed with large deposits of polymetallic ores, bituminous coal and building materials. Traditionally, the huge areas have been used as pastured. The area accounts for 16 and 13% of industrial and agricultural production of Kazakhstan, respectively, and for more than 44% of fish catch [3].

The Balkhash region is dominated by desert brown grey soils, and their genesis is due to intense freezing and by a soil moisture deficit [4]. They are characterized by a low humus content, a high carbonate content, and by a higher (than in brown soils) content of alkalized soils and their complexes. Limitedly mature rubbly soils occur. Sand massifs, takyrs, takyr-like soils and solonchaks occupy up to 30% of the area.

The ecosystems of the deserts are dominated by perennial-Salsola plant communities (up to 62%) [5]. Perennial Salsola species are dominant: *Anabasis salsa*, *Salsola arbuscula*, *Nanophyton erinaceum*, and *Salsola orientalis* G. Gmel, and Artsemisa species include *Artemisia terra-alba and A. turanica*. Of widespread occurrence on the sands are *Haloxylon persicum, H. aphyllum,* and the characteristic psammophilic shrubs and subshrubs: species of *Calligonum*, *Ephedra* and *Ammodendron*.

The desert zone with its unique Lake Balkhash is particularly sensitive to any anthropogenic impact. Quite a minor change in natural environment would suffice to present a threat to the existence of plants and animals. It becomes evident that the natural reserves of the territory of the Balkhash region are not unlimited. The water, forest, soil, animal and fish resources are being depleted from year to year.

Irrigated agriculture in the Balkhash region accounts for 82% of all the water used. The efficiency of the irrigation systems does not exceed 40–50%, and the ageing of main melioration equipment makes up more than 40% to date. The start of intense water-economic activity led to a disturbance of the natural hydrological regime of Lake Balkhash. As a result, the years 1970-1980 saw a recession of the lake level and a degradation of the coastal territories. While prior to the construction of the Kapchagai hydroelectric power plant the water level varied between the marks of 341 and 342 m, it dropped at the period from 1984 and 1989, and the absolute minimum (340.65 m) was observed in 1987 [6]. Accordingly, the surface area of the area decreased, and water salinity increased in the area of the city of Balkhash. During the last several years the water level in Lake Balkhash has stabilized; however, the quality of water causes concern.

To date, the air basin of the Balkhash region is undergoing intense pollution by harmful substances from nonferrous metallurgy enterprises, power generating facilities and motor transport. The entire territory shows high concentrations of hydrogen sulfide, sulfur dioxide and nitrogen dioxide. The shore of Lake Balkhash is home to the nonferrous metallurgy giant, Balkhashtsetmet; lead-and-zinc integrated plant is in operation on the bank of the Karatal river; bituminous coal and polymetallic ores open-pits have been prospected, and work has started on their exploitation. Also, local raw materials are being used by enterprises of the light industry.

The lake is being polluted by pesticides and other compounds washed away from irrigated fields. The saturation of Lake Balkhash with residual amounts of incecticides of dichlorodiphenyl-trichloroethane (DDT) and pesticides of hexachlorocyclohexane (HCH) is recorded continuously. Thus, the actual concentrations of the sum of HCH isomers vary within 0.0027 to 0.157 μg/L with the mean values 0.045 μg/L, whereas the sum of DDT metabolites varies from 0.0036 to 0.060 μg/L with the mean value of 0.0261 μg/L. It should be noted that in the presence of pesticides, alpha-, beta- and gammaisomers of HCH and DDT are recorded continuously, with the transformation of the last isomer to metabolite of dichlorodiphenyldichloroethylene or the dissolved compound of dichlordiphenyldichloroethane [3].

Lake Balkhash exhibits increased content levels of sulfates, nitrites and heavy metals. For instance, in waste waters discharged into Tarngalyk Bay the copper concentration varies from 35 to 300 MPC, and the concentration of phenol and petroleum products is 4–6 MPC. The most polluted area of the lake is Bertys Bay near the city of Balkhash. Seventy-five tons of chemical substances are discharged into it every year. According to data reported in [7], the mean annual copper and zinc concentrations in the bay exceed 32–35 and 2 MPC, respectively. Every year the bay receives more than 90 nil. m^3 of waste waters from Balkhashtsvetmet, together with 300 kg of copper, lead and arsenic. The tailing dumps of the plant include as much as 430 thou t of copper, 300 thou t of silver and 200 t of rhenium [7]. Even higher content levels of different components are encountered in wastes from dressing of lead-zinc and gold-rare metals ores and, especially, slags from metallurgical, copper and lead production facilities.

An analysis of the following samples was made in the city of Balkhash in summer 2014: silt from the "bog" near the tailing dump of the plant, silt from the lake, and soil from children's playgrounds. The most critical indicators of lead were detected in the soil around the houses near the plant as well as in the Ili river and in the reservoir of the tailing dump. Arsenic in high concentration was also detected in the Ili river, in the "bog" of the tailing dump, and in two soil samples, one of which was taken from the children's playground. In Kazakhstan there are no standards regulating contents of such elements in soils of children's playgrounds; therefore, the European MPC were used as the standard. With a standard of 10 mg/kg, the arsenic content was 232.2 mg/kg, lead 2217 (standard 50 mg/kg), cadmium 15.3 (standard 0.3 mg/kg, норма – 0.3 mg/kg), zinc 1226.2 (standard 50 mg/kg), and copper 4866.1 mg/kg (standard 45 mg/kg). And while the amount of copper might be accounted for by the historically established background, the amounts of the other elements present a hazard.

In these circumstances the issue of the protection and rational utilization of the region's natural resources is becoming more and more critical. The protection problem is not a new one; it has particularly aggravated in recent years due to an enhancement in anthropogenic impact on natural biocenoses. As a result, a large number of plant and animal species became rare and are endangered.

One of the most important factors for the existence of ecosystems is self-organization as well as the stabilizing principle determined by it. V.B. Sochava reasoned that the main way to understand geosystems is by studying the processes of self-organization, largely the mode of its intercomponent linkages [8]. The biota performs stabilizing functions in their dynamics. The methodological aspects of experimental research, based on identifying the connections between the changeable physical characteristics of soils and vegetation and between biological, biochemical, geochemical and hydrological characteristics of landscapes, were developed at Siberian permanent stations and are described in publications of V.M. Plyusnin and L.M. Korytny [9], A.A. Krauklis [10], V.S. Mikheev [11], Yu.M. Semenov [12], A.K. Cherkashin [13] and V.M. Plyusnin [14].

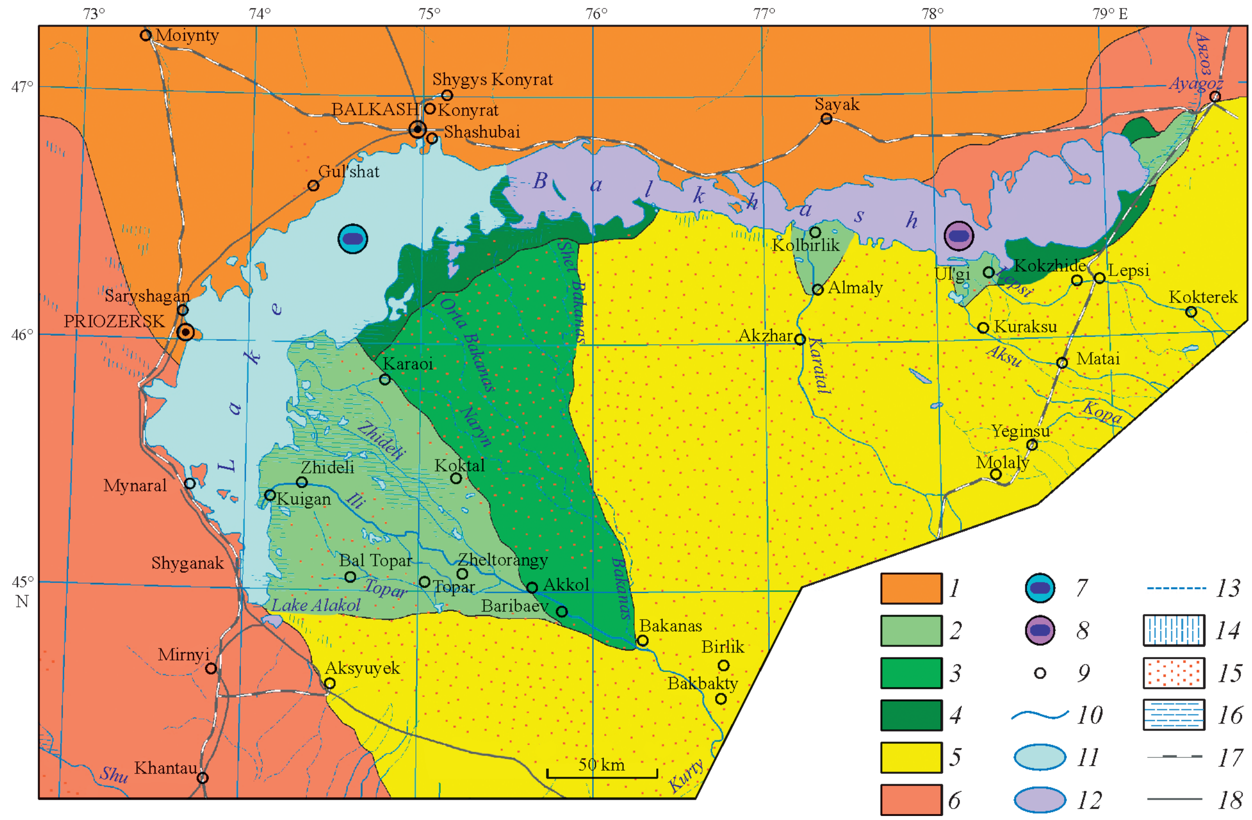
In the just cited references, the methodological tools for landscape analysis of mountainous territories were tested; also, they covered the issues related to experimental landscape studies, the concepts of the geosystem as a set of functionally connected variable states of a natural complex, the methodology of understanding the landscape, and the theoretical-and-methodological framework.

The landscape scientists' interest in the substance-energy exchange between biological and abiotic components, and in biologic productivity of landscape has quickened recently. This interest might be triggered by some influence of the ecological concept, and by the fact that landscape science and biocenology have come closer together. Therefore, this paper gives much attention to the issues related to ecological assessment of the biota.

It is known that the biotic component of landscape is a sufficiently reliable indicator of the heat and moisture flow as well as of changes in physicochemical settings in landscape systems [15]. Therefore, a relative stability of the existing biogeocenoses and the capacity for self-regulation are due to the fact that vegetation forms a special class among the components of the biogeocenoses. It is characterized by its own dynamics; besides, it is involved in dynamical manifestations of geosystems as a whole.

The character of heat and moisture flows, and the mass transport are determined, on the one hand, by the living functions of plants, and, on the other, by the conditions of their habitat (the character of climate and soil, human and animal influences, and by other factors).

For assessing the geoecological state o the region's bioresources the geoecological regionalization map was constructed having regard to the characteristic of the main plant communities in the Balkhash region (*see figure*). A comprehensive assessment was made on the basis of investigating cartographic and reference material. Use was made of the physical-geographical maps for Almaty Region, the maps of specially protected areas of the Republic of Kazakhstan, the soil map, the vegetation map, the map of ecological stress, the map of agricultural lands, the landscape map, and information ecological bulletins on the state of environment for 2010–2014 [16, 17]. Published data [1–6, 18] were also taken into consideration in compiling the map, and in analyzing the state of landscape components. The last reference emphasizes a very close correlation between total amounts of organic matter and heavy metals in bottom sediments from Lake Balkhash, the end substance of pollutants accumulation. Thus the regionalization efforts took into account a substantial



Fragment of the 1:2 500 000 geoecological regionalization map for the main plant communities in the Balkhash region 1:2 500 000. Main plant communities: *1* – hummocky plains with wormwood-saltwort vegetation on rubbly soil-ground (hummocky desert); *2* – contemporaneous alluvial delta plains with tugais and floodplain meadow-forb vegetation on meadow-alluvial soils (intrazonal desert); *3* – old-delta takyr plains with black-saxaul and wormwood-saltwort vegetation on clay-sandy soil-ground (desert-delta-plain); *4* – lakeside, coastal-solonchak, desert plains on bog-solonchak soil-ground (coastal solonchak-bog); *5* – old-alluvial-lakeside aeolian sandy plains (rindge-and-mound- sandy plain); *6* – hummocky ouval-hilly plains with wormwood-saltwort vegetation on rubbly soil-ground (hummocky-rubbly-desert); *7* – aquatic lacustrine freshwater; *8* – aquatic lacustrine brackish-water. *9* – settlements; *10* – rivers; *11* – fresh lakes; *12* – salt lakes; *13* – ephemeral streams; *14* – solonchaks; *15* – sands; *16* – bogs; *17* – railroads; *18* – motor roads.

body of various information regarding the state of landscape components as available to date.

In compiling the geoecological regionalization map for the Balkhash region, use was made of the methods of mapping the structuraldynamical landscape, ecologo-geographical analysis, and phytocenological zoning. The structural-dynamical approach includes the technique of obtaining cartographic products which are used to identify the diversity of dynamical natural processes occurring in landscapes, and to determine the limits of their possible substantial and not infrequently negative changes beyond the framework of the geosystem invariant.

A classification of biocenoses used the schemes developed in phytocenology, because vegetation serves as the most convenient indicator of the entire biotic community. There are a relatively large number of such schemes but the association (the type of phytocenosis) is customarily used as the smallest unit. Together with the respective abiotic components, it is commensurate with the smallest unit in a classification of biocenoses, the type of biogeocenosis (elementary geosystems). The association is characterized by one or several dominants for each layer, a similar spatial structure and conditions of existence [19].

To develop the electronic version of the map used state-of-the-art technologies: ArcGIS, and ArcView. Cartographic and reference-informational materials were analyzed in the process of constructing the map. The following attributes were used as the basis for identification of geoecological areas: genetic commonality, and the unity of the entire set of natural conditions (topography, soil cover); spatial-regular distribution of dominant plant communities in the region at the level of association unit; ecological state of the atmosphere (according to MPC exceedance); degradation of soil cover; decline in specific biological productivity of plant communities; state of the fauna, and geoecological state with due regard for the parameters of technogenic load (input of pollutants to the particular soil individuals).

RESULTS AND DISCUSSION

We now consider the geoecological peculiarities of the Balkhash region for characteristic plant communities (*see figure*).

1. *Hummocky plains with wormwood-saltwort vegetation on rubbly soil-grounds (hummocky desert area)* include the southeastern margin of the Kazakh fold system adjacent to the northwestern coast of Lake Balkhash. Hummocky plain topography is common here. Wormwood-saltwort vegetation is characteristic on grey-brown alkalized desert soils. Typical of the depressions between bald mountains are solonchaks and alkalized takyr soils under succulent-saltwort vegetation. Intermittent surface streams are the Mointy and Tokrai. The region is home to the Balkhash industrial hub which includes the city of Balkhash with Kazakhmys (nonferrous metallurgical enterprise), the Kounrad mine, and the relevant industrial infrastructure. Atmospheric pollution by sulfur dioxide was 6.8 MPC, suspended materials 4.4, carbon oxide 3.2, and nitrogen dioxide 2.4 MPC; API_5 was 2.9 (as of 2014).The consequences of the technogenesis include deep open-pits (as deep as 300 m), and huge rock spoil heaps in the neighborhood of the Kounrad mine, slag disposal sites, soil pollution by petroleum products (6 MPC), phenol (4 MPC) and heavy metals: lead (10 MPC) and copper (10 MPC). Pastoral stock-breeding on the basis of spring-autumn and year-round pastures is pursued.

Rare and endangered faunal and floral species: mammals include *Gazella subgutturosa*, *Ovis ammon*, *Otocolobus manul*, and *Selevinia betpakdalaensis*, *Cardiocranius paradoxus*; birds: *Aquila nipalensis*, *Anthropoides virgo*, and *Syrrhaptes paradoxus*.

2. *Contemporaneous delta alluvial plains with tugais and floodplain meadow-forb vegetation on meadow-alluvial soils (intrazonal desert area)* occupy the contemporaneous delta of the Ili river as well as the deltas of the Aksu, Karatal and Ayagoz rivers. The region is well developed for agriculture. It is experiencing the disappearance of river branches and lakes, and the drying of river deltas caused by intense water consumption for agricultural purposes. Lake-bog biotopes and reed vegetation are disappearing, biodiversity is declining, spawning areas are drying, and muskrat hunting is discontinued. The waters of the Ili, Karatal, Aksu and Ayagoz rivers contain a broad gamut of trace elements with an exceedance of the allowable concentrations of manganese (2.5 MPC), copper (15.6 MPC), nitrite nitrogen (1.5 MPC), and total iron (1.2 MPC). The API value in 2014 was 2.74 (class 4: polluted).

Rare and endangered faunal and floral species include mammals: *Cervus elaphus bactrianus* **Lyddeker**, *G. subgutturosa*, *Vormela peregusna*, *Salpingotus pallidus*; birds: *Pelecanus onocrotalus*, *P. crispus*, *Platalea leucorodia*, *Plegadis falcinellus*, *Cygnus cygnus*, *Aythya nyroca*, *Oxyura leucocephala*, *Pandion haliaetus*, *Circaetus gallicus*, *Aquila nipalensis*, *Aquila heliaca*, *Haliaeetus albicilla*, *Grus communis*, *A. virgo*, *Otis tarda*, *Tetrax tetrax*, *Chlamydotis macqueenii*, *Larus ichthyaetus* Pallas, *Ichthyaetus relictus*, *Pterocles orientalis*, *S. paradoxus*, *Bubo bubo*, and *Podoces panderi* ilensis; fish species: *Barbus brachycephalus*, *Schizothorax pseudaksaiensis*, and *Perca schrenkii*; flora: *Tulipa alberti, T. kolpakowskiana*, *Berberis iliensis*, *Aldrovanda vesiculosa*, and *Agaricus tabularis*.

3. *Old-delta takyr plains with black-saxaul, wormwood-saltwort vegetation on clay-sandy soil-grounds (desert-delta-plain area)* are occupied by old-delta takyr plains of the Ili river. Grey-brown soils dominate over wormwood-saltwort vegetation. The area is characterized by intense processes of natural-anthropogenic desertification. In the past (the years1950–1960) it was covered by saxaul forests, the cutting of which intensified the desertification processes. There occur dry branches ("bakanases") of the old delta of the Ili river. Discharges of collector-drain waters from the Akdala irrigation massif into the Ili river contain sulfates from 74–90 to 235 mg/L. A threefold exceedance of irrigation standards causes a secondary salinization of soils. The region is characterized by wormwood-saltwort vegetation resistant to saline soils.

Rare and endangered faunal and floral species include mammals: *C. elaphus bactrianus* **Lyddeker,** *G.subgutturosa*, *V. peregusna*, *S. pallidus*; birds: *C. gallicus*, *A. nipalensis*, *A. heliaca*, *H. albicilla*, *B. bubo*, *P. panderi* ilensis; flora: *A. vesiculosa* and *A.tabularis*.

4. *Lakeside, coastal-solonchak, desert plains on bog-solonchak soil-grounds (coastal solonchak-bog area)* occupy the floodplains of the Karatal, Aksu, Lepsa and Ayzgoz rivers. They are dominated by lacustrine-alluvial plains with Pamirian winterfat, erkek-Pamirian winterfat and grey-wormwood vegetation on brown and brown alkalized soils. The river valleys are home to tugais and Aeluropus-reed meadows on meadow and meadow-alluvial soils. The water quality in the Lepsa drainage basin and in the floodplains of the Ayagoz river refers to class 6: very dirty. The API value was 8.48. There occurs a high degree of mineralization as well as increased concentrations of sulfates (11.34 MPC), copper (22.14 MPC), magnesium (7.23 MPC) and ammonium nitrogen (9.26 MPC).

Rare and endangered faunal and floral species include mammals: *C. elaphus bactrianus* **Lyddeker**, *G. subgutturosa*, *S. pallidus*, *C. paradoxus*, and roe;

birds: *P. leucorodia*, *C. cygnus*, *O. leucocephala*, *P. haliaetus*, *C. gallicus*, *A. nipalensis*, *A. heliaca*, *O. tarda*, *T. tetrax*, *L. ichthyaetus* Pallas, *I. relictus*, *P. orientalis*, саджа, *B.bubo*); fish species: *B. brachycephalus*, *S. pseudaksaiensis*, and *P. schrenkii*; flora: *Rindera ochroleuca*, *Pachyfissidens grandifrons*, and *A. tabularis*.

5. *Old-alluvial-lacustrine aeolian sandy plains (ridge-mound-sandy plain area)* are occupied by sandy massifs of the Southern Balkhash region: Saryesik-Atyrau, Zhamankum, Irzhar, Zhalkum, Lyukkum, and others. The sands are dominated by wormwood-forb and saxaul vegetation. The region is characterized largely by pastoral stock-breeding on the basis of extensive spring-autumn and year-round pastures. The characteristic feature is the light mechanical composition of soil-grounds, increased effects of wind erosion, uneven water availability for the territory, and a high degree of salinization and swampiness of soils in the river valleys. The main manifestations of ecological destabilization are due to the increasingly intense processes of desertification. The water quality in the Karatal and Aksu is characterized as clean (class 2) with the API value 0.99 and elevated contents of copper (1.3 MPC), manganese (1.1 MPC) and nitrite nitrogen (1.4 MPC).

Rare and endangered faunal and floral species include mammals: *G. subgutturosa*, *Salpingotus crassicauda*) and *Felis lynx* isabellina; birds: *A.nipalensis*, *O. tarda*, *T. tetrax*, and *P. panderi* ilensis; flora: *Soranthus meyeri*, *R. ochroleuca*, and *Scutellaria navicularis*.

6. *Small-hummocky ouval-hilly plains with wormwood-saltwort vegetation on rubbly soil-grounds (small-hummocky-rubbly-desert)* include the southeastern margin of the Kazakh fold system adjacent to the northeastern coast as well as to the western coast of Lake Balkhash. Ouval-hilly topography is of widespread occurrence. A characteristic feature is the wormwood-saltwort vegetation on grey-brown desert soils. In the depressions between bald mountains there usually occur solonchaks and alkaline soils under succulent-saltwort vegetation.

Typical is a high degree of pollution of the atmospheric air, the waters of Lake Balkhash and soil-grounds as a result of the operation of Balkhashtsvetmet as well as the combined impact of industrial enterprises on the water body. There occur a strong negative impact of the Konurad and Sayak mines on the environment and the anthropogenic desertification of the territory as a result of the technogenesis and overgrazing. The water quality is characterized as very dirty (class 6) with the API value 8.94. Increased concentrations of sulfates (10.0 MPC), copper (29.6 MPC), magnesium (7.4 MPC) and ammonium nitrogen (5.6 MPC) are observed.

Rare and endangered faunal and floral species include mammals: *S. betpakdalaensis* and *C.paradoxus*; birds: *A. nipalensis* and *C. macqueenii*; flora: communities of *Allium Galanthum*.

7. *The aquatic lacustrine freshwater area* occupies the western part of Lake Balkhash. In this part of the lake there are two hollows as deep as 7–11 m. One of them stretches from the western coast from Tasaral Island to the Korzhyntubek promontory, and the other hollow lies south of the Bertys bay, the deepest place of western Balkhash [20]. Large bays include Saryshagan, Kashkanteniz, Karakamys, Shempek (the southern termination of the lake), Balakashkan, and Akhmetsu. The lake's islands are Ortaaral, Ayakaral, and Olzhabekaral. However, as the water level grade is lowering, new islands are produced, with an increase in the area of the existing islands [21].

The water in the western part of the lake is used as drinking and process industrial water; it is an almost freshwater (the mineral content is 0.74 g/L) and more turbid (transparency 1 m), yellowish-grey in color. A high degree of pollution of the Bertys bay by waste waters from the city of Balkhash was recorded: increased concentrations of copper (29.6 MPC), zinc (2 MPC), sulfates (10.0 MPC), ammonium nitrogen (5.6 MPC), and other pollutants; the API value of the water is 10.16 (class 7, extremely dirty) [22].

8. *The aquatic lacustrine brackish-water area* occupies the eastern part of Lake Balkhash. The hollow of eastern Balkhash reaches 16 m in depth, with a maximum depth of 27 m [20]. Here, the Guzkol', Balyktykol', Kukun and Karshigan bays are identified, and the Baigabyl, Balai, Shaukar, Kentubek and Korzhyntubek peninsulas, and also Ozynaral, Ultarakty and Korzhyn Islands are situated here. There are 43 islands totaling 66 km^2 in their area [20].

The eastern part has high salinity (from 3.5 to 6 g/L) and transparency (5.5 m) [20].

Across the water area of the southeastern part of Lake Balkhash API varies within 7.03–8.94. The quality of water is characterized as very dirty (class 6), with the API of 8.94. Studies detected increased concentrations of sulfates (10.0 MPC), copper (29.6 MPC), magnesium (7.4 MPC) and ammonium nitrogen (5.6 MPC) [22].

Desert poplar (*Populus*) (as part of tugai forests) and willow (*Salix*) grow on the lake's shore; Poales species include *Phragmites australis*, *Typha angustata*, several species of reed: *Scirpus litoralis*, *S. lacustris*, and the endemic species: *S. kasachstanicus*. Two species of Myriophyllum grow under water: *Myriophyllum spicatum* and *M. verticillatum*), as well as several species of Potamogeton: *Potamogeton lucens*, *P. perfoliatus*, *P. crispus*, *P. pectinatus* and *P. macrocarpus*; there occur *Utricularia vulgaris*, *Ceratophyllum demersum* as well as two species of Najas: *Najas marina* and *N. minor*. The phytoplankton is represented by numerous algal species [23].

In the past, the lake's fauna was relatively rich; starting in the 1970s, however, the biodiversity began to decline due to the water quality deterioration. Before that period the benthos was represented by mollusks, crustacean larvae, and aquatic insects; chironomids and oligochaetes ere also encountered. The fauna was relatively abundant, especially in the western part. The lake was home to about 20 fish species including six typical species: *S. pseudaksaiensis*, *Schizothorax argentatus*, *P. schrenkii, Nemacheilus strauchi and Phoxinus poljakowi*, while the others were introduced species: *Cyprinus carpio*, *Acipenser nudiventris*, *Abramis brama orientalis*, *B. brachycephalus, Leuciscus baicalensis*, *Cyprinus carpio carpio*, *Tinca tinca*, *Stizostedion lucioperca*, *Silurus glanis*), *Diptychus dybowskii*, *Carassius gibelio,* and others. The main commercial fish species are *S. lucioperca, S. glanis, Rutilus caspicus* and *C. carpio*, while the contribution from the aboriginals (*P. schrenkii* and *S. argentatus*) approaches to zero [22, 25]. According to data reported in [22], the mean annual catch for the period from 1986 to 2014 was 8.6 thou t, with yearly fluctuations from 3.4 to 12.6 thou t.

Rare and endangered faunal and floral species are: *A. nipalensis*, *A. virgo*, and *S. paradoxus*; fish species *S. argentatus* and *P. schrenkii* .

The threats to most of the animal species in the desert zone involve a decline in their population over the last several decades, a reduction in habitats and nesting areas due to an enhanced aridization and desertification of the territories, overgrazing, tamarisk and tugai forest devastation as well as illegal harvesting and simply the thoughtless extermination by humans (this refers largely to amphibians and reptiles, and to Arachnida). Some contribution to this process is also made by unfavorable natural factors (cold and snow-deficient winters and, as a result, deep freezing of the soil and water bodies, summer droughts, and pressure from predators). Preventive measures would include a strengthening of the struggle against desertification of the territories in this region and illegal felling (destruction) of desert and tugai vegetation.

CONCLUSIONS

Forecasting of the future state of the flora and fauna in Lake Balkhash is of exceptional current importance. Given the continuous increase in pollution, the degradation processes of the lake's ecosystem may well proceed along quite an unpredictable direction and at an accelerated rate. This brings up the questions as to the preservation of Balkhash not only as a fishery reservoir but largely as a unique center of ecological integrity of the Zhetysu (Semirechie) region.

In particular, there is a need for measures, such as:

– the measures for maintaining a stable water level in Lake Balkhash and preventing pollution of the water bodies, and the protection of the lake floodplains are necessary for all regions, except for sand massifs. The preservation of tugai forests and saxaul vegetation is a top priority for the delta and mouth, river branches, reed vegetation, sand massifs, and specially protected areas; it is not as significant for aquatic freshwater and aquatic brackish-water regions

– a monitoring of the desertification processes is important for the lake shores, the delta and mouth, river branches, reed vegetation, sand massifs, and specially protected areas; it is not as necessary for aquatic freshwater and aquatic brackish-water regions, and

– a geoecological monitoring is required for all categories.

The research reported in this paper suggests the following conclusions.

1. On the basis of analyzing the spatiotemporal physical-geographical development regularities of the territory of the Balkhash region, eight characteristic plant communities were identified, and the geoecological regionalization map was constructed.

2. The analysis of the state of spatial-regular distribution of dominant plant communities in the region showed that such communities are: wormwood-saltwort, floodplain-forb, wormwood-forb, white-saxaul, wormwood-black saxaul, and saltwort communities.

3. The ecological state of the region's atmosphere is assessed as "polluted". Atmospheric pollution by sulfur dioxide is 6.8 MPC, suspended material 4.4, carbon oxide 3.2and nitrogen dioxide 2.4 MPC; API_5 in the region is 2.9 (2014).

4. The assessment of the present state of the water bodies suggests that the surface waters refer to class 4 (category of polluted water), class 6 (category of dirty water), and to class 7 (category of extremely dirty water). The waters of Lake Balkhash and of the Ili, Karatal and Lepsy rivers are experiencing the greatest load.

5. The analysis of the ecological state of the region's soil cover showed that the content levels of arsenic, lead, cadmium, zinc and copper exceed maximum permissible levels.

6. The Balkhash region is the home for more than 30 species of vertebrates which are in need of special protection and are included in the Red Data Book of the Republic of Kazakhstan, as well as for rare and vanishing floral species.

7. The main sources of pollution of the Balkhash region include the mining industries, the communal and housing services of settlements and agrocenoses, specifically irrigated agriculture. Almost all landscapes

are represented by anthropogenic modifications of natural landscapes. It was found that as a result of the badly thought-out strategy of bioresources utilization and the neglect of the need and possibilities for scientific regulation of anthropogenic loads, the degradation of bioresources continues.

REFERENCES

1. Bekenov, A.B., Gvozdev, E.V., Gavrilova, Z.I., and Lobachev, Yu.S., *The Fauna of Balkhash*, A.B. Bekenov, Ed., Almaty: Karina, 1998 [in Russian].
2. *The 1:2 500 000 Landscape Map of the Kazakh SSR*, N.A. Gvozdetskii, Ed., Moscow: GUGK, 1979 [in Russian].
3. *The Present Ecological State of the Lake Balkhash Basin*, T.K. Kudepov, Ed., Almaty: Kaganat, 2002 [in Russian].
4. *Faizov, K.Sh., Soils of the Desert Zone of Kazakhstan (Regional Characteristic of Soils)*, Alma-Ata: Nauka, 1983 [in Russian].
5. Pavlov, N.V., Ageeva, N.T., Baitenov, M.B., and Goloskokov, V.N., *Flora of Kazakhstan*, in 9 Vols., Vol. 3: Salicaceae–Caryophyllaceae, N.V. Pavlov, Ed., 1960 [in Russian].
6. Burlibaev, M.Zh., Dostai, Zh.D., Nikolaenko, A., Mirkhashimov, I.I., and Tursunov, E.A., *The Present Ecological State of the Ecosystems Within the Ili-Balkhash Basin*, Almaty: OO OST-XXI Vek, 2009 [in Russian].
7. *The Problems of Hydroecological Stability Within the Lake Balkhash Basin*, A.B. Samakov, Ed., Almaty: Kanagat, 2003 [in Russian].
8. Sochava, V.B., *An Introduction to the Theory of Geosystems*, Novosibirsk: Nauka, 1978 [in Russian].
9. Plyusnin, V.M. and Korytny, L.M., The 55th Anniversary of the V.B. Sochava Institute of Geography RAS, *Geogr. Nat. Resour*., 2012, vol. 33, issue 4, pp. 263–269.
10. Krauklis, A.A., *The Problems in Experimental Landscape Studies*, Novosibirsk: Nauka, 1979 [in Russian].
11. Mikheev, V.S., Landscape-Geographical Support of Diversified Problems, Novosibirsk: Nauka, 1987 [in Russian].
12. Semenov, Yu.M., *Landscape-Geochemical Analysis and Organization of Geosystems*, Novosibirsk: Nauka, 1991 [in Russian].
13. Cherkashin, A.K., *Polysystem Analysis and Synthesis, Application in Geography*, Novosibirsk: Nauka, 1997 [in Russian].
14. Plyusnin, V.M., Response of Inland Mountain Systems to Global Climate Change, *Geogr. Prir. Resur*., 2007, no. 3, pp. 67–74 [in Russian].
15. Antipov, A.N. and Fedorov, V.N., *Landscape-Hydrological Organization of a Territory*, V.A. Snytko, Ed., Novosibirsk: Izd-vo SO RAN, 2000 [in Russian].
16. *The National Atlas of the Republic of Kazakhstan*, in 3 Vols., Vol. 1: Environment and Ecology, A.R. Medeu, Ed., Almaty: TOO Vit Brand, 2006.
17. *The National Atlas of the Republic of Kazakhstan*, in 3 Vols., Vol. 2: Social and Economic Development, A.R. Medeu, Ed., Almaty: TOO Vit Brand, 2006.
18. Sharipova, O.A., Distribution of Heavy Metals in Bottom Sediments of Lake Balkhash Depending on Natural and Anthropogenic Factors, *Vestn. Tom. Gos. Univ*., 2015, no. 390, pp. 225–230 [in Russian].
19. Vtorov, P.P. and Drozdov, N.N., *Biogeography: Textbook*, Moscow: Vlados-press, 2001 [in Russian].
20. Modern Illustrated Encyclopedia "Geography", A.P. Gorkin, Ed. URL: http://www.alleng.ru/d/geog// (Accessed 01.20.2015) [in Russian].
21. Lake Balkhash, Kazakhstan: Image of the Day. http://www.britannica.com (Accessed 01.20.2015) [in Russian].
22. Information Bulletin on the State of Environment Within the Lake Balkhash Basin for 2010–2014. URL: http://www.kazhydromet.kz/ru/monitor_beluten_arhiv2014 (Accessed 05.20.2015) [in Russian].
23. Kezer, K. and Matsuyama, H., Decrease of River Runoff in the Lake Balkhash Basin in Central Asia, *Hydrol. Process*., 2006, vol. 20, issue 6, pp. 1407–1423.
24. Mitrofanov, V.P. and Dukravets, G.M., History of Fish Acclimatization in Kazakhstan, in *Fishes of Kazakhstan*, E.V. Gvozdev and V.P. Mitrofanov, Eds., in 5 Vols., Vol. 5: Acclimatization, Commercial Fisheries, 1992, Alma-Ata: Gylym, pp. 6–44 [in Russian].
25. Mamilov, N.Sh., Invasive Fish Species in Small Water Bodies of the Balkhsh Basin and Their Interactions With the Aboriginal Ichthyofauna, Proc. II Int. Symp "Invasion of Alien Species in Holarctic» (September 27–October 1, 2005, Borok-2), Rybinsk; Borok, 2005, pp. 190–191 [in Russian].