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IMPACT OF CLIMATE CHANGE AND ANTHROPOGENIC ACTIVITIES ON THE WATER AND BIOLOGICAL RESOURCES OF LAKE SHALKAR IN WESTERN KAZAKHSTAN

Annotation. Climate-induced changes in the biodiversity and resource potential of Shalkar lake are considered. It is a lake located in the arid Caspian region of the Republic of Kazakhstan (50°33′ nl. and 51°40′ el.). The authors analyze the causes and consequences of the deterioration of this valuable natural object due to a gradual annual decrease in the water level by more than two meters (since 1995), which later stabilized at a low level of 16 m. The methods commonly used in biogeography, hydrology, zoology and ichthyology revealed that the greatest damage to the biological diversity of aquatic and near-water ecosystems was caused by the retreat of the coastline from reeds, as well as an increase in water salinity in 2012-2019 from 5 to 12 g/l. These changes led to a decrease in species diversity and abundance of zooplankton and zoobenthos. Due to the deterioration of spawning grounds and food supply, only 7 species of fish remained in 2018-2019, whereas in 1998 there were 19 species, two of which were endemic to the lake. If ten years ago the total fish stocks were 936.1 tons, now they are only 142.9 tons. Industrial fishing has led to the almost complete disappearance of bream, pike, roach. Due to the deterioration of nesting and flight conditions of near-water birds, their number decreased in 1998-2019 from 55 to 45 species, and red – book birds-from 12 to 4 species. The ecological situation in the coastal zone is even worse due to the increase in the number of pets and uncontrolled recreation. Methods for optimizing nature management in the basin of the entire lake Shalkar are proposed.

Keywords: Caspian lowland; lake Shalkar; shallowing; increased mineralization; reeds; reduced biodiversity; increased recreational load;climate; hydrochemistry; fish; Red book.

Introduction

According to the conclusions of the intergovernmental panel on climate change [1], the warming of the climate system is an indisputable fact, and since the 1950s, many observed changes are unprecedented on a scale from decades to millennia. Global warming is recognized as one of the most important factors affecting the current state of the biosphere. In addition to well-known macroclimatic phenomena, transformations of certain elements of the landscape, in particular, lake ecosystems of the zone of arid sharply continental climate, with an average annual air temperature of 4.3 °C and precipitation of 282 mm, are observed. Gradual changes in the hydrological regime of reservoirs over several decades lead to changes in the composition and quantitative characteristics of biota. National and regional studies conducted in Central Asia indicate that the region as a whole is experiencing a warming climate with an increase in average annual temperature of 0.5°C over the past thirty years [2,3]. Within the territory of neighboring Russia, the rate of warming is more than 0.45 °C/10 years, and the intensity of warming varies in different parts of the country [4,5]. In Kazakhstan, warming is observed throughout the country in every season. Between 1941 and 2011, the average annual air temperature increased by 0.28°C every 10 years [6]. The highest level of warming occurs during the winter period, while the lowest temperature increase is observed during the summer months. In Kazakhstan, according to national reports for the period from 1941 to 2011, the annual precipitation decreased by 0.5 mm per decade [6].

Dynamic phenomena in aquatic ecosystems caused by climate change significantly change the conditions of living aquatic and near-water organisms [7-9]. The response of ecosystems to changes in hydrology may be a violation of the integrity of some of the existing ecological communities in the future [10-12]. Protecting biodiversity and restoring habitats of organisms are important tools both for reducing the adverse effects of climate change and for stimulating their adaptations in ecosystems [13,14]. This is especially important for the arid conditions of Central Asia, for example, for the lake. Shalkar (50°33′ nl. and 51°40′ el.), which is the main link of the ecological framework for the West Kazakhstan region. Lake Shalkar has been relatively well studied in hydrological, hydrochemical and hydrobiological terms for a long period of time. The position of lake Shalkar at the junction of natural and climatic zones contributes to the formation of a kind of mixed flora and fauna, characterized by high species richness and diversity. Physical and geographical conditions of the surroundings of lake Shalkar determined its biodiversity, which includes more than 583 species of plants, represented by 272 genera and 66 families, about 103 species of vertebrates, including 55 species of birds, 15 species of fish, 21 species of mammals, 7 species of reptiles, 3 species of amphibians [15-22]. Of these, the red Book of the Republic of Kazakhstan includes: Cornuch-Trotsky's navel (*Anthemistrotzkiana* Claus ex Bunge, 1848), tatarkatran (*Crambetatarica* Pall. ex Gueldenst.), Schrenk's tulip (*Tulipasuaveolens* Roth, 1794), Meyr's bedbug (*Lepidiummeyeri* Claus), spring adonis (*Adonis vernalis* L., 1753), lesser white Heron (*Egrettagarzetta* (Linnaeus, 1766), spoonbill (*Platalealeucorodia* Linnaeus, 1758), loaf (*Plegadisfalcinellus* (Linnaeus, 1766), whooper Swan (*Cygnus cygnus* (Linnaeus, 1758), steppe eagle (*Aquila nipalensis* Hodgson, 1833), long-tailed eagle (*Haliaeetusleucoryphus* (Pallas, 1771), beauty crane (*Anthropoidesvirgo* (Linnaeus, 1758), flutter (*Tetraxtetrax* (Linnaeus, 1758), black-headed chuckler (*Ichthyaetusichthyaetus* (Pallas, 1773) and others [20,21, 23-27]. Located on the path of seasonal migrations of waterfowl, lake Shalkar is their place of rest and feeding. Endemic fish species were previously observed in the lake: the Shalkar herring (*Clupeonelladelicatulacaspiamorphacharchalensis*) and the Shalkar roach (*Rutilusrutiluscaspicus nation charchalensis* (Berg)) [22, 28-31].

Lake Shalkar is included in the "List of environmental protection objects of special ecological, scientific and cultural significance " (Decree of the Government of the Republic of Kazakhstan dated May 3, 2005 No. 416). Lake Shalkar belongs to the key ornithological territory (Important Bird Areas) (IBA no. KZ001), where regular one – time concentrations of waterfowl and near-water birds on the flight of up to 20,000 or more are noted, and the nesting of a globally vulnerable species-the *Tetraxtetrax*-is also noted here [32]. We believe that the unique natural complex of the lake Shalkar basin is also a promising key Botanical area (Important Plant Areas) of West Kazakhstan region [33]. It is possible to organize monitoring and protection not only of valuable plant species and their habitats, but also of the entire plant biodiversity as a whole. Based on the biological and landscape diversity of lake Shalkar, it seems appropriate to consider this object as a key landscape area (Important Landscape Areas) [34]. Lake Shalkar and its surroundings reflect the diversity of the region's landscapes and are important for identifying and preserving standards of zonal, characteristic, rare and endangered geosystems at the level of localities, tracts and their regional combinations [34]. The value of this reservoir is also determined by high recreational indicators, since it is almost the only place of recreation for the population of a large city (Uralsk), as well as the areas of the left Bank of the Ural river in the West Kazakhstan region [26,27,35].

It was believed that due to the huge water area (27530 ha), hunting on the North and North-East coasts, recreational activities on the southern shore of the lake, livestock farming on the Eastern shore, and other factors of concern do not significantly affect the number of birds [32].

Our research has shown the opposite-the presence of this impact and the decrease in the number of birds. A serious natural threat is the periodic shallowing of the lake in dry years and the decline in fish numbers in the event of its overfishing. At the present stage, there is a strong drop in its level (more than 2 m since 1995), the causes of which are associated with climate change, tectonic phenomena, anthropogenic impact on the catchment area, etc. [36-42]. In this regard, it is interesting to conduct an expert assessment of the reliability of all assumptions and to identify the root cause of the dynamics of the water level in this pond and to determine the effects of changes in the degree of flooding of site on biodiversity, water and aquatic ecosystems.

Materials and Methods

The research was conducted in the lake basin Shalkar. Lake Shalkar is located in the Caspian lowland 70 km South-East of the regional center of Uralsk (Fig.1). The area of the mirror varies from 190 to 200 km2 in different years. The reservoir occupies a vast circular basin 18 km long and 15 km wide in the center of the salt massif. The average depth of the lake is 7 m, the maximum – 12 m. The lake is as if squeezed from the North and South by two chalk mountains Santas (70 m) and Sasay (94 m), which are raised sides of the salt dome. Mount Sasay rises almost 80 m above the lake. At its base, the mountain is composed of a powerful salt layer of the Kungur age (P1k). There are Sandstone outcrops on the Western slope of the mountain. The low-water Sholak and YesenAnkaty rivers flow into the lake, and the drying Solyanka river flows out (it belongs to the Ural river basin). The water of the lake Shalkar is bittersweet and undrinkable (Fig.1).

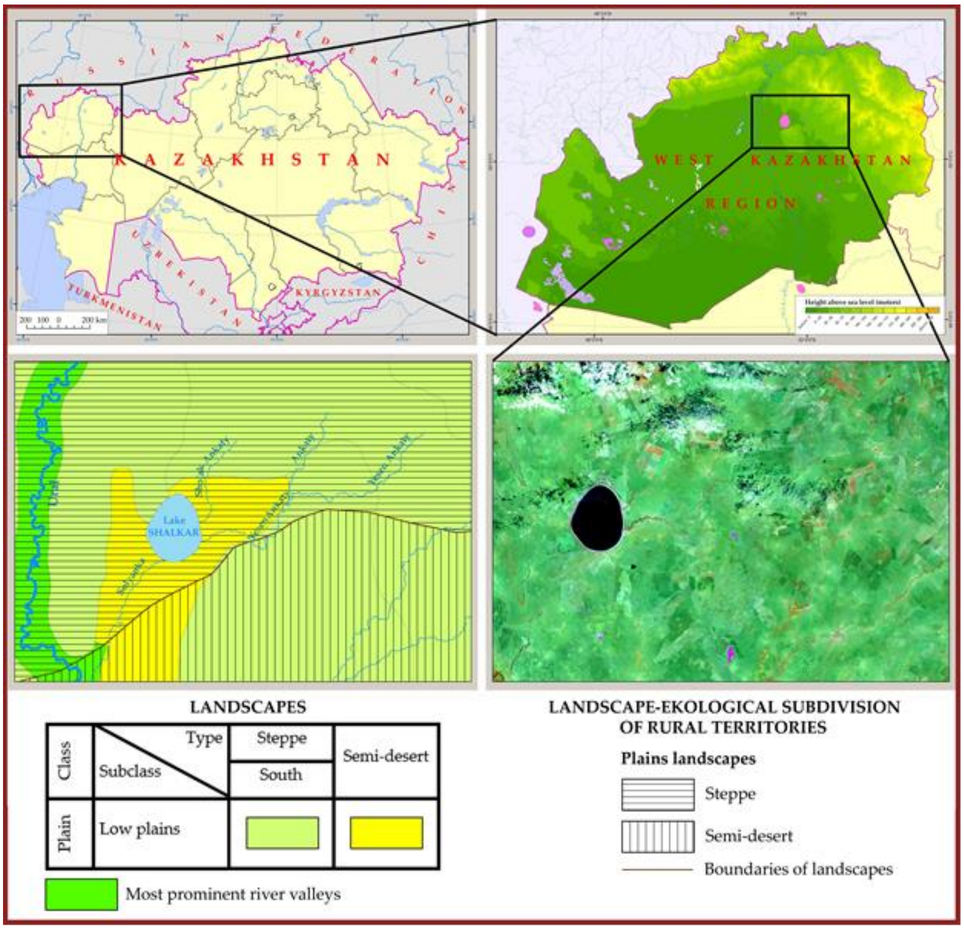

***Figure 1** - Geographical location and landscape-natural zones of the nearby territory of lake Shalkar [43,44]*

The lake catchment area was determined using the highest points of the isolines using cartographic material and the ArcGIS 10.1 program. The research was conducted using the route-expedition method using the latest satellite images. Hydrothermal aspects of dynamic natural phenomena in the Caspian lowlands were analyzed using data from Kazhydromet and natural resources Management (Uralsk) and stock materials on the ground water level at the Dzhanybek science station of the Institute of Forest Science of the Russian Academy of Sciences (49°23′ nl. and 46°47′ el.). Laboratory analysis of the main hydrochemical indicators of the surface natural waters of lake Shalkar was carried out in the accredited testing laboratory of ecology and biogeochemistry of the West Kazakhstan State University named after M. Utemisov.

Changes in the biological diversity of near-water and aquatic communities of the lake Shalkar was analyzed based on literature data and own field research. Studies of zooplankton and zoobenthos were conducted using generally accepted hydrobiological methods [45,46]. To determine the taxonomic affiliation of hydrobionts, appropriate determinants were used [46-49]. The assessment of the level of feeding capacity of reservoirs for zoobenthos is given by S. P. Kitaev [50]. Standard geobotanical and floristic methods were chosen as the basis for assessing the biodiversity of vegetation and flora of the studied area [51,52]. Geobotanical descriptions were carried out on reference sites of 100 sq.m. during the expedition, rare plant species and typical plant formations were observed on the route. The plant species we found were determined using determinants [53-55]. The nomenclature of species, genera and families is given according to the reports of S. A. Abdulina [56] and Z. N. Ryabinina, M. S. Knyazev [57].

Data on the species composition, territorial distribution, biotopic abundance and relative abundance (occurrence) of amphibians, reptiles, birds and mammals were collected on automobile and hiking routes. Additional Zoological information was collected in the course of hiking routes made at the places where the expedition vehicles stop. "Points" where vertebrates or traces of their life activity were found were recorded using a GPS Navigator (GARMIN). By "point" we mean to some extent the surveyed area of the territory, the greatest length of which does not exceed 500 m. If possible, the vertebrates encountered, as well as the biotopes in which they live, were photographed using a Nikon D7200 camera with Nikor 70-300 or Tamron 150-600 lenses. Bird observations were made using BMPTS-12*50 binoculars and a Yukon 10x100 telescope. When defining species, we were guided by definitions and reference publications [58-61]. The study of the species composition of the ichthyofauna, collection and processing of the material was carried out according to generally accepted methods [62]. The number of ichthyofauna and the fishing stock were determined by direct accounting of passive fishing gear using biostatic methods [63,64].

Results

At the present stage, there is a tendency to a significant deterioration of the environmental situation in the studied area, which is caused by the gradual shallowing of the lake itself against the background of increasing anthropogenic impact (recreational load, dams in gullies and small rivers, water extraction for economic needs, overgrazing of farm animals, harvesting of reeds, etc.).

The fluctuations of the water level in lake Shalkar show an intra-century cyclical pattern typical of lakes in the Central Asian region [38,39,41,42]. Alternation of low-water and high-water periods is associated with a general change in the moisture content of the region. According to regime observations (from 1956 to 1995) of the water level in lake Shalkar, there was a forty-year cycle of increased water content of the lake, with highs in 1958 and in 1995, with a minimum in 1978. According to this 40-year cycle, the lake has the following minimum water level drop between 2015 and 2020. However, for a more accurate forecast, materials are required, usually from centuries-old fluctuations in the water level. We do not have such observations, because such hydrological data are not available for the first half of the 20th century. The existence of lake Shalkar depends on the corresponding input and expenditure part of the water balance in the context of centuries-old data.

The water content of lake Shalkar is very variable and is determined by the variation and corresponding elements of the water balance both during the year and over a longer period. Due to the short series of observations of water levels in the lake, it is not possible to judge which phase of the climate cycle they belong to. There is a clear pattern of intra-century cycling from a maximum in the late fifties to a maximum in the mid-nineties with a cycle duration of about 40 years. According to the literature data, this cycle belongs to the phase of increased water availability. The filling of the lake took place quickly, shallowing considerably slower. Within the main cycle, there are a number of years with unstable water level fluctuations. Shallowing of the lake by the end of the 70s caused drying of reeds along the coastal edge, which deprived the lake of spawning grounds and food supply. To maintain the water level in this reservoir at the flood marks of reeds, it was fed in the amount of 20 million m^3 from 1972 to 1994, inclusive [65]. Artificial recharge of the lake in the amount of 20 million rubles m^3 per year, obviously, only slightly normalizes the position of the horizon in the multi-year series. Filling to the horizon of 18.79 m was due to the flow of high-water years: 1992-1993, 1993-1994 and 1994-1995. In 1993 and 1994, 38 and 30 million m3 of water from the Barbastau reservoir (the basin of the Barbastau river that flows into the river) were additionally discharged into lake Shalkar, respectively. Ural from the left Bank at 775 km from the mouth).

In low-water years, with a strong reduction in the flow of the Yesen and SholakAnkaty rivers, when the lake level falls, the salinity of the waters increases. Previously, water salinity ranged from 3 to 7 g/l, but since 2015, the salinity was more than 12 g / l, which corresponds to the level of sea water concentration. For example, the salinity of the Caspian Sea is 12 g/l [66], the Azov Sea is 11 g/l, and the Black Sea is 17 g/l. This is due, first, to the increase in salinity of YesenAnkaty (from 6.4 g/l to 11.9 g/l) and SholakAnkaty (from 11.1 g/l to 13.4 g/l), due to the reduction of their natural flow due to water retention in reservoirs and ponds. Secondly, with the absence of outflow and inflow of water from the Solyanka river, and thirdly-the lake lies on a salt dome, which contributes to the accumulation of salts. Hydrochemical studies of water samples from lake Shalkar, the YesenAnkaty and SholakAnkaty rivers and samples of bottom sediments indicate high salinity, increased hardness and permanganate oxidability, which makes it impossible to improve water quality and fill the reservoir.

The degree of overgrowth of this reservoir in the late twentieth and early twenty-first century was weak, at the time of the study, the overgrowth of the reservoir is absent. Along the perimeter of the lake along the shoreline of the lake, there is a complete reduction of reed thickets, which leads to a depletion of the floral composition of both water and water-coastal plants, i.e. the food base and spawning grounds for fish completely disappear. The reeds along the lake shore covered approximately 4,000 ha, and the width of these reeds ranged from a few meters to 500-600 m. In the 90s of the 20^{th} century, mowing of reeds in winter on the ice was carried out. This led to intense rotting in the summer of the remaining part. These residues are left in the sludge layer and lead to sedimentation, in some places the layer of silt up to 1.5 m. Until 2008, reeds bordered almost the entire lake in a wide strip, giving way to a small strip of clean sandbank about 8 km long, only on the southern side opposite the village of Saryomir. The reed belt around the lake was up to 1 km wide in places. The reed belt was not continuous, the thick reeds were dotted with numerous different areas and depth of ples – open and clear of vegetation areas of water inside the thicket. These patches are a kind of spawning grounds for fish. Since 2005, there has been a reduction in the flow of floodwater to lake Shalkar annually by an average of 30 cm, in this regard, there is a low water level, the lake shallows, which affects the overgrowth of the reservoir. This trend continues at the present time, although not so intensively. However, this has very important negative consequences for fisheries. Due to the sharp shallowing of the reservoir, the coastal vegetation in the coastal part of the reservoir was beyond the water cut. Thus, fish species such as pike have lost their natural habitats. In addition, the places of increased concentration of forage organisms located along the thickets of coastal vegetation have disappeared. At the time of the study, the average number of bottom invertebrates in the lake Shalkar was 115 copies / m^2, and the average biomass was 968.5 mg / m^2. The value of the biomass of the bottom communities of lake Shalkar on the" trophic scale " indicates a very low level of feed capacity of the reservoir [50]. High indicators of the number and biomass of the forage base of lake Shalkar fell on crustaceans and bell mosquitoes.

As a result of a sharp shallowing of the reservoir in dry years, the natural spawning grounds of commercial fish - the YesenAnkaty and SholakAnkaty rivers-are being unlined. Water in 2019 retreated from the reeds by 200-300 m, which causes their death. As a result, large areas of shallow spawning grounds and nesting sites of birds were on land, which immediately affected the reproduction of birds and fish. At the same time, the feeding places were reduced. At the moment, due to the lack of natural overgrowth of the reservoir, its ichthyofauna and avifauna suffer, which have lost their places of reproduction. The influence of overgrowth of the reservoir on the quality of the water environment was due to the presence of reeds. Shore reeds for lake Shalkar are: the basis of spawning grounds, where eggs are fixed, protection from the waves of the coastline, places where larvae develop in fish feed, places where birds nest, a natural cleaner from pollutants, a regulator of the salinity of the lake.

Along the entire shoreline of lake Shalkar on the southern side grow thickets of *Salicornia perennans*Willd., with the transition to the kokpekovo-kermekovo community with a comb, remaining under the moving Sands and silt (Fig. 2,3). Until autumn, this vegetation remains intact, and in winter it is satisfactorily eaten by sheep and goats. Under the soleros groupings, ground water lies at a depth of 20 cm and contains up to 30 g of salts per 1 l, with a predominance of chlorides.

Figure 2 -*Shoreline of the lake with Salicornia perennans salt marsh*

Figure 3 -*Thickets of tamarisk in the southern part of lake Shalkar*

In the Eastern part of the lake, an area completely devoid of vegetation is dominated by halophilic plant species typical of saline habitats. Up to 85-90% of the area is occupied by the soleros formation, with the eugalophytesoleros *Salicornia perennans*. The floral composition includes: warty Cygnus *Atriplexcana* C. A. Mey, salt marsh Aster *Tripoliumpannonicum (Jacq.) Dobrocz.,* riparian *Aeluropusintermedius* Regel, etc.

On the rivers YesenAnkaty and SholakAnkaty from coastal water plants we have registered hygrophytes: sedge Ranya *Carex praecox* Schreb., lake reeds *Schoenoplectuslacustris* L., marsh *Eleocharispalustris* (L.), bulrushs *Juncusacutus* L. and Gerard J. *gerardii*Loisel. Hydrophytes are represented by small duckweed *Lemna minor*, water lily *Nymphaea candida*, cupola *Nupharlutea* L., hornwort *Ceratop hyllumdemersum* L. at the edge of the left Bank of the river, thickets of southern reeds *(Phragmitesaustralis* (Cav.) Trin. ex Steud.). The local population uses this section of the Yesen Ankaty river for watering farm animals (Fig. 4).

***Figure 4** -Upper course of the EsenAnkaty river near the settlement of Segizui*

In the grasslands of the lake coasts and the Yesen Ankaty and Sholak Ankaty rivers that flow into the lake, along with the increased pasture impact, there is a high infestation of these territories with prickly *(Onopor dumacanthium* L.), sometimes they occupy a significant area, displacing native species, often forming monotypic structures of vegetation cover (Fig.5).

***Figure 5** -Thickets of prickly Onopordumacanthium L. on the Bank of the river Yesen Ankaty*

Here the thickets of southern reeds *(Phragmitesaustralis* (Cav.) Trin. ex Steud.), lake reeds *(Schoenoplectus lacustris* (L.) Pallas (1888)) and narrow-leaved cattails (*Typhaangustifolia* L., 1753) (Fig.6). The local population is driven to the banks of domestic animals, there are traces of harvesting reeds. Significant areas of halophiles represented by the monotypic kermek formation *Limonium (Limonium gmelinii* (Willd.) Kuntz., L. *caspium* Willd., L. *suffruticosum* (L.) *Kuntze*, L. *sareptanum* (L.) Hams.), which is evidence of the high salinity of the YesenAnkata river Bank, which leads to the loss of valuable meadow plant species from the herbage. Vegetation on the shores of lake Shalkar and in the mountains of Santas and Sasay is degraded by overgrazing of farm animals (Fig. 7).

Figure 6 *-Bank in the lower reaches of the EsenAnkaty river near the village of Chelkar*

Figure 7 ***-*** *Grazing sheep and goats near the village of Chelkar, located East of lake Shalkar*

The high salinity of the coastal territory of the lake with huge expanses of open area of the coasts, from which sand and salt suspensions are carried by the wind, allow monogroups of halophytic and weed vegetation to capture land plots every year.

As we can see, the composition and structure of the soil and vegetation cover of the territories adjacent to the reservoir is strongly negatively affected by an anthropogenic factor, which leads to a deterioration of the ecology of the entire basin of lake Shalkar, exacerbating the negative changes occurring in the lake itself.

The area of lake Shalkar is a key area for studying the flora and vegetation of the North-Eastern part of the Northern Caspian Sea. In the vicinity of the reservoir, there is a decrease in the biological diversity of plants and animals (Table 1). In total, 583 species of plants were taken into account earlier in the study area, which belong to 272 genera and 66 families. The dominant ones are complex-colored, cereals, legumes, lip-colored, quinoa and other families [23-25]. As a result of our research, 305 species of vascular plants belonging to 180 genera and 52 families were registered on the territory immediately adjacent to the lake (Table 1).

Table 1 - *Assessment of the biological diversity of lake Shalkar*

1998 year	2019 year
583 plant species that belong to 272 genera and 66 families	305 plant species that belong to 180 genera and 52 families
3 species of amphibians and 7 species of reptiles	5 species of reptiles
55 species of birds, including 12 species of birds listed In the red book of Kazakhstan: including curly Pelican, black stork, spoonbill, burial eagle, gyrfalcon	45 species of birds, of which 4 species of birds listed in the red book of Kazakhstan: whooper swan, white-tailed eagle, steppe eagle
19 species of fish, of which 2 are endemic: roach and herring	7 species of fish: perch, crucian, carp, roach, pike, rudd, ide.

The ichthyofauna of lake Shalkar in 2019 is represented by 7 species of freshwater and commercial fish: perch, crucian, carp, roach, pike, rudd, ide. (Fig. 8), i.e., in comparison with 2006 (10 species), the diversity has decreased by three species.

Figure 8 - *Some representatives of the ichthyofauna of lake Shalkar in the control catches of 2019(from left to right: carp, Carasiusgibelio (Bloch, 1782), perch, Percafluviatilis (L., 1758), rudd, Scardiniuserythrophtalmus (L., 1758)*

At the same time, the age composition of the ichthyofauna in 2019 has become younger (up to 3+) compared to 2006 (the age groups of 4+ and 5+dominated). Fish productivity has decreased compared to 2017. The total fishing stock of lake Shalkar for 2019 was 142.99 tons, fish productivity of 5.96 kg / ha. Compared to 2017, the commercial fish stock (173.6 tons) decreased by 18%, fish productivity (7.95 kg/ha) decreased by 25 %.

The results of the assessment of aquatic bioresources showed that the total fish stocks in lake Shalkar decreased by 820.1 tons compared to 2009 (Table 2).

Table 2 *- Estimated fish stocks of lake Shalkar, tons [67]*

Species	2009 год	2019 год
Bream, *Abramisbrama* (L., 1758)	479,7	0
Carp, *Cyprinuscarpio* (L., 1758)	285,5	61,84
Pike, *Esoxlucius* (L., 1758)	8,1	0
Rudd, *Scardinius erythrophtalmus* (L., 1758)	86,4	1,99
Ide, *Leuciscusidus* (L., 1758)	35,8	0
Perch, *Percafluviatilis* (L., 1758)	34,2	30,04
Crucian, *Carasiusgibelio* (Bloch, 1782)	22,9	31,14
Tench, *Tincatinca* (L., 1758)	8,4	0
Roach, *Rutilusrutilus* (L., 1758)	2,0	0
Ruff, *Gymnocephalus cernuus* (L., 1758)	0,1	0
Roach, *Rutilusrutilus caspicus* (Jakowlew, 1870)	0	17,98
Total	936,1	142,99

The bulk of the total fish stock in 2009 accounted for bream (479.7 t), and carp - about 285.5 t. Further, in descending order of stocks from 86.4 to 0.1 t, there is a group of low-value small-scale species (rudd, crucian, perch, roach, tench, ide), which give a total of about 189.8 t of bioresources. The total stock of such commercially valuable fish as pike was estimated at 8.1 t. After 10 years, we note that the stocks of carp, carp, and roach together give 110.8 t or 77.5% of the reserves, the remaining 22.5% is a small particle: perch 30.04 t and Rudd 1.99 t.

Reservoirs have a certain fish productivity that depends on a set of conditions, in particular, on feed resources. The food base of the fish of lake Shalkar is mainly represented by larvae of ringworm mosquitoes. A significant role in providing fish with food is also played by crustaceans-*Gammaridae*. Forage organisms are distributed unevenly in the reservoir. Here in 2019, 10 species of bottom organisms were identified from two classes: *Malacostraca* and *Insecta*, of which: crustaceans 3 species, insects 7 species (Hemiptera 1 species and Diptera larvae 6 species).

Species diversity and quantitative indicators of the food base of lake Shalkar are decreasing compared to previous years, for example, in 2019, 10 species from 3 groups with a biomass of 0.9 g/m² were recorded in the bottom invertebrates, in 2017-2018, 14 species from 4 groups with a biomass of 3.79 g/m², respectively, while in 1996, zoobenthos organisms consisted of representatives of 22 species from 6 groups: including Brooks, mollusks, oligochaetes.

Thus, in the conditions of reduced water content in lake Shalkar, there is a decrease in the diversity of fauna of planktonic and bottom invertebrate communities, a decrease in the quantitative indicators of zooplankters and local structural changes in bottom associations.

According to literature data, representatives of 3 amphibian species and 7 reptile species are found in the vicinity of lake Shalkar [15,18,19]. In the course of field research in 2019, we confirmed the presence of five species of reptiles in the vicinity of lake Shalkar – colorful lizard *Eremiasarguta* (Pallas, 1773), agile lizard *Lacerta agilis* (Linnaeus, 1758), patterned skidder *Elaphedione* (Pallas, 1773), common grass snake *Natrixnatrix* (Linnaeus, 1758), eastern steppe viper or Renard's viper *Viperarenardi* (Christoph, 1861) (Table 1).

According to the literature data [20,21,68,69], the avifauna of the vicinity of lake Shalkar included at least 55 species. In 2019, we observed 45 species of birds, a significant number of which are migratory (Table 1). At the moment, there is a sharp reduction in the species composition of the avifauna of lake Shalkar. This is due to the strong shallowing of the reservoir and increasing recreational load. At present, Shalkar has become very shallow, and the coastline has receded from its former borders, and the reeds have disappeared. The birds had no place to nest. The mouth of the Sholak and Esen Ankaty rivers has dried up. On the shores of the lake began to build recreation areas, dry shallows allow cars to pass along the water's edge. Noise and disturbance, especially during the breeding season, also contribute to the depletion of the avifauna. During the expedition research, we have repeatedly noted the grazing of farm animals along the banks of the reservoir, spent cartridges from hunting rifles (hunting is prohibited on the lake) and a lot of garbage.

We have previously noted 12 species of birds listed in the Red book of Kazakhstan in 2019, 4 species were noted: whooper Swan (*Cygnus cygnus* (Linnaeus, 1758), white-tailed eagle *Haliaeetusalbicilla*. (Fig.9), steppe eagle *Aquila* nipalensis (Fig.10),black-headed chuckler *Ichthyaetusichthyaetus* (Pallas, 1773)(Fig.11).

In the southern coastal part of lake Shalkar, there is an increase in recreational load, there are objects for recreational and tourist purposes of capital and light Assembly and disassembly type (Fig.12). The infrastructure area for swimming and recreation along the shore of lake Shalkar is about 5 km away. During the summer, lake Shalkar is visited by about 20 thousand tourists. Infrastructure of light Assembly and disassembly type is not connected to power lines, which is due to their absence in the coastal recreation area of the reservoir. There is a lack of public toilets, and there are no special places for Parking tourist’s vehicles. Vacationers do not fully comply with basic environmental rules and requirements, which leads to the littering of the coastal zone of lake Shalkar with solid household waste and contamination of the soil and vegetation cover with sewage and car exhaust gases. All this leads to an increase in anthropogenic influence on lake Shalkar (Fig.13).

Figure 9 *-White-tailed Eagle, Haliaeetusalbicilla*

Figure 10 *-Nest of the steppe eagle (Aquila nipalensis) on the top of Sasay mountain*

Figure 11 *-Black-Headed chuckler, Ichthyaetusichthyaetus (Pallas, 1773)*

Figure 12 *- A strip of recreational and tourist infrastructure of light Assembly and disassembly type along the southern shore of lake Shalkar*

Figure 13 *-One of the polluted areas with solid household waste along the southern shore of lake Shalkar*

As we can see, the recreational load significantly worsens the ecology of the coastal zone. However, the main reason for the modification and depletion of the resource potential of the lake Shalkar basin is a long period of low standing of its annual inter-soil level. In this regard, it turned out to be absolutely necessary to identify the reasons for the deterioration of waterlogging of the entire territory and shallowing of the lake in order to make economic decisions to improve the environmental situation in this region.

There are many reasons for the drop in the water level in the lake: natural cycles, fluctuations in the height of the Aral-Caspian shield, fluctuations in the level of the Caspian Sea, salt dome tectonics and internal karst processes, anthropogenic impact, etc. [36-42]. To clarify this issue, a coupled analysis of the dynamics of the water level in the lake was conducted. Shalkar, the Caspian Sea and in the soils of the Caspian lowland on the General background of changes in the moisture content of this territory. An amazing statistically significant synchronicity in the dynamics of these indicators was revealed, which indicates a common climatogenic nature of their occurrence [70-72]. The discovered regularity indicates that no other natural or anthropogenic causes determine the main trend of water level dynamics in the lake. Shalkar, including the impossibility of affecting this lake by the level of the Caspian Sea (~ -28 abs. m.), which in relation to it occupies a hierarchically subordinate position. In other words, hydrological fluctuation processes in water levels in reservoirs and soils occur due to climate change independently of each other. These processes are general, but non-linear due to local conditions. For example, the balance of ground water (arrival-flow) under different plant communities is affected by their different evapotranspiration capacity, and the balance of reservoirs may change due to water intake for household needs, as well as when constructing dams that intercept part of the spring surface runoff of meltwater.

The main input part of the water balance of lake Shalkar consists of atmospheric precipitation falling on its surface (less than 300 mm, which is equal to 30 cm of water column), and periodic surface runoff of spring meltwater from the entire basin area of about 4000 km^2, which can fill the bowl of this reservoir to the level of discharge of flood water into the river Ural on the Solyanka river. The expenditure part of the water balance mainly consists of evaporation from open water surface (900 mm) and the minor abstraction of water for domestic needs (watering of domestic animals, provision of settlements Saryomir, Chelkar, etc.). Note also that in the vicinity of lake Shalkar as of October 1, 2019 live 6,436 inhabitants were Shalkar, Ankaty, Aksogym and Shagatay rural districts of Terekti district of West Kazakhstan region and 4 rural districts, the total number of farm animals was 56,036 heads.

As you can see, to establish the optimal dynamic-equilibrium state of the water level in the lake, more than 600 mm of water (60 cm of water column) is required due to the flow of meltwater. Anthropogenic interference in this process is possible only by changing the capacity of the hydrographic network of the lake basin Shalkar. To fill the lake to the normal horizon (the threshold of the Solyanka river is 18.69 m according to the Baltic system, in high-water 1995 it was 17.8 m), it is necessary to cover the deficit formed in recent years, equal to 168 million m^3 (from 50 years of observations, 12 years are high - water, i.e. the level regime of the lake was then above average; 25 years - low-water years, i.e. the water level was below average, when the deficit was formed). Replenishment of the lake can only occur due to the flow of high-water rivers if the Yesen and Sholak Ankaty channels are fully opened, and water from the entire catchment area reaches the lake. In addition, it is desirable that the entire coastal zone of the lake (1000 km^2), which lies in a circle with a radius of 2 km, would be prepared for optimal snow distribution and surface runoff of spring meltwater. In this regard, it is obviously advisable to carry out economic measures to clean up water channels, including the demolition of unnecessary temporary dams and dams. However, it should be clarified that even these actions will not be effective in the long absence of such a flow.

We recommended a number of practical measures to improve the water quality of lake Shalkar to local Executive bodies (Fig.14). At the moment, some recommendations have started to be used by the authorities.

Figure 14 *- Measures to restore the water content of lake Shalkar: regulated spillway from the reservoir on the river Sholak Ankaty (a); clearing of springs (b); water supply from the Ural river through the Ural-Shalkar canal, the place of water intake (c); places where the Ural-Shalkar canal flows into lake Shalkar (d)*

Our survey of the catchment area of lake Shalkar, including the YesenAnkaty, Sholak Ankaty rivers and their tributaries of the Yersary Ankaty and Kuper Ankaty rivers has established that the only reservoir is a reservoir of 6.5 million m³ on the SholakAnkaty river, located 1.6 km from the village Toganas of Syrym district of West Kazakhstan region. A regulated spillway from this reservoir would have slightly replenished lake Shalkar. In November 2019, water from this reservoir was released into lake Shalkar (Fig.14 a).

We consider it necessary to clear bottom springs by carrying out selective mechanical cleaning and dredging on the rivers YesenAnkaty, SholakAnkaty and their tributaries of the rivers YersaryAnkaty and KuperAnkaty, which would also slightly add to the level of the Shalkar. In April 2020, the clearing of the spring located in the village of Saryomir, located on the shore of lake Shalkar (Fig.14b), was started.

In the case of water availability in the Ural river, it was recommended to recharge lake Shalkar by mechanical pumping along the Ural-Shalkar canal with a length of 76.06 km in a closed way through the system of a water conduit in pipes (Fig.14c). There is currently no water supply (Fig.14 d).

In the fisheries sector in lake Shalkar, we recommended to introduce a ban on fishing during the growing season with permission only for winter amateur fishing. Stocking the reservoir is not recommended at this time. In order to develop the tourist and recreational infrastructure and tourism industry, it is recommended to develop and sanitize the coastal and nearby territories of lake Shalkar.

Discussion

Water availability from surface water and shallow ground water depends on seasonal fluctuations and interannual variability of runoff, and reliable water supply is determined by seasonal volumes of low runoff. In pools with a predominant snow supply, higher temperatures lead to a decrease in runoff and, thus, to a reduction in water supply in summer [73]. Climate is an active factor that determines the overall moisture regime of the territory by the ratio of incoming and outgoing components-precipitation and evaporation, however, in relation to this study, the most important characteristic that determines the hydrological regime of the lake is the surface runoff of spring meltwater. The region shows an increase in the sum of positive air temperatures over the winter period, and this indicator is important both for the accumulation of snow and water resources and the passage of spring floods, and for the formation of underground water reserves that feed rivers in low water [74].

In the Caspian lowlands, periodic surface runoff of varying intensity in 1950-1994 is usually observed every 2-4 years, but it was completely absent in 1995-2009. It was during this long 15-year drainless period that there was a trend of permanent climatogenic lowering of the water level in the lake. Shalkar [70]. As we can see, the shallowing of the lake could not be stopped by anthropogenic intervention, except by increasing the incoming part of the water balance by taking the necessary amount of water from the river Ural. By the way, the lack of runoff during this period due to a gradual warming of the winter months, which prevents deep soil freezing, which is one of the necessary conditions for the occurrence of this process during rapid spring transition temperature of zero degrees [71,72]. As considers S. A. Long et al [75], scenarios of regional climate change on various models of General circulation of the atmosphere agree that the air temperature in Kazakhstan will continue to grow much. Note that the steady return of winter cold began in 2006, and in 2010-2011. there is a tendency to restore periodicity in the surface runoff of meltwater [72]. However, it seems that the incoming moisture was sufficient to maintain only the existing lake level in a dynamic equilibrium state, and not to increase it.

According to the weather station Zhympity, from 1955 to 2018, the average annual temperature increased by 1.6 ºC due to an increase in the temperature of the cold period of the year, which was 1.2 ºC, and the amount of precipitation in winter decreased by 6 mm. The warming of winter-spring is explained by the influence of the Atlantic on the thermal regime during the cold period. This leads to the frequent thaws and the absence of a stable snow cover. As a result, the spring runoff of meltwater in the lower relief does not occur, and the flow of water into the lake and the Sholak and YesenAnkaty rivers that feed it decreases. It should be taken into account that most of the precipitation in the region falls mainly in the warm season, but, as is known, the flow of rivers of the Kazakhstan type is formed by precipitation of the cold period. Precipitation of the warm period, although it does not have such a significant role (as winter) in the nutrition of steppe rivers, a significant reduction in their number cannot but affect the water content of rivers and lakes that feed on them, respectively.

Thus, it can be stated that the general lowering of the water level in lake Shalkar since 1995 has a climate-specific nature. At the moment, it is not clear what combination of processes can lead to the establishment of the desired structure and functions of lake Shalkar as a wetland when carrying out measures to restore it [14]. At the same time, it is possible to optimize the expenditure part of its balance by carrying out measures to increase the flow of meltwater, for example, clearing flowing water beams and small rivers, reducing the cost of household needs, as well as pumping the necessary amount of water from the river Ural in recent years.

Conclusions

On the Caspian lowland near Uralsk (Kazakhstan) lake Shalkar is located, which is a unique object for the semi-desert zone, a reserve of many species, including endemics, and, in addition, is intensively used as a recreational facility and watering place for farm animals. At the present stage, due to the lowering of the inter-level level of the lake, its ecological condition is deteriorating: the shoreline is removed from the thickets of reeds, which are a refuge for birds and a food base for fish; increase in water salinity that changes the development of zooplankton and zoobenthos; decrease in the biological diversity of fish, birds and other animals; degradation of coastal water vegetation, etc. The situation is complicated by the economic activity of the local population, which includes violation of sanitary standards for the location of livestock facilities near the lake and excessive overgrazing of farm animals in the adjacent pastures. Fishing activities have led to a decrease in the fish population, for example, the practical disappearance of commercial species such as bream, pike, roach, and the use of fishing tools in the form of small-mesh nets from fishing lines did not leave any chances for the young to grow and further spawn. The intense anthropogenic load on lake Shalkar is especially evident in areas where settlements, recreation and recreation areas are located, and agricultural animals are watered. To preserve and restore the biological diversity and general resources of lake Shalkar, it is necessary to optimize the use of land in socio-economic activities, taking into account the natural and climatic conditions of the territory and the capacity of the reservoir ecosystem.

However, it should be pointed out that the main reason for the gradual decrease in the water level in this lake is the steady warming of the winter months, which contributed to the absence of spring surface runoff of meltwater for 15 years (since 1995), which is the main supplier of additional water to this reservoir, along with precipitation falling on the open water surface. At the present stage, only after the restoration of periodic replenishment of the lake with a small amount of meltwater (since 2010), its sinking stopped with the establishment of a dynamic-equilibrium state of its inter-soil level. For optimal filling of the reservoir bowl, much more water volumes are needed. In the future, it is necessary to take measures to improve the surface water flow by clearing the streams that flow into this reservoir (gullies, eriks, small rivers), and in critical periods, to provide artificial replenishment from the river Ural.

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БАТЫС ҚАЗАҚСТАНДАҒЫ ШАЛҚАР КӨЛІНІҢ СУ ЖӘНЕ БИОЛОГИЯЛЫҚ РЕСУРСТАРЫНА КЛИМАТТЫҢ ӨЗГЕРУІНІҢ ӘСЕРІ

Аңдатпа. Қазақстан Республикасының аридті Каспий маңы өңірінде орналасқан **(**50°33′ с.е. және 51°40′ ш.б.) Шалқар көлінің биоалуантүрлілігінің климатогендік өзгерістері және ресурстық әлеуеті қарастырылады. Су деңгейінің жыл сайын екі метрден астам (1995 жылдан бастап) біртіндеп төмендеуіне байланысты осы құнды табиғи объектінің жағдайының нашарлауының себептері мен салдары талданады, ол кейіннен 16 м төмен белгіде тұрақтанды. Биогеографияда, гидрологияда, зоологияда және ихтиологияда жалпы қабылданған әдістер су және су маңындағы экожүйелердің биологиялық әртүрлілігіне ең үлкен зиян қамыс қопаларынан жағалау сызығының шегінуіне, сондай-ақ 2012-2019 жылдары судың минералдануының 5-тен 12 г/л-ге дейін артуына әкелгені анықталды. Уылдырық шашатын жерлер мен азық-түлікбазасыныңнашарлауынабайланыстымұнда 2018-2019 жылдарыбалықтың тек 7 түрі қалды, ал 1998 жылы олардың 19 түрі болды, олардыңекеуі көлдің эндемиктеріболды. Егер он жылбұрынбалықтыңжалпықоры 936,1 тоннанықұраса, қазір – бар болғаны 142,9 тонна. Өнеркәсіптікаулаутабан, шортан, тортаныңтолықтай жойылуына әкелді. Су маңындағықұстардыңұя салу жәнеұшужағдайларыныңнашарлауынабайланыстыолардың саны 1998-2019 жылдары 55 – тен 45-ке дейін, ал Қызылкітапқаенгендер 12-ден 4-ке дейіназайды. Жағалау аймағындағы экологиялық жағдай үй жануарлары санының көбеюіне және бақыланбайтын демалысқа байланысты одан әрі нашарлайды. Шалқар көлінің бассейнінде табиғатты пайдалануды оңтайландыру әдістері ұсынылады.

Кілт сөздер: Каспий маңы ойпаты; Шалқар көлі; таяздау; минералданудың ұлғаюы; қамысқопалары; биоалуантүрліліктің азаюы; рекреациялық жүктеменің ұлғаюы; климат; гидрохимия; балықтар; Қызыл кітап.

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ВЛИЯНИЕ ИЗМЕНЕНИЯ КЛИМАТА НА ВОДНЫЕ И БИОЛОГИЧЕСКИЕ РЕСУРСЫ ОЗЕРА ШАЛКАР В ЗАПАДНОМ КАЗАХСТАНЕ

Аннотация. Рассматриваются климатогенные изменения биоразнообразия и ресурсного потенциала оз. Шалкар, который находится в аридном Прикаспийском регионе Республики Казахстан (50°33′ с.ш.и 51°40′ в.д.). Анализируются причины и последствия ухудшения состояния этого ценного природного объекта из-за постепенного ежегодного понижения уровня воды более чем на два метра (с 1995 г.), который в дальнейшем стабилизировался на низкой отметке 16 м. Общепринятыми в биогеографии, гидрологии, зоологии и ихтиологии методами выявлено, что наибольший вред биологическому разнообразию водных и околоводных экосистем нанесло отступание береговой линии от камышовых зарослей, а также увеличение минерализации воды в 2012-2019гг. с 5 до 12 г/л. Эти изменения привели к уменьшению видового разнообразия и обилия зоопланктона и зообентоса. Вследствие ухудшения мест нерестилищ и кормовой базы здесь в 2018-2019 гг. остались только 7 видов рыб, тогда как в 1998 г. их было 19 видов, два из которых были эндемиками озера. Если десять лет назад общие запасы рыб составляли 936,1 тонн, то сейчас – всего 142,9 тонн. Промышленный отлов привел почти к полному исчезновению леща, щуки, плотвы. В связи с ухудшением условий гнездования и пролета околоводных птиц, их численность сократилось в 1998-2019 гг. с 55 до 45 видов, а краснокнижных – с 12 до 4 видов. Экологическая ситуация в прибрежной зоне еще более ухудшается вследствие увеличения количества домашних животных, и неконтролируемой рекреации. Предлагаются методы оптимизация природопользования в бассейне всего озера Шалкар.

Ключевые слова: Прикаспийская низменность; озеро Шалкар; обмеление; увеличение минерализации; камышовые заросли; уменьшение биоразнообразия; увеличение рекреационной нагрузки; климат; гидрохимия; рыбы; Красная книга.