The Promise for Freshwater Biodiversity Conservation in Central Asia: Focus on the Aral Sea Basin

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Although the Central Asia subregion is biologically diverse, it suffers from many environmental problems and is the most degraded area of the former Soviet Union. During the second half of the twentieth century, the natural environment of Central Asia has changed dramatically. The areas under grain and cotton production expanded far beyond the traditional boundaries of the ancient irrigated oases. These changes were exacerbated by the large scale development of oil, natural gas, iron, and copper, as well as the rapid expansion of the cities and industrial settlements. A massive system of irrigation was created, stretching for thousands of kilometers and accompanied by a vast network of hydroelectric stations and reservoirs (IUCN, 2004).

The meteorological monitoring conducted during more than 100 years in the region has shown the positive trend of air temperature, and thus, allow us to conclude that tendency to climate warming is observed within all territories of the region either in the cold or in the warm half of the year (Fig. 1).

Central Asia has experienced similar air temperature trends to those observed at global and regional scales. Thus we can conclude that regional climate change reflects global warming trends (Fig. 2).

The assessment of the possible changes in the air temperature in the climatic zones of Uzbekistan and adjacent mountain territories for the scenario of the emission of greenhouse effect has shown that till 2030 the most significant effect of global warming can be expected in the north-western parts of the republic. Moving south, the effect becomes weaker; the weakest effect will be observed in the adjacent mountain areas. Empiric statistic evaluation of the average annual temperatures recorded the annual changes as being between 1-3°C.

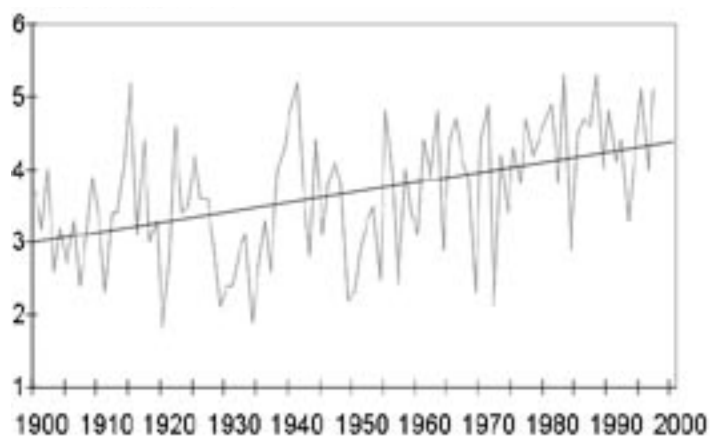

Fig. 1: Annual average air temperature of Tashkent (Uzbekistan) during 1900-2000.

The increase of the winter temperatures varies also from 1 to 3°C. Outside Uzbekistan, in the southern regions of Central Asia, the forthcoming warming does not exceed 0.5°C in summer and 1°C in winter. In the high mountain vast depressions of Tien-Shan and Pamir-Alay, the summer warming reaches 1°C and winter warming reaches 2°C. The autumn warming in the depressions is commensurable with the levels of the plains.

According to the natural climate conditions in Central Asia the most typical regional ecosystems were desert ecosystems of the plains, semi-deserts and steppes of the foothills, river and coastal ecosystems, wetlands, and mountain ecosystems.

Each of these ecosystems presents a complex of natural components that determine the development and functions of plants and animals associations. Ecosystems of the plains occupy more than 70% of the territory, and mountains stretch over other areas where the main river runoff forms (Shults, 1958; Talskykh, 2001). In the case of the warmth (heat) abundance in the arid zone, the limiting factor for the development of natural ecosystems in the region is water resources. Therefore, the rich and productive regional ecosystems basically were located in the flood-lands and deltas of rivers (Chub et al., 1998).

The mountain area of Central Asia, with its diverse precipitation distribution (60 – 2,500 mm per year), has 3.5 times more water resources than the flat (plain) areas. It gives these resources to lower plains - basically, as surface runoff - where intensive dispersion and evaporation take place. The territorial connection between desert, steppe areas, and water-bearing rivers cutting through them results in the development of intensive use of these rivers for irrigation purposes in the dry plain areas. Thus, economic activity of human societies has been the main factor leading to changes in the rivers runoff since the ancient times.

The different trends of the flowing processes in the mountains and within the plains gave grounds (Shults, 1958; Agaltsova & Borovikova, 2002), in Central Asia, to the selection of the area of flow formation, corresponding the mountain elevations and area of drainage (flow) dispersion where the flow use for irrigation and evaporating occurs.

Climate changes and possible consequences on water resources

The current climate change leads to the activation of global hydrologic circle and essentially influences the regional water resources. The conditions of the formation of water resources are changed, resulting in changes to the rectangular components of the water-balances in the river basins and types of river supplies. The data of long-term periods of hydro-meteorological monitoring in the region has shown that the current global warming is apparent in Central Asia. The trends of some components of the hydrologic circle, such as the increase of evaporation layer, decrease of snow accumulation, and significant decline of the mountain glacial forms, are observed (Fig. 3).

The calculations realized on the mathematic model of the water flow forming under the condition of various scenarios of climate change indicate that in the considered diapason of climate parameters changes during the next 20-30 years the water resources' changes will not be very evident. However, in the condition of climate warming, the average discharges of water for the vegetation period will decrease. The possible changes of flow in this period will vary naturally from +3-10 to -2-7%. The change of annual inflow of the main rivers of Central Asia – the Amu Darya and Syr Darya – can differ significantly under various scenarios of climate change (Fig. 4).

Fig. 2. The changes of average annual global air temperature and air temperature at the stations of Uzbekistan and 10-year slippery average values.

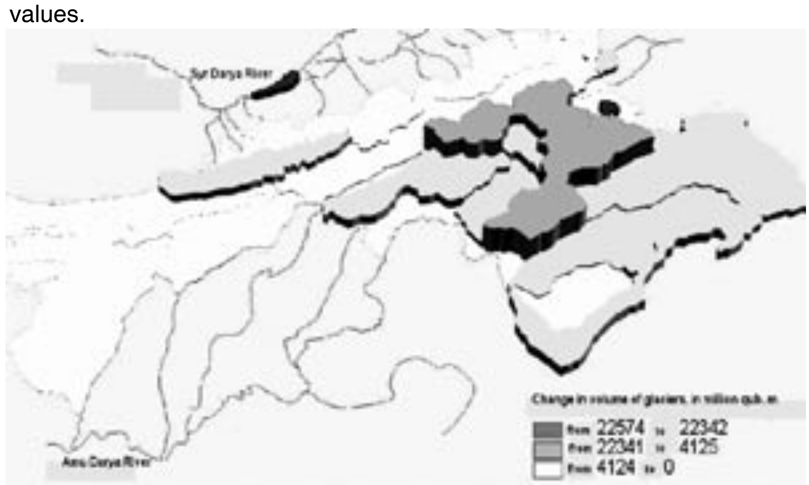

Fig. 3. Changes of the Pamir-Alay glaciation extent during second part of 20 Century.

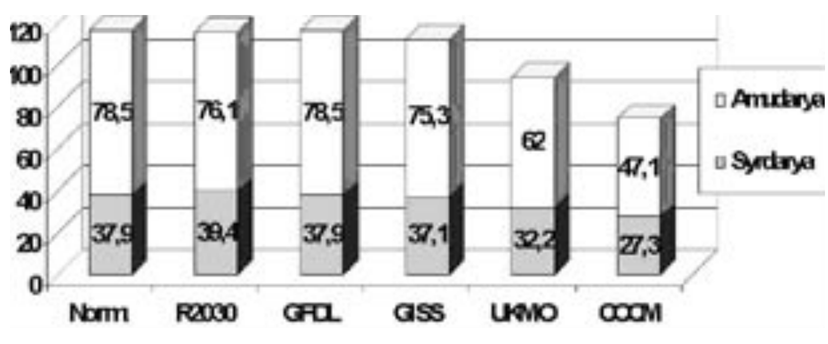

Fig. 4. The annual runoff of the Amu Darya and Syr Darya Rivers under various climate change scenarios: CCCM – The model of Canadian Climate Centre, spatial resolution - 2,22° in latitude and 3,75° in longitude; UKMO - The model of UK Meteorological Bureau, spatial resolution - 2,5° in latitude and 3,75° in longitude; GFDL-The model of the Laboratory of Geophysical Hydrodynamics, USA, spatial resolution - 2,22° in latitude and 3,75° in longitude; GISS - The model of the Goddard Institute of space research, USA, spatial resolution - 7,83° in latitude and 10,00° in longitude.

Role and essential features of the inner freshwaters

Most parts of Central Asia are located in the arid zone within the area of inner drainage of the Aral Sea basin. The water resources of this territory are constituent part and regulators of all terrestrial and aquatic systems with interaction of main elements of hydrological circle and concomitant migration of chemical substances. Water resources of the region present the base for the sustainable survival of natural and ameliorated environment, and play an important role in social economic life of local human populations. The peculiar properties of hydrologic circle, the basin of the Aral Sea is divided into areas of formation, dispersion and transit of drainage that mainly corresponds with mountains, foothills and flat territories. The most distinctive peculiarity of the hydrograph network and water resources of the region is their extremely uneven distribution within the territory. For most parts of the plain area, the layer of atmospheric precipitates does not exceed 100 mm per year. Under the condition of potential possible evaporation of 1200-1800 mm per year, the drainage is not formed from this territory.

According to the orographic, hydrographical, and geomorphological peculiarities, the territories in Central Asia are divided to two large areas with principal distinctions. These include the plain area, which occupies almost 70% of the territory where there are no rivers; and the mountain area where all rivers are generated for the whole region. The main origin of forming of water resources, as everywhere, is the moisture borne by air. In average, over Central Asia about 2,700 km3 of water are transferred with air masses per year. About 490 km3 of water fall on the territory as atmospheric precipitation. In the Central Asian region, there are 89,000 rivers and about 5,900 lakes (Table 1). According to data of N.L. Korzhenevsky, the density of river system in the mountains of Central Asia is 0.617 km/km², and in the plains is 0.02 km/km². The value of water resources in the region has been estimated several times by different scientists on the basis of observation material for the gauging-station network in hydro-meteorological services of the region. Nowadays, it could be concluded that the value of surface water resources of Central Asia has been determined quite precisely.

Origin and estimations of freshwater resources

Water resources of rivers are generated in mountain systems of Tien-Shan and Pamir-Alai due to thawing of seasonal snow, glaciers and atmospheric precipitation. In the states of Central Asia, the majority of water resources are formed in Tajikistan (36%) and Kyrgyzstan (34%); water resources forming in Uzbekistan and Turkmenistan do not exceed 8.03% of the region's water resources. Kazakhstan is responsible for the formation of only 5% of the water in the Aral Sea basin.

In accordance with the type of water supply, which depends on prevalent height of the catchments basin, all rivers of Central Asia are divided into 5 categories (Table 2). These categories define rivers' water content, hydrological and temperature regimes, and other ecological features and peculiarities.

As it was mentioned above, the largest part of Central Asia is located in the area of the inner drainage of the Aral Sea basin where the main river runoff concentrates in the biggest trans-boundary rivers of Amu Darya and Syr Darya. The largest in terms of water content is the basin of Amu Darya River. Its total catchment area in the zone of flow forming, including the drainage areas of Zaravshan and Kashkadarya rivers, occupies 227,300 km² and provides the plains with about 79 km³ of water. The catchment area of Syr Darya River is estimated at 150,100 km² with river flow of about 38 km³ (Shults, 1958). The lakes are mostly located in the valleys of the rivers. They have various origins: the mountain lakes usually descend from stone obstructions or glacier origin, and the plain water-bodies in the last decades mostly are formed (generated) by drainage waters. These are the drainage-overflow (secondary or man-made) lakes, which are widely distributed either over the same places of former natural lake systems, supplied by river waters, or, to a greater extent, over secondary artificial water reservoirs formed in the last 20-40 years in the depressions of landscape as a result of break flood or drainage flow from the irrigated areas (Gorelkin et al, 2002; Gorelkin,

Table 1. Distribution of rivers and lakes in the main regions of Central

River basin, region/ number of water bodies	Rivers		Lakes	
	Total	Length > 10 km	Total	Area > 1.0 km²
Amu Darya	40999	1787	2619	129
Syr Darya	29790	1907	1405	65
Talas	3632	276	467	23
Chu	5244	491	506	38
Sarydzhaz (Chinese Aksu)	4495	214	260	4
Issyk-Kul Lake	1976	134	183	20
S. Turkmenistan	2972	167	211	42
Total:	89018	4978	5961	321

Table 2. Types of river supply in Central Asia

Prevalent type of supply	Characteristic features
1.Glacier – snow	Full- owing and cold-water rivers with extended ood having the peak in s`ummer-autumn and summer vegetation period. They have the weak development of water biota and comparatively high stagnancy related to climatic factors.
2. Snow – glacier	
3. Snow	Intermediate type with spring-summer more short period of ood and less stagnancy related to climatic factors.
4. Snow-rain (pluvial)	Rivers containing little waters with short period of spring ood, intensive summer warming-up of the water mass, and good or abundant development of water biota. They are sensitive to change in climatic factors, and characterized by pronounced seasonality of hydrological and biological phases during the year.
5. Ground-rainy (pluvial)	Rivers and streams containing little waters with very short spring ood period, abundant development of water biota, and prevalence of the heterotrophic components in the structure of water biocenoses. They are extremely sensitive to change in climatic factors and state of adjacent terrestrial landscapes.

1988). Their overall volume in the basin of Aral Sea exceeds the volume of all water reservoirs (Gorelkin, 1988). So, at present, the water resources of the region are presented in average by 113.3 km^3 per year and collected in the two biggest basins of the Amu Darya River (73.5 km^3) and Syr Darya River (38.8 km^3) (Table 3). The area of ice (frozen area) in the basins of these rivers is 16.6 thousand km^2. The volume of ice in the glaciers of Gissar-Alay is estimated at 88 km^3, and in the glaciers of Pamir at 465 km^3. The amount of water in the mountain lakes of Amu Darya basin is 46.6 km^3, and in the lakes of Syr Darya basin is 5.6 km^3. The lakes mainly are located in the valleys of rivers. Mountain lakes generally are defined as having goaf and glacial origin, but the lakes of the plain area are formed by drainage water. The irrigation-overflow lakes are formed on the edges of the irrigated lands in the natural falling of relief. Such lakes as Aydar-Arnasay-Tuzkan, Sarykamysh, Dengizkul, and Kamashlybash in their existing sizes were generated from drainage waters at places of local depression. The volume of water in the lakes of plain territory, not including the Aral Sea, is approximately 70 km^3. In the last 60-70 years, the natural regime of drainage in Central Asia was distorted by the diversion of flow for arable irrigation, replenishment of water reservoirs, and discharge of drainage waters. Within the area of Central Asia, 98 water reservoirs, which are still functioning today, were built. The biggest of them allows regulating the long-standing water flow in the Syr Darya basin and the seasonal water flow in the Amu Darya basin.

The abundance of solar energy and presence of the vast plain areas determined the intensive development of irrigated farming (arable agriculture). In connection with this, the demand on water resources, especially in the middle of the 1960s, increased sharply and water consumption tripled (Crisis of Aral, 1995). From the total water inlet in Central Asia (117.7 km^3 per year), 108.4 km^3 or more than 90% of water resources are being used in the zone of intensive water consumption. For the satisfaction of the needs of the growing agriculture and human population in the basin of Aral Sea, the complicated irrigational economy from connected natural water currents, artificial water reservoirs, integral water-intake station and arable channels of the drainage system was created (Talskykh, 2001). However, due to low efficiency of the majority of water facility systems, enormous irrevocable loss of water exists (Environment 2003). In the basin of the Aral Sea, a system for the regulation of the river flow was created. The system included the significant number of channel basins and water reservoirs with a volume of 60 km^3, 33.4 km^3, which belong to the water reservoirs of the Syr Darya basin with a river discharge of about 38 km^3 per year almost completely regulated runoff (Table 4).

Water quality

In general, the quality of river waters based on integral biological indexes (25, 35) is still high (very pure or pure waters) with mineralization ranging from 89-309 mg/l to 420 mg/l. Specific contaminants, such as heavy metals, phenols, oil products, and pesticides do not exceed or slightly exceed MPC (Maximum Permissible Concentration). Therefore, the quality of the water allows its use without any limitation for all sorts of water consumption. In this context, this water is used widely in the lower oases, even for drinking purposes. The river systems of the flow forming zone are significant for their biosphere importance; being the original centers of mountain landscapes that support the balance of the terrestrial ecosystems. However, the processes of degradation, such as disafforestation and soil erosion, overgrazing, and waste pollution,

Table 3. Water resources (km³/year) of the rivers in Central Asia

River basins	Average multiyear discharge, m³/sec	Annual ow volume, km³/year		
		Average	Max.	Min.
Amu Darya basin:				
Pyandzh	1140	35.91	-	-
Vakhsh	661	20.8	27.60	16.2
Kafirnigan	187	5.89	9.81	4.09
Surkhandarya and Sherabad	127	4.00		
Kashkadarya	49.0	1.56	2.72	0.897
Zerafshan	169	5.32	6.86	3.81
Subtotal:	2334	73.50	-	-
Syr Darya basin:				
Naryn	448	13.8	2.34	0.817
Fergana valley rivers	401	12.8		
The rivers of the northern side of Turkistan ridge towards the west from Fergana valley	9.63	0.30	0.446	0.225
Akhangaran	38.5	1.22	3.04	0.557
Chirchik	248	7.82	14.15	4.53
Keles	6.67	0.21	0.507	0.088
Arys	64.2	2.02		
The rivers of the southern-western Karatau ridge	21.1	0.663		
Subtotal:	1237	38.83		
Kyrgyzstan:				
Talas	68.0	2.14		
Chu	137	4.33		
Issyk Kul Lake	118	3.72		
Sarydjaz (Chinese Aksu)	225	7.07		
Subtotal:	548	17.26		
Turkmenistan:				
Atrek	9.85	0.30		
Tedzhen	27.0	0.85	0.530	0.093
Murgap	53.3	1.68	2.60	0.373
The rivers of the north Kopetdag ridge	10.4	0.33		
Subtotal:	101	3.16		
Total:	4219	132.77		

are increasing in the mountains. The zone of intensive flow consumption shifts to the flow forming zone due to expansion of urban settlements and recreational zones.

In the zone of water flow forming the absolute majority of the rivers, lakes, and water reservoirs are characterized by high water quality, although in the inland basins salty (Issyk-Kul and Karakul) and salty lakes (Rangkul and Shorkul) exist. In the glacier zone, the water-mineralization is 100-150 mg/l, in the middle zones of mountains it is 200-300 mg/l, in some foothill places it can reach 500 mg/l. Content of specific pollutants (oil products, metals) does not exceed or slightly exceeds the MPC (Maximum Permissible Concentration). In general, the quality of water in the region is suitable for the basic types of water consumption. However, in the last years, the dangerous trend of a biological intensification processes (eutrophication) was noted. This trend, which is possibly due to recreation load increase and to the drawing of water from small rivers without control, has resulted in the deterioration of water quality.

The quality of national and trans-boundary waters in the consumption zone of water flow, under the influence of regulatory processes and anthropogenic pollution, is bad. The transformation of water flow quality is more evident in the increase of mineralization levels in the river courses. Increase of mineralization is connected with concentration of all mineral components downstream. The most significant changes occur below the big collectors flowing into the rivers. During the past ten years, the following tendencies concerning change of superficial water quality were noted:

- Stabilization of the mineral composition and delay of mineralization growth;
- Decrease of general level of organic pollution and level of saprogenity of currents, as the average annual concentrations of ions of pollutants (nitrates, oil products, pesticides, phenols, and metals) in the zones of increased anthropogenic influence, which is connected with the decreasing of technologically outmoded (obsolete) plants and with high-water levels by the end of 1990;
- Increase of water eutrophication of the small and medium rivers in the mountain -foothills belts as a result of urbanization and recreation processes.

Ecological risks related to the use of water resources and natural events

Among the possible negative influences of water resources on humans' sustainable development and biodiversity conservation are the spontaneous hydro-meteorological events, particularly the catastrophic floods, mudflows, and water-breaks, including breaks of mountain lakes. In Central Asia, 23 large mountain lakes can be broken by water as a result of unexpected natural events; the Sarez Lake is the biggest among them. The problem facing Sarez Lake is its possible break through of the natural Usoy dam. In case of its failure, a catastrophic flood will occur in the valleys of the Bartang, Pyandzh, and Amu Darya rivers. It is estimated that the flood will affect as area of 69,000 km^2 in Tajikistan, Uzbekistan, Turkmenistan, and the Islamic Republic of Afghanistan, with a total population of 6 million people. The height of the wave could reach from 17 to 34 m, and all objects of human settlements, agricultural lands, vegetation, and animals would be annihilated in this case. Lake Sarez was formed on February 18, 1911 as a result of 9- to 10-point (Richter scale) earthquake, which caused a 2.2 cubic kilometer ground mass to hang over the Murgab River valley. Water in the lake is fresh; its volume is 18 km^3. Its surface area is 86.5 km^2, and its length is 80 km with a maximum width of 3.68 km. The average depth of the lake is 200 m, and its maximum depth is 505 m. Lake Sarez is situated at the altitude of 3,252 m above sea level, and this a significant danger because in the event of breakthrough such a large amount of water flowing down from the altitude of over 3,000 m will create a powerful torrent with a high velocity, destroying everything along its course. From 1913 to 1995, the water level raised about 187 m. At present, the volume of water in Lake Sarez is still increasing. Due to water seepage through Usoy natural dam, water upwells up in springs, which have formed a canyon 2 km long and 30-35 m deep in the downstream of the Usoy dam. Flow rate through the Usoy dam is 44.6 m^3/sec. The unstable regime of Sarez Lake in the twentieth century and possible future changes caused by the global climatic changes require greater attention to the hydro-meteorological aspects of the Sarez Lake problem, particularly to urgent restoration and development of adequate hydro-meteoro-

Table 4. The volumes of the water reservoirs in the basin of Syr Darya River

Water reservoirs	Country	River	Total amount (km^3)	Useful amount (km^3)
Toktogul	Kyrgyzstan	Naryn	19,5	14,0
Chardara	Kazakhstan	Syrdarya	5,2	4,7
Kairakum	Tajikistan	Syrdarya	3,4	2,5
Andizhan	Uzbekistan	Karadarya	1,9	1,75
Charvak	Uzbekistan	Chirchik	2,0	1,6
Others			1,4	1,2

logical monitoring system.

Transformation of the Aral Sea basin as a result of human activity

The intensive developments in the region during the second half of the twentieth century led to considerable changes to hydrological and hydro-chemical regimes of water surfaces causing many ecological problems. Numerous investigations have been carried out leading to the assessment of the influence of anthropogenic factors on the regimes of rivers, canals, collectors, lakes, and water reservoirs. Especially in the basin of the Aral Sea the changes had multi-scaled consequences (Fig.5), because the redistribution of water has resulted in change to the region's water regime as a whole. At present, the water resources of the region are being used by all states of Central Asia. The annual water intake is 80-100 km^3. The general water consumption falls to the share of arable agriculture. Constructed water facilities, including 94 water reservoirs, 24,000 km of channels, and 8,000 stations of vertical drainage, support the irrigation in a 7 million-hectare territory. With development of irrigation the portion of secondary or recycled waters increases. They are represented by amounts of collector-and-drainage waters and discharge of drainage from irrigated territories, manufacturing, agricultural, and communal-general waters. Collector-and-drainage and discharge of irrigated waters are presented annually on average by 42.7 km^3 (about 40 % of river drainage). 9 km^3 out of this amount is not going back to the river-beds, but is taken outside the irrigated areas and used for the supply of irrigated drainage (human-made) lakes and wetlands. In the desert areas, where transit waters, channels, and collectors are absent, the general sources of water are the underground waters and atmospheric moisture forming the ephemeral (recurrent) water reservoirs and water flow (water-streams). The total annual potential of underground water resources is estimated at 31.5 km^3, 12.98 km^3 of which are approved for use. The water supply in lakes and wetlands of the flat territories (without Aral Sea), according to information in 2000, is 65 km^3. The high changeability (unsteadiness) and long-term fluctuations of water resources elements, hydro-chemical regime, and water quality are typical for the Central Asian region. In the little water periods of the recent years, the flow of the Amu Darya and Syr Darya rivers has not reached the Aral Sea.

Impact on freshwater biodiversity

The biological diversity of the region reflects the region's various landscapes and ecological conditions, and is relatively high for this geographical zone. There are 2,500 species of bacteria and about 3,000 species of fungi. Also plants in Central Asia are diverse, including more than 8,000 species with about 6,000 species growing in the mountains and more than 3,000 growing within the plains. Diversity of invertebrates is extremely high – about 20,000 species, and vertebrates in the region include about 1,000 species (these include about 120 fish species, 15 amphibian species, 103 reptile species, about 600 bird species, and about 160 mammal species).

Intensive irrigation and agriculture underlies land use in Uzbekistan and Turkmenistan. Irrigation has dramatically changed the ecological situation in many regions, rendering the survival of many desert animals impossible under the new ecological conditions. Changes in the valleys of great plain rivers also have led to the decline of tugai forests that were cut down or degraded as a result of the decrease in water flow. Owing to these changes and to direct threats from human activities, the ranges of Bukhara Deer, a local endemic pheasant subspecies, and other inhabitants of river forests have shrunk. As a result of extensive hydrological construction, salinization, and dropping of the level of the Aral Sea, the native ichthyofauna became extinct and several species of molluscs and crustaceans are nearing extinction. Likewise, regulation of the great rivers' water flow, appearance of new water reservoirs, wide development of irrigation networks, industrial pollution of water areas, mountain mining and exploitation of upper reaches of rivers, and the influence of introduced species of fishes, all have negatively affected the existence of many species of the original

Fig. 5. Scheme of the Aral Sea basin and its boundaries.

ichthyofauna and malacofauna. Owing to changes in ecological conditions in the Aral Sea region, the wetlands in the deltas of the Amu Darya River have lost their richest avian diversity. The breeding habitats of Mute Swan, Dalmatian and Great White Pelicans, Pygmy Cormorant, and other threatened bird species have declined noticeably.

The Aral Sea and its biodiversity

The Aral Sea, which had once ranked fourth in size in the world, has been drying up for the last four decades. By the year 2002, the Aral Sea had lost 4/5 of its primary capacity, its surface area had decreased to less than 1/3 the original area, its water level had dropped to 22 m (Fig. 6), and the salinity of its water had increased by 6-12 times. Furthermore, the Aral Sea deviated some 100-150 km from its previous shores, leaving behind over 45,000 km^3 of former seabed that turned into salty desert. Over 100 million tons of salty dust are blown far from the Aral Sea by winds annually. In the years with little amount of water the flow of rivers does not reach the current sea shores. By the end of 2002, the Aral Sea had been divided into three water reservoirs: the "Small Sea" having a surface area of 3,000 km^2, a capacity (volume) of 20 km^3, and a salinity of 18-20 g/l; the eastern part of the "Large Sea" having a surface area of 9,150 km^2, a capacity (volume) of 29.5 km^3, and a salinity of 120 g/l; and the western part of the "Large Sea" having a surface area of 4,950 km^2, a capacity (volume) of 79.6 km^3, and a salinity of 80 g/l (Fig. 7).

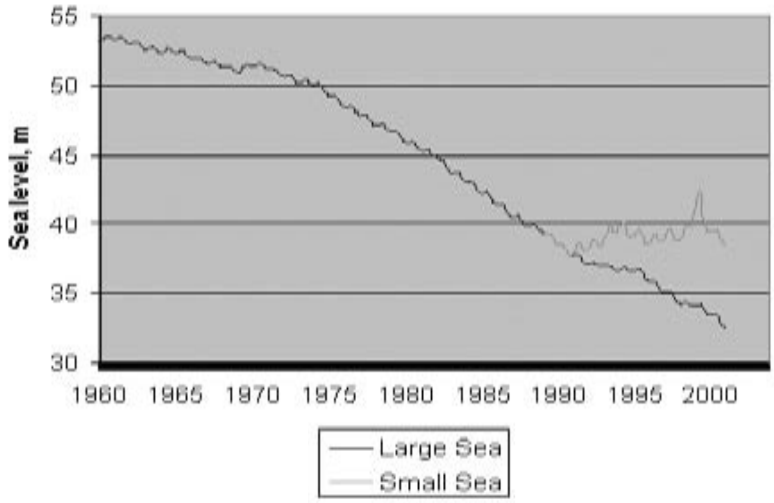

Fig. 6. Changing of Aral Sea level during 1950 - 2000.

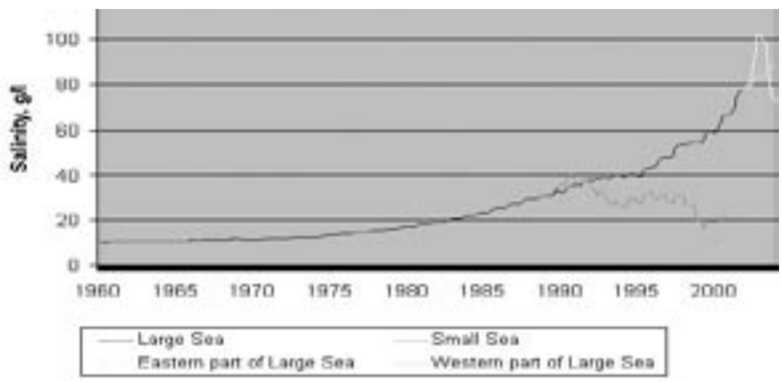

Fig. 7. Changes in the salinity of Large and Small Aral Seas during 1989-2001.

The inflow of the river waters in the deltas decreased about 5 times in the last 40 years. At the same time, the ratio of drainage waters increased. The average annual water discharge in the delta in the conditionally natural period was 1,060 – 2,090 m^3/sec. Between 1960 and 1970, these figures decreased to 850-1000 m^3/sec (excluding the extraordinary abundance in water in 1969, when the inflow to the delta was 2,090 m^3/sec). The lowest water supply was observed between 1980 and 1990 (Fig. 8). In the 1990s, the years of high water resources, water supply of the river flow into the delta increased by 10-15%. The change in the character of the Aral Sea configuration between 1964 and 2002 is presented in (Fig. 9).

Decrease of water supply considerably decreased the density of water reservoirs and wetlands and diminished their areas. By the middle of 1970, the majority of the lakes, supplied by river waters, dried up (Fig. 10).

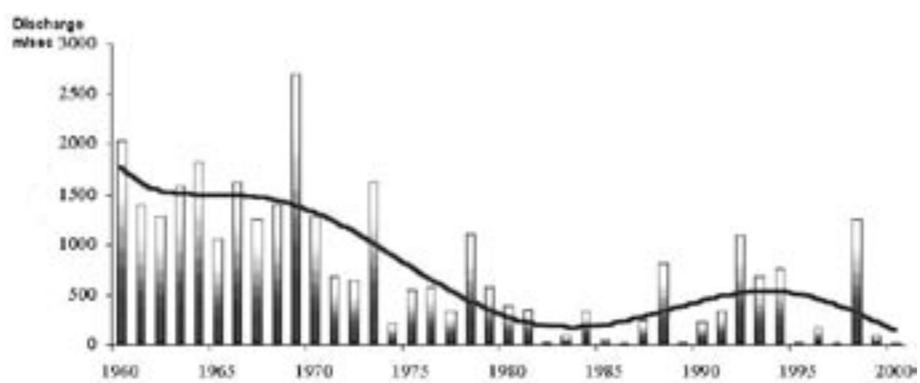

Fig. 8. Dynamics of in ow to delta of the Amu Darya River during 1960-2002.

Since 1980, work has been conducted on the supporting of irrigating-drainage lakes and on the creation of new water reservoirs, supplied by river and collector-drainage waters, in the recent delta and at the bottom of the Aral Sea. In the region of Shegekul Lake, the Mezhdurechenskoe water reservoir was built. Many breaks of dams and main bank have caused the flooding of the Dumalak Lake, forming the new ways for the flow of Amu-Darya River waters to the Aral Sea. The important direction of strategy is the work on restoration and rehabilitation of the Sudochie wetland. As a result of the conducted work, the summed area of the lakes reached 3,000 – 4,000 km^3 by

1990. However, to date, the area of the delta has increased by 40%, and the sum of lakes covering has not reached its past figures.

Significant and impetuous changes to the hydrologic regime of the Aral Sea (speed, scale, and problems of transformation of the sea regime and environment followed this process) reflected on the ecological state of the whole region, particularly on the status and survival of plants and animals (Tables 5-8; Figs. 11-13). The Aral Sea lost its fishing value. Many species of flora and fauna disappeared or were depressed. This phenomenon requires the detailed quantitative assessment of its temporary states, analysis of ongoing processes, and estimation of influences on the environment of the region. The tremendous changes brought about to the Aral Sea ecosystem currently have no analogues, and only can be compared to the evolutionary transformation of the salty paleo-water-reservoirs. The current crisis of the Aral Sea ecosystem resulted in the extinction of fauna and flora which preceded the explosion of speciation in the geological past. Impact of the current regression of the Aral Sea on its fauna is similar to the impact of the regression of the marine and salty paleo-water-reservoirs on the conditions of the ancient marinelife. The current state of this sea allows the natural laboratory to observe the evolutionary processes within the separate taxa and the whole ecosystem. The universe character of the transformation permits discussing the current evolution of the Aral Sea ecosystem as a global biota evolution model.

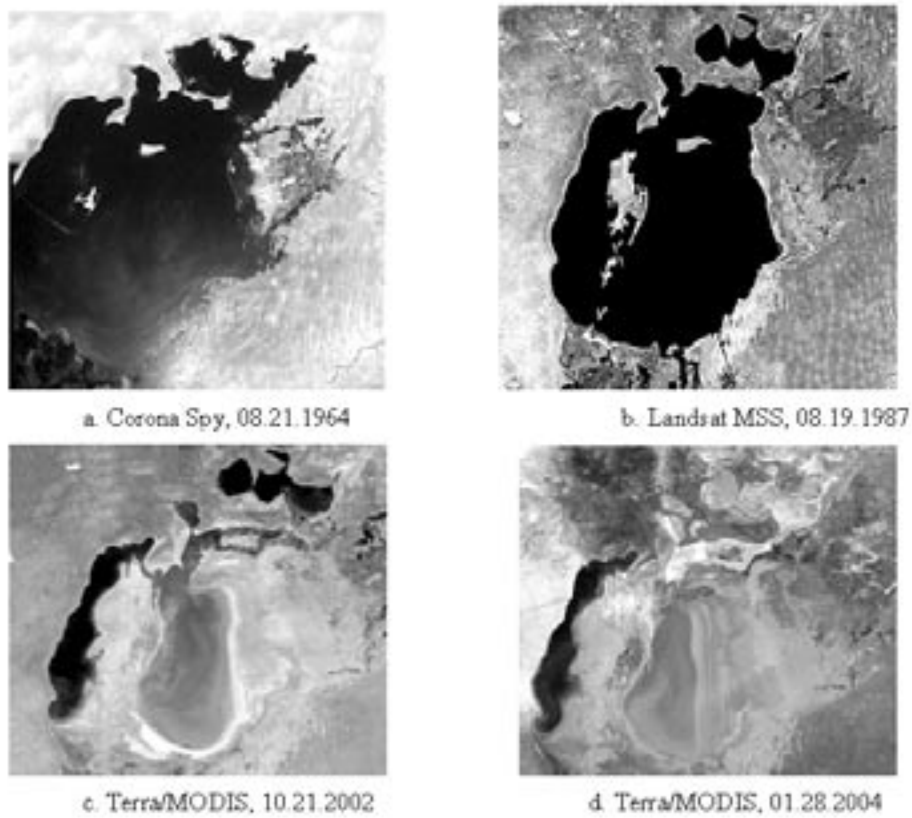

Fig. 9. Change of Aral Sea surface during 1964 – 2004 (a-d: satellite photo).

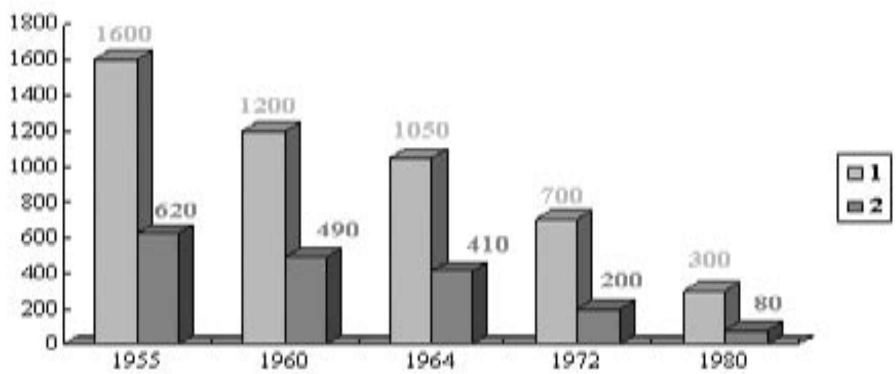

Fig. 10. Ratio of total square of river waters feed lakes in Amu Darya delta and water in ow to the delta top during 1955-1980: 1- water supply to the delta, m^3/sec; 2 - total square of lakes in delta, km^2.

Threatened biodiversity

Freshwater Biodiversity is affected and threatened by large-scale development and transformation of the inner water resources. At present, the Red Books of the Central Asian countries of the region list 30 species of fishes, 4 species of amphibians, 54 species of reptiles, 99 species of birds, and 79 species of mammals (Table 9). It is necessary to note that one of the main threats to the biodiversity of the region is the transformation of water ecosystems (besides the direct persecution of animals), which has led to the loss of unique ecosystems in the region, such as the gallery river forests ("tugai") with their original fauna and flora. Some animals were lost as a result of direct and indirect human influences, habitat loss, and deterioration. For example, in 1954, the last Caspian Tiger was killed in the "tugai" forest in Amu Darya River near Nukus town in Uzbekistan. This subspecies of tigers has disappeared not only because of the direct human persecution, but also, and perhaps mostly, as a result of the destruction of the gallery river forest and the drying up of reedbed areas along the Amu Darya and Syr Darya rivers. The Bukhara Deer is another large mammal occurring in the gallery river forests of Central Asia that is nearing extinction; it was saved through special conservation measures, breeding "ex-situ"

Table 5. Depletion of the taxonomic structure of the phytoplankton in the Aral Sea

Taxon/ Year	1925	1967-1974	1999-2002
CYANOPHYTA	41	79	30
BACILLARIOPHYTA	210	104	115
PYRRHOPHYTA	15	28	3
EUGLENOPHYTA	-	3	2
CHLOROPHYTA	109	60	9
Total number of species	375	306	159

Note: data for 1925 after Kiselev (1927); data for 1967-1974 after Pichkily (1981).

Table 6. Species composition of the zooplankton in the Aral Sea

Taxon/ Year	1971	1981	1989	1994	1996	1998	1999	2000	2001	2002
Hexarthra spp.	+	+	+	–	–	+	+	+	+	–
Synchaeta sp.	+	+	+	+	+	–	–	–	–	–
Nereis diversicolor	+	+	+	+	+	+	+	+	–	–
Cerastoderma isthmicum	+	+	+	+	+	+	+	+	–	–
Syndosmya segmentum	+	+	+	+	+	+	+	+	+	–
Chironomus salinarius	+	+	+	+	+	+	+	+	+	+
Moina salina	+	–	+	–	+	+	+	+	–	–
Podonevadne camptonyx	+	+	+	–	–	–	–	–	–	–
Halicyclops rotundipes	+	+	+	+	+	–	–	–	–	–
Cletocamptus retrogressus	+	+	+	+	+	+	+	+	+	+
Halectinosoma abrau	+	+	+	+	+	–	–	–	–	–
Calanipeda aquaedulcis	+	+	+	+	+	–	–	–	–	–
Artemia parthenogenetica	–	–	–	–	–	+	–	+	+	+
Number of species	42	18	12	9	9	8	7	8	5	4
Salinity, ppt	12	18	30	37	44	54	56	58-63	63-68	69-74

Note: data for 1972-1980 partly omitted.

Table 7. Species composition of the zoobenthos in the Aral Sea

Taxon/ Year	1950	1970	1980	1990	1995	1999	2000	2001	2002
Nereis diversicolor	–	+	+	+	+	+	+	+	–
Syndosmya segmentum	–	+	+	+	+	+	+	+	+
Cerastoderma ishtmicum	+	+	+	+	+	+	+	+	–
Caspiohydrobia spp.	+	+	+	+	–	–	–	–	–
Cyprideis torosa	+	+	+	+	+	+	+	+	+
Paleomon elegans	–	+	+	+	+	–	–	–	–
Rhithropanopeus harrisii	–	+	+	+	+	–	–	–	–
Turkogammarus aralensis	+	+	+		–	–	–	–	–
Chironomus salinarius	+	+	+	+	+	+	+	+	+
Number of species	60	67	32	14	7	5	5	5	3
Salinity, ppt	10	12	17	30	42	56	58-63	63-68	69-74

Note: data for 1950-1980 after Andreev et al. (1992); data for 1990 after Filippov (1996).

Table 8. Ichthyofauna of the western part of the Aral Sea

Species/ Years	1990	1995	1998	2000	2001	2002	2003
Atherina boyeri	+	+	+	+	+	+	–
Platichthys esus	+	+	+	+	+	–	–
Clupea harengus membras	+	+	+	+	–	–	–
Neogobius uviatilis	+	+	+	–	–	–	–
Knipowitschia caucasica	+	+	+	–	–	–	–

Table 9. Threatened taxa in the Red Books and Red Lists of Central Asian countries

Taxonomic groups\ countries & official sources	KZ Red Book, 1996; Red List, 1999	KG Red List, 1985	TJ Red Book, 1988	TM Red Book, 1999	UZ Red Books, 1998, 2003
Fishes	16	1	4	13	18
Amphibians	3	0	0	1	0
Reptiles	10	3	21	22	16
Birds	56	20	37	41	51
Mammals	40	13	42	30	24
Invertebrates	96	5	58	45	80
Fungi	-	-	4	-	-
Plants	100	65	222	109	301
Total:	321	107	388	261	490

(in captivity) and reintroduction in appropriate places. The irrigation process and the taking of water from rivers for this purpose as well as the pollution and mineralization of waters have led to the loss and decline of the biodiversity of the wetlands and water ecosystems. First of all, the biodiversity of the Aral Sea was affected; from the 34 fish species of the original fauna, not many have survived to the present day. In general, water reservoirs of the Aral Sea basin lost a significant part of their original fish fauna: some fish taxa became extinct – Aral Sturgeon, Aral Trout, Chu Sharpray, Turkestan Dace, Kessler's Loach - and others are nearing extinction – Syr Darya and Amu Darya Dwarf Sturgeons, Pike Asp, Brachycephal Barbel, Ili Marinka, etc.
The assessment conducted in the framework of INTAS regional project 99-1483 "Correlates of the extinction risk for Central Asian biodiversity" using IUCN Categories and Criteria (version 3.1) (2001) showed that 63 fish species from about 120 species presented in the current fauna are threatened and that the Aral Trout subspecies became globally extinct. These are mostly species of the Caspian and Aral seas. However, many original endemic mountain species have been affected by pollution, competition with invasive species, and changes of environment. From the 15 amphibian species, 6 species are threatened; the Iranian Long-legged Wood Frog has disappeared from the region. Furthermore, 29 bird species related to water are threatened. The unique breeding places in the region of the Aral Sea and the deltas of the Amu Darya and Syr Darya rivers are, particularly, threatened, and the Scalybellied green woodpecker is a regionally extinct species. As for mammal species, 7 species related to freshwater ecosystems are threatened, 2 of which are extinct: the Caspian Tiger is a globally extinct subspecies, and the European Mink is regionally extinct as a result of the competition with the introduced American Mink.

Invertebrates also have been affected considerably, basically as a result of transformation and loss of ecosystems; several invertebrate species seem to be globally extinct. Thus, the large-scale transformation of freshwater ecosystems has led to the loss and decline of species.

Influence of introduced species on the native biodiversity and their role in local economy

The human economic activity in the twentieth century became a powerful factor in changing the environment. The anthropogenic influence on the change of wildlife in the Aral Sea region was significant. As a result of the introduction of 16 invertebrate species and 22 fish species into this sea, its fauna was changed radically. Acclimatization of commercially sold fish and incidental acclimatization of some hydrobionts in the first half of the twentieth century undermined the food base of the local native fish species and decreased the commercial catch of fish. Constant decreasing of rivers flow and salinization of the Aral Sea has led to the unsuitability of the Aral Sea as a habitat for most of the local, native and introduced invertebrate and vertebrate species.

On the one hand, the introduced species affected the status of native original biodiversity, and many local species declined or were displaced due to the expansion of the introduced species. For example, the introduction of the American Mink has changed the status of the native European Mink (in Kazakhstan) and Eurasian Otter (in other countries of the region). On the other hand, some of the introduced species, such as Muskrat and Nutria, occupied free ecological niches and currently play an important role in local economies. The Muskrat species was introduced intentionally for its valuable fur; the Nutria species, however, acclimatized accidentally, escaping from the captivity of fur farms. Many intentionally- and accidentally- introduced fish species play an important role in fishery, successfully occupying the secondary water reservoirs (Grass Carp, Carp Bream, White Amur Bream, Prussian Carp, Silver Carp, Bighead Carp, Peled, Rainbow trout, Sevan Trout, Amur Snakehead, and Flounder). Some of the introduced species are used in the biological control of malaria-transmitting mosquitoes (Eastern mosquitofish). On the other hand, some accidentally-introduced fish species cause decline in the population size of several endemic fish species in the region, such as Chatkal Bullhead, Turkestan Sculpin, Turkestan Catfish, Aral Ninespine Stickleback, Turkestan Ide, Tashkent Riffle Bleak, Pike Asp, Turkestan Barbel, and Sharpray.

As the practice has shown, it is necessary to assess more carefully the impact of introduced and acclimatized species on the native wildlife, evaluating negative and positive influences and taking into account the regulating measures for the support of the original flora and fauna to achieve a state of balance.

The preliminary analysis of this situation has shown clearly the necessity, in the management of water ecosystem resources, to evaluate their productivity, carrying capacity, and acceptable bounds of their use. The implementation of special legislative regulations is enough to support the survival of some species (many hunting game species: ducks, gray geese, pheasant, muskrat, fishes, etc.). For other species, particularly the currently threatened ones, it is necessary to provide special conservation measures, monitoring, and proper management.

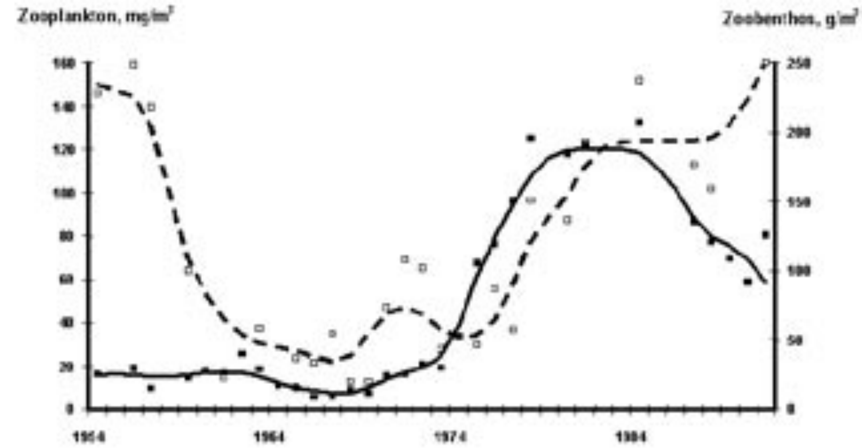

Fig. 11. Changes of zoo-benthos (firm line) and zoo-plankton (dotted line) in Aral Sea during 1954 -1991.

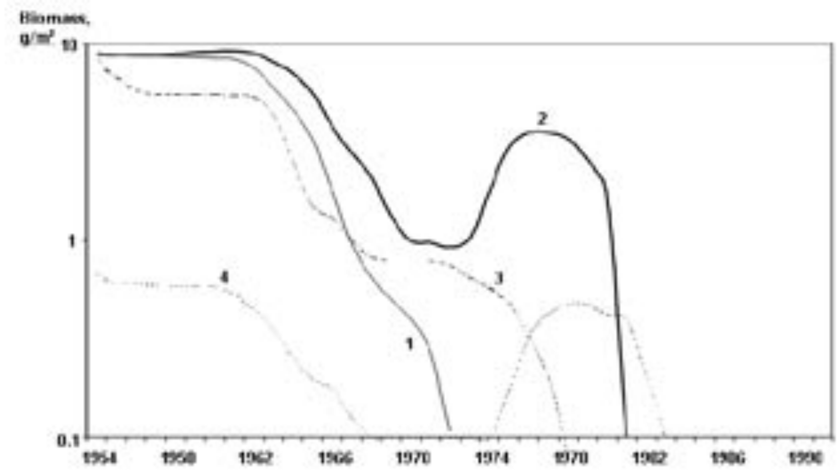

Fig.12. Changes in biomasses of some freshwater and brekish species of zoobetos in Aral Sea during1954 -1991: 1 - Chironomidae; 2 - Dreissena spp.; 3 - Hypanis spp.; 4 - Theodoxus pallasi.

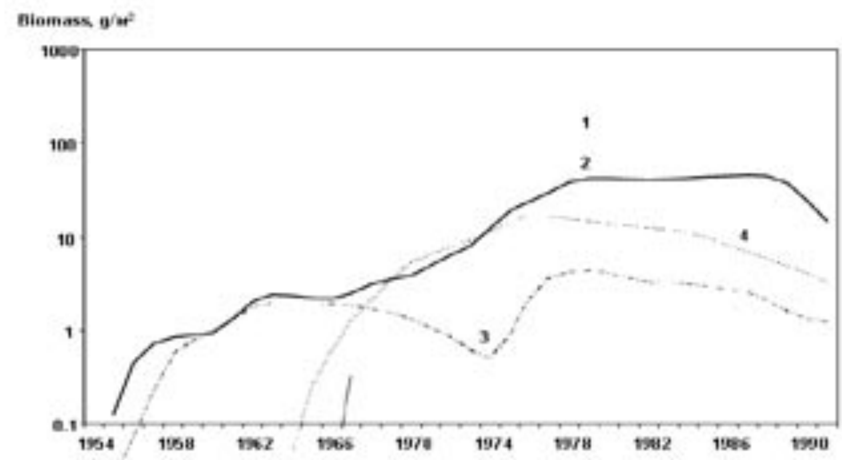

Fig.13. Changes of biomass of aboriginal and acclimatized euryhaline species of the Aral Sea zoobenthos during 1954 -1991: 1-Syndosmya segmentum; 2-Cerastoderma isthmicum; 3 -Caspiohydrobia spp., 4- Nereis diversicolor

Change in the productivity of the desert pastures under human and climatic factors

Change in climate as a result of the decrease in the Aral Sea surface area and the loss of the sea's thermal capacity is highly evident, although not so considerable. Influence of the sea-level drop on the thermal regime of the near-land (near-earth) layer of atmosphere is limited by coastal zone to 120-150 km. This is approximately the territory which is cleared from water or where the climate regime is affected by changes in deltas or level of subsoil (underground) water bedding. With the retreat of the Aral

Sea, the humidity of air near the land surface also has decreased. According to observations of the Aral Sea Station, the average monthly air humidity decreased during development of irrigation activity from 42% to 30 %, i.e. a reduction of 12%. The change in humidity also has been registered in the Syr Darya River delta and in the Southern Aral Sea region, where it applies to a huge area and extends to the higher layers of atmosphere. Contents of moisture in 1.5 km layer of atmosphere decreased and provoked displacement of zone of convective nebulosity formation and influence of breeze winds. Owing to secondary effects and feedback, the influence of the sea on the climate of the boundary layer of atmosphere is of a bigger scale than on the near-land layer.

Table 10. Protected Areas system in Central Asia

Categories of PA Countries	KZ	KG	TJ	TM	UZ
Strict Nature Reserves	9	6	4	9	9
National Parks	7	6	2	-	2
Nature Reservations	2	-	-	2	1
Sanctuaries (Zakazniks)	57	71	16	6	10
Nature Monuments	79	-	-	17	4
Total area (km^2):	135,385	7,773	26,202	19,783	23,243
Percentage of country area:	0.3%	3.9%	18.3%	4.02%	5.2%

It is evident that the new salty desert named Aralkum is the destabilizing factor influencing the state of ecosystems and surrounding areas because the processes of salty desertification became stronger owing to the transfer of salts from the dry seabed. The special long-term observations conducted within the arid lands of Kyzylkum desert have shown changes in the productivity of arid pastures due to human activity (overgrazing) and climate change. To prevent and stop the degradation of the pasture areas and to optimize these areas, it is necessary to provide special measures, such as afforestation and recovering of grass on the dried-up bottom of the Aral Sea, rehabilitation of wetlands in the Aral Sea region, and creation of regulated wetlands around human settlements. Some measures on the solution of this problem are undertaken in the National Plan for the combating of desertification in Uzbekistan. In particular, this Plan considers the special program on the phytomelioration of pastures.

Species translocation

Under the negative circumstance influencing the ecological conditions of freshwater ecosystems in Central Asia, many species shifted to zones with appropriate conditions. This particularly has affected the migratory species, such as birds. Today, we can state that the distribution of many waterfowls and other water-birds has changed significantly. On the one hand, the disappearing of wetlands in the region of the Aral Sea has led to the loss of breeding habitats and important migratory stop-over places in the region. On the other hand, the new secondary wetlands have created similar conditions for the migratory flows and birds, new breeding, migratory, and wintering sites. The climate change and the observed warming, especially in the winter season, provide the appropriate conditions for the enlargement of wintering zone and for the forming of new wintering sites in the regions that used to be fully deserts. All other wildlife (fauna and flora) also have been influenced by existent changes and responded by adaptation to new ecological conditions. The poor fauna and flora of the traditional desert regions were fortified by new elements. In this process the leading role is the easy adaptive species play.

Conservation of biodiversity and protected areas covered freshwater ecosystems

The system of protected areas in the region includes various types of PA according to IUCN classification (Table 10). The core role in the conservation of biodiversity belongs to the strict protected areas (nature reserves and national parks, categories I and II of IUCN, respectively).

In spite of the rather good representation of different categories of protected areas, only part of them covers the biodiversity within freshwater ecosystems. For example, in Uzbekistan, there are 3 strict nature reserves out of 9 established in the zone of gallery river riparian forests (or tugai forests) – Badai-Tugai, Kyzylkum, and Zeravshan; in Turkmenistan, there is one only, the Amu Darya nature reserve; and in Tajikistan, there is also one, Tiger Gulli. The special strict protection of lakes and wetlands in Kazakhstan is realized in the Kurgaldjin, Naurzum, and Markakol nature reserves, and in Kyrgyzstan, in the Sary-Chelek and Issyk-Kul nature reserves. The wetlands are formally protected also by the system of special sanctuaries or “zakazniks” (category IV of IUCN), but the real protection and monitoring of wildlife within this category of protected areas are absent. Therefore, it is necessary to analyze the current system of existing protected areas within the wetlands and determine the gaps. Secondly, it is essential to elaborate the national, provincial, and local management plans for the governing of biological resources within the wetlands. But, it is necessary to note that all protected areas play a very important role in the conservation of freshwater biodiversity, because, for example, the mountain nature reserves and sanctuaries secure the protection of all freshwater streams and currents with their specific wildlife.

In the region, the legislative base for the conservation of freshwater biodiversity is presented as the system of national regulations and quotas on the using of biodiversity. The hunting regulations consider the questions of terms and rates for the hunting bag and fishery within the countries. The hunting terms should be revised each year on the base of regular census or survey of hunting game resources. In the region, the system of monitoring for the freshwater resources existed in the past. The permanent monitoring of water quantity and quality is conducted in all countries of the region, the monitoring of wildlife is carried out on the base of existed protected areas network (strict nature reserves) and within hunting management. Today, this system works only partially, especially in the area of wildlife monitoring.

Promise of Freshwater Biodiversity Conservation in Central Asia

Analyzing all the processes going in the region we can suspect now the relative stabilization of freshwater biodiversity in new ecological conditions. However, it is necessary to keep in mind several scenarios for the future use of water resources. The main task directly concerned with freshwater biodiversity sustainability is the value of so called "unused water reserves". These are not used for the purposes of agricultural or industrial development, or for public or drinking purposes, and are a basic ecosystem component for the survival of regional wildlife. From 1960, the value of such unused water reserves decreased more than 7 times (Fig. 14).

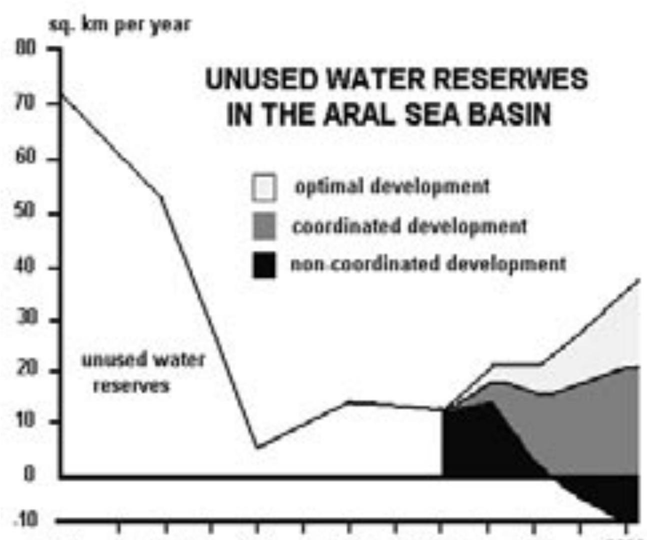

Fig. 14. Unused water reserves in the Aral Sea Basin

Actions on improvement of environmental and socio-economic situation in the Aral Sea Basin for the period of 2003-2010

The ecological crisis and the bad socio-economic situation in the Aral Sea basin are recognized by the world community to be among the greatest catastrophes of the twentieth century. Aiming at improving the conditions of the Aral Sea basin, the Heads of the Central Asian Governments created, in year 1993, the International Fund for Saving the Aral Sea (IFAS). In October 2002, the Presidents of the Republics made a decision to launch a new program under IFAS. They stated basic directions and entrusted the executive committee of IFAS, together with ICWC and ICSD, with the task of developing the "Plan of Actions for the Period of 2003-2010 on Improvement of Environmental, Social and Economic Situation in the Aral Sea Basin", with the agreement of the governments of participating countries.

At the Dushanbe's (August 28, 2003, Tajikistan) meeting of State Leaders "The main directions of the program of concrete actions on improvement of environmental and socio-economic situation in the Aral Sea basin for a period of 2003-2010" have been approved. The proposals are listed below according to their priorities.

1. *Development of coordinated mechanisms on comprehensive management of water resources of the Aral Sea Basin;*
2. *Rehabilitation of hydro-economic facilities and improvement of use of water and land resources;*
3. *Improvement of systems on environment monitoring;*
4. *Program on combating natural disasters;*
5. *Program on assistance to the solution of regional social problems;*
6. *Strengthening of the material-technical and legal base of the interstate organizations;*
7. *Development and implementation of regional and national programs on actions of environment protection in zones of water flow formation. The conservation of mountain and foothill ecosystems and glaciers is a priority objective. In this context, a study of factors that have dynamic effects on decreasing mountain glaciers and on the degradation of mountain ecosystems will be carried out. Also developing actions on reducing the negative influences of these factors will be taken into consideration.*

Generally, it is clear, that future status of freshwater biodiversity in the Central Asia region directly depends on the value of unused water reserves. It is expected that the current situation is cloase to the Coordinated Development Scenario. For example, in 2003 more than 17 km^3 of freshwater reached the Aral Sea, the most threatened water ecosystem in the region; after 40 years of the diminishing of the sea level, this process is under control today. More-over, the new coordinated decisions approved by the governments of the Central Asian states lead to the conclusion that there are realistic promise for the sustainable use of water resources and freshwater biodiversity conservation.

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