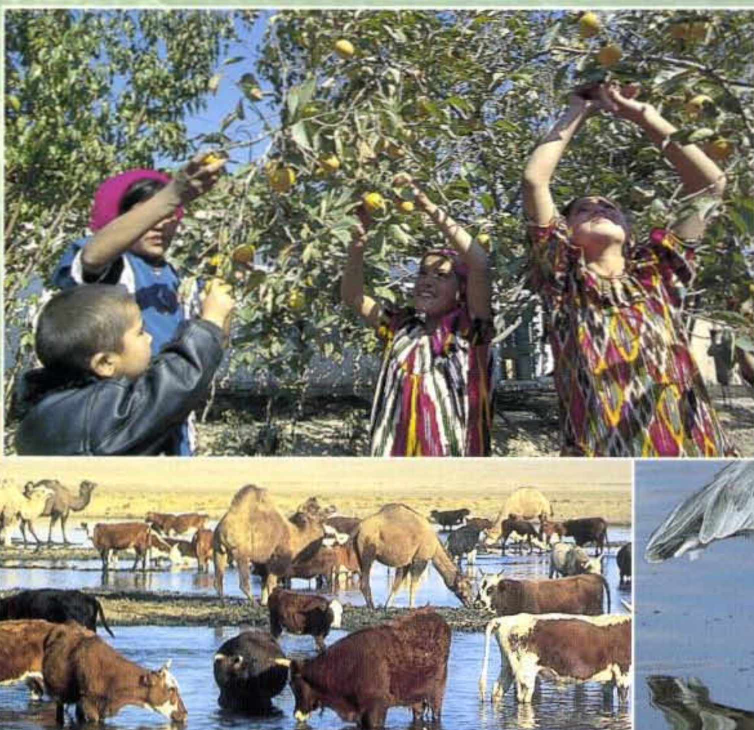
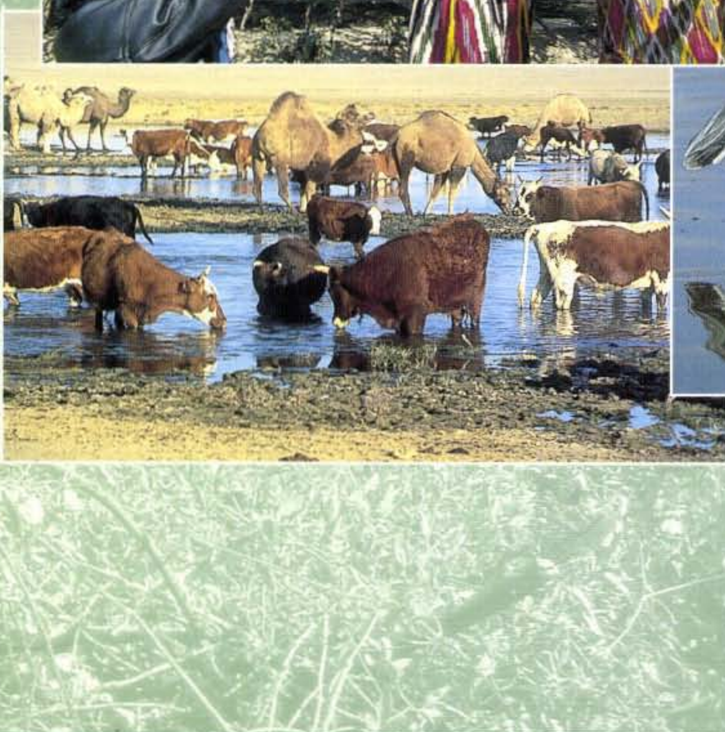
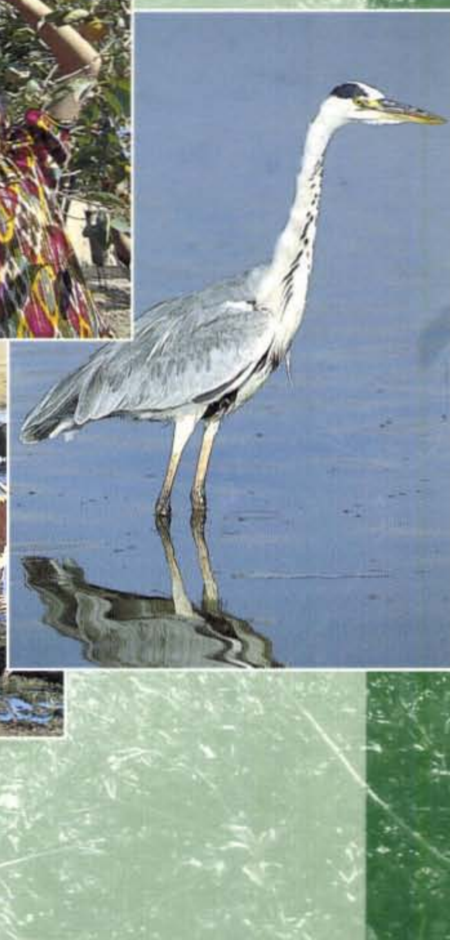
ECOLOGICAL RESEARCH AND MONITORING OF THE ARAL SEA DELTAS

A basis for restoration







UNESCO **Aral Sea Project**

1992-1996 FINAL SCIENTIFIC REPORTS

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INTRODUCTION

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In recent years, the Aral Sea has become synonymous with man-made ecological and social crisis. When the five Central Asian republics of Kazakstan, Kyrgyzstan, Tadjikistan, Turkmenistan and Uzbekistan became independent in 1991, they took over all the environmental and economic problems besetting their region. No longer able to fall back on the Union of Soviet Socialist Republics (USSR), they are going to have to alleviate today's problems by themselves.

During the Soviet era, some international help had been directed towards the Aral Sea region. In 1992, the United Nations Environment Programme (UNEP) published a comprehensive Diagnostic Study of the problems encountered in the Aral Basin. However, in the years immediately following independence, external aid was scant and the situation worsened.

Even if the causes of most environmental problems were already well-known to scientists, political leaders and the population concerned, the necessary action for change remained either ill-defined or economically unfeasible to implement. Moreover, much scientific knowledge was being drained off by the exodus of specialists familiar with the region and its problems. It was feared that this 'brain drain' would take on major proportions as the region's economic difficulties incited scientists to seek job opportunities elsewhere.

To help prevent this, Germany set up a programme to support the region's scientists and their work. In 1992, a joint project run by the German Federal Ministry for Education, Science, Research and Technology (BMBF) and the United Nations Scientific, Educational and Cultural Organization (UNESCO) was launched, entitled *'Ecological Research and Monitoring in the Syr-Dar'ya and Amu-Dar'ya Deltas at the Aral Sea, as a Basis for Restoration'*. Since scientists from different regions of the former USSR had been actively involved in Aral Sea-related research, it was hardly surprising that the new project mobilized over 130 scientists from Russia, Uzbekistan, Karakalpakstan, Kazakstan and Turkmenistan. The present publication presents the results of the basic and applied research conducted within the framework of the BMBF/UNESCO Project from 1992 until 1996.

General geographical information

Central Asia extends from east of the Caspian Sea to the Tien-Shan mountains. Bordered in the south by the mountains of Hindukush and its prolongations, and on the northern side lying wide open to the Russian and Siberian lowlands, Central Asia is marked by cold winters and hot summers. It has an arid climate with only 400 mm annual precipitation in the lower mountainous regions and as little as 100 mm or less around the Aral Sea depression. Hence, most of the area is characterized by extensive deserts, such as the Kara Kum, Kyzyl Kum and the newly formed Aral Kum, as well as large steppe-like landscapes like the Hunger-steppe in the northern part of Central Asia.

The main geographical feature of the region is, of course, the Aral Sea, fed by two rivers: the Amu-Dar'ya with a length of 2,500 km and an average annual flow of about 80 km^3, and the Syr-Dar'ya with a length of 2,137 km and average flow of 40 km^3.

Agriculture is the main economic activity in the lowlands of this region, but, in the arid climate, high yields are made possible only by irrigation with water taken from the two rivers. In addition, herdsmen, among them nomads, have always been at home in this region, raising sheep, camels and horses on the steppe-like territories. The same agricultural system has prevailed for thousands of years and the area is known for its high oasis culture. Due to high solar energy in the summer months, a great variety of crops grows here: grapes, vegetables, fruits, grain, cotton and many other crops are commonly found in the region.

In the former USSR, Central Asia was ideal for growing cotton. The demand for cotton being very high, the cotton-growing land in Turkmenistan and Uzbekistan expanded over huge areas from 1960 onwards. In southern Turkmenistan, the 1,500-km-long Karakum Canal was built, removing about 12–15 km^3 of water from the Amu-Dar'ya annually. Other large-scale irrigation projects followed and the Central Asian region became the third-biggest cotton-producing site in the world.

Water requirements grew in proportion to the expansion of irrigation, the two rivers being the sole sources of the water taken. A huge network of canals was built for the distribution of this water, diverting into the irrigated fields and small water bodies in the deserts huge amounts of water that would normally have flowed into the Aral Sea. A good example of this is the Sarykamysh Lake, which expanded in area many times during these years. As a result, the Aral Sea did not receive enough water and evaporation from the sea considerably exceeded inflow, leading to the accelerated desiccation of the Aral Sea.

The delta areas have been heavily affected by the shrinking of the Aral Sea, owing to the reduced water supply and increasing concentrations of pesticides, minerals and fertilizers, as well as defoliants used in large quantities for the cotton monoculture. This eroded much of the local population's quality of life, especially in the lower zones of the Amu-Dar'ya and Syr-Dar'ya. Deprived of a supply of clean drinking water and with no possibility of pursuing traditional agriculture or fishing, the local population lost its means of existence. By resolution in 1988, the USSR declared the area around the Aral Sea a disaster zone. For the first time, the USSR appealed to the international community for assistance, in addition to turning to both Russian and local scientists and institutions.

The BMBF/UNESCO Project

In 1991, Central Asia was divided into five independent states, three of which – Kazakstan, Turkmenistan and Uzbekistan – were directly affected by the Aral Sea crisis. Close links existed between the three states and scientists in Russia, with most of the factual information about the crisis being stored in Russia. After the disintegration of the USSR, the economic situation in Russia became very difficult, hitting particularly hard those scientists with no income from production. The plight of scientists in Central Asia was even worse.

In light of its close ties with the Central Asian republics, Germany tried to help. The BMBF set up a programme to support scientists in the former USSR by providing them with the necessary funds to pursue their research.

Within this programme, a project was launched for the mitigation of the situation in the river delta areas of the Syr-Dar'ya and Amu-Dar'ya. About US$800,000 were set aside to help scientists continue their research in the region and to maintain links between scientists in Russia and their counterparts in the newly founded states, which was thought to be the only way for real progress to be made in the ecologically endangered areas. The German Government decided to co-operate with UNESCO in execution of the project. An agreement was signed with UNESCO and the project started in late 1992.

The main objective of the co-operative research programme was a systematic study of natural and anthropogenic changes in the Aral Sea delta regions. The acquisition through scientific research of a better understanding of the prevailing processes was expected to spawn recommendations to governments on measures for sustainable development in the region. However, the complexity of the ecological structure and the very size of the Aral Sea depression did not allow the launching of comprehensive investigation programmes because of financial constraints. It was therefore planned to develop representative models of the aquatic and terrestrial ecosystems that could then be extrapolated to those areas not investigated. In order to develop such models, scientists in different fields needed to work on roughly the same area, thus promoting more comprehensive investigations.

The planned research was largely application-oriented in continuation of the work already carried out most effectively in the area. The programme covered the assessment of terrestrial and aquatic ecosystems in a region badly affected by anthropogenic activities. Twenty-two sub-projects from Kazakstan, Karakalpakstan, Russia, Turkmenistan and Uzbekistan were accepted. A variety of subjects were covered by extensive study programmes ranging from soil and phyto-sociological questions to sedimentological, hydrobiological, ecotoxilogical and hydrochemical investigations, including agrochemical and environmental aspects.

With the help of agriculture and environmental engineering, it was hoped that the results of scientific research would be incorporated into working installations of drip irrigation, water treatment plants with sewage fields, flow simulation models for the prediction of water levels and pollution in the Amu-Dar'ya river system, as well as new agricultural techniques. The research results would then be co-ordinated and combined into a Geographical Information System (GIS).

With the support of the Governments of Kazakstan, Karakalpakstan and Uzbekistan, two field stations were established, one in Kazalinsk in the Syr-Dar'ya delta and the other in Muinak in the Amu-Dar'ya delta. Equipped with the necessary scientific instruments, these stations are now the nuclei of co-operative research for groups from different republics, but also for other countries around the world wishing to participate in research on the Aral Sea.

Available data of ecological monitoring in the Aral Sea deltas obtained in the past by various scientific groups were duly used and verified in fresh research, taking special care to acknowledge the scientific work of all authors involved. Difficulties arose in using existing data, partly because it was not always explicitly stated which methods had been used and partly because different scientific schools often opposed rather than co-operated with each other.

Difficulties of the kind mentioned above also arose in running the new project, but were mitigated after the first seminar in Tashkent, in 1994. On that occasion, the participating scientists could appreciate the value of free information exchange between the different sub-projects. Such insight greatly improved work on the Project.

The co-operation between sub-projects resulted in new, valuable approaches described in the present publication. The evaluation of botanical succession (Novikova *et al.*, Chapter 4) contributed greatly to understanding of developments in desert landscapes (Geldyeva *et al.*, Chapter 2) and to understanding of the distribution patterns of hazardous infection-carrying rodents in the newly formed landscapes (Reimov *et al.*, Chapter 13).

A model of the Amu-Dar'ya run-off (Razakov et al., Chapter 18) explained some of the tugai forest development (Treshkin *et al.*, Chapter 3) and helped to evaluate the findings of water quality studies (Borodin *et al.*, Chapter 10).

Experiments with biota in naturally polluted water bodies (Elmuratov *et al.*, Chapter 9) contributed to the knowledge needed for biological water treatment installations (Rahmonov *et al.*, Chapter 19) and to a better understanding of the spread of parasites (Azimov *et al.*, Chapter 14). The experiments were also relevant to the study of potential refuge areas for different species in the increasingly saline Aral Sea (Orlova *et al.*, Chapter 6), especially those for different species of fish (Zholdasova *et al.*, Chapter 11), and the changing distribution of birds (Rustamov *et al.*, Chapter 12).

In agriculture, reducing the excessive use of water to irrigate rice by introducing different Eastern European rice varieties (Rau *et al.*, Chapter 17) was investigated. The introduction of these varieties also helps to limit the application of pesticides, the stable isotopes of which persist for a long time in the soil (Bogdasarov *et al.*, Chapter 5) and accumulate in the biotic food chain (Dubitsky *et al.*, Chapter 15). The introduction of hydroponic and drip irrigation on saline soils would act in the same way (Khabibullaev *et al.*, Chapter 20).

Together with the historic reconstruction of the development of the Aral Sea (Aladin, Chapter 1), all the above-mentioned results are available for incorporation into a GIS (Ptichnikov *et al.*, Chapter 16). Combined in data bases and dedicated partial models, the results obtained will allow the development of more comprehensive models for prognostic purposes. Such a model for the run-off of the Amu-Dar'ya (Razakov *et al.*, Chapter 18) has already been applied to water management in the river basin.

An evident drawback has been the lack of efficient transfer of research results between republics, although some positive activities are already under way. This is particularly valid as regards the introduction of the new rice variety developed in Kazakstan into Karakalpakstan and Khorezm and, vice-versa, the putting into practice in Kazakstan of Uzbekistan-developed biological water treatment technology. Further efforts are needed to adapt the Amu-Dar'ya river flow simulation model for water management of the Syr-Dar'ya river system.

The Project's main achievements may be summarized as follows:

1) The Project contributed substantially to the continuity of the Aral Sea research policy.

2) By focusing on the delta regions, the Project directed research efforts towards the most affected ecological disaster zones.

3) The scientists in the region were offered the experience of different research set-ups, along with international and national co-operation.

4) The Project encouraged mutual confidence within the international scientific community and, in particular, between the co-workers on the project.

5) Close co-operation was established between scientists from the Aral region and those from Germany.

6) Several scientific achievements have been put forward for consideration by the respective authorities.

Palaeolimnology

SOME PALAEOLIMNOLOGICAL RECONSTRUCTION AND HISTORY OF THE ARAL SEA BASIN AND ITS CATCHMENT AREA

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Isolation from other great water basins and a sharp arid continental climate are the most important distinctions of the Aral Sea. These are common features of the large brackish water basins of the former USSR, such as the Caspian Sea and Balkhash Lake, and evidently of the majority of brackish and hyperhaline lakes of the World situated in arid and semi-arid zones. In their turn, these features lead to extremely strong dependence of the Aral Sea ecosystem upon any external impacts, of both natural and anthropogenous origin, which often change the hydrological and hydrochemical regimes of the basin. These changes, in their extreme cases, are often reflected in extensions and regressions of the Lake (Fig.1), owing to its position as a terminal basin of two rivers, Amu-Dar'ya and Syr-Dar'ya.

Strong oscillations of the Aral Sea level have been observed periodically since the Pliocene. In historical times (we mean since the beginning of written history, including events from previous times, reflected in annals), floods and desiccation were often connected with the development and decline of settled agricultural civilisation, which appeared in the deltaic districts. These civilisations usually impacted the Aral Sea, disturbing the water outflow of one or both of the rivers.

Water level fluctuations in prehistoric times were evidently caused by climatic changes, whereas the recent regression (since the early 1970s) is of anthropogenous character. The main difference from the former ones is its abrupt and fast character. Within 15-20 years, the lake level sank by 15-17 metres. Catastrophic socio-economic consequences for the densely populated districts were soon recorded. The present situation has justly been called a "crisis" (Micklin, 1991; Kuznetzov, 1993, etc.), the main features of which are:

- great change in the local climate for the worse, (dust-salt storms, etc.);
- complete loss of the economical importance of the Aral Sea (fishing and fishery were the main occupation of the local population), caused by the radical modification of aquatic living associations and the disappearance of navigation, caused by disjunction of the Sea ports and aquatic territories;
- degradation of deltaic ecosystems and elimination of large areas from agriculture, due to soil salinization, wind erosion and lowering of the groundwater table.

As a consequence of all these changes, the state of health of the local populations has declined, quasi-total unemployment ensued, accompanied by uncontrolled migrations, not to mention direct financial losses.

The evolution of a terminal lake in arid and semi-arid areas depends upon the evolution of the river basins and catchment areas of the rivers discharging into the lake (Fig. 2). In general, in arid areas, the combined input from rainfall, surface runoff, groundwater and deeper underground waters is considerably less than the input from rivers. Examples are, among others, Lake Chad with two rivers, and the Dead Sea with one river. In the case of the Aral Sea, two major factors determined the history of the

Amu-Dar'ya and Syr-Dar'ya river basins: local tectonic movements and alternation between pluvial and arid climatic phases (the storage of water in ice fields at high altitudes within the catchment areas was also important during glacial events).

In the following, we refer to changes in the level of the Aral Sea and its associated basins, in terms of transgressions and regressions. These local events relate to the net hydrological balance within the basins and do not reflect global eustatic sea level changes. Rubanov (1991) noted three significant regressions in the course of the history of the Aral Sea: the first in the late Akchagylian (late Pliocene), the second in the lower Quaternary and the third in the late Holocene - all three resulting in the deposition of salts from the water. These salt deposits, and indeed the salt dissolved today in the Aral Sea, originate from the inflowing rivers: the halite and associated deposits appeared through the evaporation of freshwater as attested by their chemistry (Blinov, 1956).

Rubanov (1991) considered that the Aral Sea Depression first formed about three million years ago, in the late Neogene, earliest Akchagylian stage. Two questions have been addressed by scientists in recent years: first, how was the Aral Basin formed, and second, how did it become filled with water. The majority accepts the idea that it began as a small, incipient depression, which collected local surface water runoff. This runoff was slightly saline due to the dissolution of local salt deposits. As the water evaporated, it left behind a thin veneer of salts. This surface layer made the sediments highly prone to wind erosion and eventually, a 'dust bowl' effect excavated the depression, enlarging it. The process would have been repeated many times. Kes (1969) and Pinkhasov (1984) noted that the Aral Depression first became linked with the Sarykamysh Depression, to form the Aral Basin as we know it today, between the middle and late Akchagylian. The earliest phase of water inflow (during the Akchagylian stage), led to the filling of what is known by some authors (Khrustalev et al., 1977; Rubanov, 1991) as the Akchagylian Basin. Subsequent discharge of the 'proto' Amu-Dar'ya into the basin from the south resulted in the deposition of sediments dividing the main basin into two smaller ones, the Sarykamysh Basin to the south-west and the Aral Basin in the eastern-central area.

The modern drainage pattern in Central Asia began to develop following the regression of the Palaeogene Sea which had previously covered the area. The development of the Aral Sea can be traced through the evolution of the Amu-Dar'ya and the Syr-Dar'ya rivers; however, we must also consider other, now 'extinct', rivers which have played a part in the evolution of the Aral Sea.

The Proto-Zeravshan River, together with the Proto-Amu-Dar'ya, flowed to the Caspian area, where it formed thick deposits of sand and clay. By the middle of the early Pleistocene, the Amu-Dar'ya had changed its course from the Zaungusky Karakumy towards the 'Nizmenie', or Lower, Karakumy and through the Balhansky and Donatinsky Corridor to finally reach the Caspian Sea. This change of direction of the Amu-Dar'ya resulted in an extensive sequence of sediments up to 340 metres thick (known locally as the "Karakumskaya Swita") being deposited in the Karakum, and consisting of sand, clay and carbonate mud.

During the late Pleistocene, the Amu-Dar'ya again flowed through the Karakum to the Aral Basin and the Sarykamysh Depression. This change of flow from the Caspian to the Aral probably happened during a pluvial period, when an increase in water discharge caused the flooding of the Amu-Dar'ya valley with one particular overflow into the valley of the Zeravshan River. This overflow finally resulted in uniting the two rivers and turning the Amu-Dar'ya to the north. Kes (1960) suggested that the Amu-Dar'ya, now united with the Zeravshan, broke through a second barrier at Tuyamuyun to reach Horezm Lake. This lake existed during the early Khvalinian period. Subsequently, Horezm Lake enlarged northwards, eventually linking with the Aral along the Akchadarya Corridor, and the Akchadar'ya Delta developed through this process.

The Amu-Dar'ya and Syr-Dar'ya first flowed together into the Aral Depression, after the change of direction of the former river due to the increased discharge, associated with the onset of the Lavlakansky pluvial period (Rubanov, 1991).

Prior to the Holocene, the upper reaches of the Syr-Dar'ya, having risen in the Tien Shan, crawled from one inter-mountain basin to the next until each in succession became filled with sediment. The Syr-Dar'ya worked its way through the depressions of the Fergana Valley and the Golodnaya Steppe, from where it found its course directly to the Aral Basin.

Before 10000 B.C, the Amu-Dar'ya and the Syr-Dar'ya had relatively low discharges; however, with the onset of the Lavlakansky pluvial period, which started about 9000 B.C., warmer and wetter conditions led to a marked increase in the flow of these rivers. This resulted in the extension of the Aral Sea to cover the Aral, Horezm and Sarykamysh Depressions, the so-called 'Great Aral Sea' stage. This large water body discharged through the Uzboy Channel to the Caspian Sea. At about 3500 years B.C., the climate became much drier and discharge via the Uzboy decreased considerably. Kvasov & Mamedov (1991) considered that the final cessation of discharge via the Uzboy was due, not to a climatic change, but to anthropogenic influences. Kvasov (1976) also believed that, through irrigation, humans had a greater influence in the separation of the Aral Sea into the Aral, Horezm and Sarykamysh, than is usually recognized.

The population of the Horezm State (ancient time) controlled the run-off of the Amu-Dar'ya into the Aral and the Sarykamysh Basins. They may have caused the river to reach either water body or both simultaneously and, in the latter case, the level of discharge to each lake may also have been controlled. Control of the Amu-Dar'ya could have been maintained only during periods of relatively stable society. Civil unrest in the area, often the result of water disputes, doubtless led to periods during which control of the river was lost and it reverted to its natural course, towards the Aral Sea.

Although the Amu-Dar'ya had reached the Aral, the gradual build up of sediments in the Horezm depression led, once more, to the re-routing of the Amu-Dar'ya westwards, towards the Sarykamysh Depression. The level of water in the Sarykamysh gradually increased to 58 metres above sea level, at which point the water outflowed along the Uzboy Channel, towards the Caspian Sea. According to Kes (1960) the Sarykamysh Delta developed to the east of the Sarykamysh depression during the Holocene. Shnitnikov (1969) criticised Kes' ideas on the existence of the Amu-Dar'ya deltas at different times. He proposed that during dry periods, the Amu-Dar'ya flowed into the Aral Depression, forming the oldest Aral Delta and suggested that during cold, wet climatic phases, the water in the Aral Sea reached such high levels that it overflowed both into the Akchadarya Corridor and the Sarykamysh Depression and through the Uzboy Channel into the Caspian. Pinkhasov (1984) confirmed Shnitnikov's idea that the Amu-Dar'ya flowed, after Touyamouyoun, into Lavakski Bay, a shallow part of the Aral Sea limited to the east by the cliffs of the Ustyurt Plateau and to the west by the Touyamouyoun - Soultanuzdag - Muinak line.

The discharge of the Amu-Dar'ya increased the level of the Aral Sea and resulted in the accumulation of alluvial deltaic deposits, leading finally to the present level of the Amu-Dar'ya River in the Horezm region, about 75-90 metres above sea level. This resulted in the deposition of the Akchadar'ya and Sarykamysh alluvial complexes.

The pre-Holocene evolution of the Syr-Dar'ya is less well-known. According to Fedorovich (1970), tectonic uplifting of the central Tien Shan area developed large ice fields, subsequent melting of which united the Nareen and Syr-Dar'ya valleys. This runoff flowed from one inter-mountain depression to the next and finally left the Fergana depression flowing north-west depositing up to 500 metres of alluvial sand and clay deposits in the area of the south-east Kyzyl Kum just to the west of the modern river course (Gramm, 1962).

Fedorovich (1952) and Andrianov & Kes (1967) noted that during the early and middle Pleistocene, the Syr-Dar'ya migrated through the northern Kyzyl Kum and its present position was only reached in the latest Holocene.

In the lower reaches of the Syr-Dar'ya, to the east of the Aral Sea, a large delta area was created in the late Pleistocene. This delta is today situated north of the Kyzyl Kum, between the Aral Sea and the modern Syr-Dar'ya. This delta was connected in the west to the Akchadar'ya Delta of the Amu-Dar'ya.

During the Khvalinian and Mangyslakskiy periods, a cold, dry climate persisted in Central Asia, resulting in a very marked regression of the Aral Sea. This led, during the dry Paskevich Period, to an almost complete drying of the Sarykamysh Depression and cessation of the flow through the Uzboy Channel. Between the early and the middle Holocene, about 9000 years B.C., the climate changed from cold and dry to much warmer and wetter. The ice fields retreated to 5000-7000 metres above sea level. The excess water discharging from the Amu-Dar'ya began to flow via the Akchadar'ya towards the Aral Sea and also to the Caspian Sea via the Sarykamysh Depression and the Uzboy Channel (Shnitnikov, 1969). Three deltas probably existed simultaneously, near Sarykamysh, Akchadar'ya and close to the Aral (i.e. the modern delta). However, since the early 1970s the 'modern delta' has been drastically altered due to the excessive withdrawal of water from the Amu-Dar'ya for irrigation (Fig. 3).

According to Korobkova & Yusupov (1976), early Neolithic settlements on the terraces of the Uzboy Channel indicate that some of the Amu-Dar'ya water reached Sarykamysh and, through the Uzboy, the Caspian Sea about 8000-7000 years B.C. and not 6000-5000 B.C., as suggested previously. Vinogradov & Mityaev (1979) proved that the Akchadar'ya Delta had existed since at least 7000 B.C. According to Sorokina & Yagodin (1980) there was also a delta close to the Aral Sea from 5000-4000 B.C. It is highly probable that all three deltas existed simultaneously because, according to Vinogradov & Mamedov (1975) and Vinogradov (1981), this coincided with the Lavlyakansy pluvial phase. Since about 4000 B.C., the flow through the Uzboy Channel and the Akchadar'ya decreased, disappearing completely about 3000 B.C.

During the middle Holocene, the Syr-Dar'ya River occupied a series of narrow channels on the left (south) side of the Inkardar'ya Delta. These channels traversed the northern edge of the Kyzylkum and then turned northwards towards the Aral Sea. These channels were later filled by waters of the Janadar'ya. In the period from the 13th, or more probably the 14th century, until the 19th century, a minor glacial epoch existed, shown through studies of the ice sheets of Northern Europe, Asia and America. The build up of ice led to an augmented melted-water supply during the Summers and consequently an increased supply to the Amu-Darya and Syr-Dar'ya Rivers.

It is probable that during the 13th and 14th centuries, but certainly during the 14th to 16th centuries, the lower reaches of the Amu-Dar'ya and the Sarykamysh had a good water supply, sufficient to permit at least a small occasional excess of water to flow into the Uzboy Channel. Historical records show that in 1573 the Amu-Dar'ya "turned" from Sarykamysh to the Aral Sea. This may have happened as the local population lost control over the course of the Amu-Dar'ya which had been artificially diverted to flow into the Sarykamysh. Subsequently, the entire Amu-Dar'ya discharge went into the Aral Sea. The first Englishman to visit the Central Asian area, a merchant, Anthony Jenkins, wrote in 1558 of the likelihood that the local population would lose control of the river:

"..The water that serveth all the country is drawn by ditches out of the river Oxus (old name for the Amu-Dar'ya), unto the great destruction of the said river, for which it falleth not into the Caspian Sea as it hath done in times past, and in short time all that land is like to be destroyed, and to become a wilderness for want of water, when the river Oxus shall fail...".

Scientific evidence for a change in the course of the Amu-Dar'ya, discharging totally into the Aral Sea, comes from various sources and puts the timing of this event between the middle of the 16th to the first half of the 17th century. It is probable that within a period of about seventy years, the inflow from the Amu-Dar'ya to the Sarykamysh Depression had been completely cut off.

Due to the cessation of flow towards the Sarykamysh Depression and the Uzboy Channel, these soon dried up and the level of the Aral Sea increased swiftly. The previous re-direction by the local population of the Amu-Dar'ya away from the Aral, during the Middle Ages, resulted in desiccation of the Aral Sea to a level comparable with that of today A subsequent rapid increase in the level of the Aral Sea about four centuries ago destroyed saxaul forests which had existed along the fringes of the sea. Radiocarbon analyses of drowned Saxaul stumps (now uncovered by the recent level fall) give an age of 1663 ±5 years (i.e. A.D. 287±5., S.Stine, pers.comm.).

Shnitnikov stated (1983, p.107) "The History of the Aral Sea is the History of transgressions and regressions". The most obvious features today which indicate past changes in the level of the Aral are the seven terrace levels recognised in the Aral Basin (figures given in m.a.s.l.) (Fig. 4).

I. 72-73 m. (Maximum during the Lavlakansky pluvial period)
II. 57-58 m. ("Drevne Aralskaya" or Ancient Aral).
III. 54-55 m. ("Pozdne Aralskaya" or late Aral)
IV. 53 m. ("Sovremennaya Aralskaya" or Modern Aral. This is considered to represent the 'normal' level recorded during the first half of this century).
V. 43.7-44.5 m.
VI. 40-41 m.
VII. 35.5-36 m.
VIII. 31 m. "Paskevich" period.

Vainbergs & Stelle (1980) recorded terrace VIII during bottom sediment investigations of Shevchenko and Tsche-Bas Bays. They considered that terraces V, VI and VII merely reflect periods of stability following sea level increases from the (lowest) Paskevich period terrace (VIII). The main sediments deposited during the Paskevich period are clay with thin layers of halite and gypsum. It is believed that the Paskevich period occurred during the late Pleistocene and early Holocene.

Epifanov (1961) was the first to describe the uppermost terrace (72-73 m.) from the north and west coast of the Aral Sea. Hondkarian (1977) and Fedorov (1980) described the presence of a dividing feature in the south-east of the Aral Basin which would have permitted the sea level to have risen to the proposed maximum of 72-73 m. These authors also noted that this feature was soon breached, reducing the water level to 57-58 m.a.s.l. (the "Drevne Aralskaya" or Ancient Aral terrace). They rejected any suggestion that the fall in level was attributed directly to climatic factors, but rather, that it resulted from the breaching of the wall.

Both terrace I (72-73 m.) and terrace II (57-58 m.) contain *Cerastoderma edule* or *Cerastoderma lamarcki* and, therefore, cannot be older than the first appearance of these taxa in the Caspian region i.e. the "New Caspian Layers"; consequently, they must obviously be pre-Holocene.

Several authors proposed dates, from different carbon sources, for terrace level II ("Drevne Aralskaya") with widely varying ages, Yanshin (1953) and Vainbergs & Stelle (1980) dated it as 5000 years B.C., Kes (1983) as 3000 years B.C., Maev et al.(1983) as 3000-2000 years B.C. and Serebryanniy et al. (1980) and Shnitnikov (1983) as 12000 years B.C. Although the exact date of terrace II remains uncertain, we do know that the short duration of the containing wall means that terrace I cannot have been much older than terrace II. The best dating available for terrace II relates to Neolithic settlements connected with this level which give an age of 5000 years B.C. Since *Cerastoderma edule* first entered the Caspian Sea at about 7000-5000 years B.C. (Fedorov, 1983) and the species first entered the Aral Sea not earlier than 5000 years B.C. (Maev et al., 1983), its presence in both terraces I and II means that these levels can be not older than 5,000 years, supporting the more direct archaeological evidence.

Archaeological evidence dates the appearance of the Uzboy connection to the Caspian Sea at between 8000-7000 years B.C., although the channel itself was a relict feature of some previous water course. These data also suggest that the Aral Sea existed at the level of 57-58 m. during 8000-5000 years B.C., marked by terrace II ("Drevne Aralskaya" or Ancient Aral). The archaeological information is in accordance with the palaeoclimatic evidence for a Lavlakan pluvial period during this time.

At this time of maximum regression (4th century A.D.), the east-central and western depressions of the Aral Basin were linked by a single connection in the north. During slightly higher levels there was also a connection further south between the two depressions. Salinity levels in the east-central depression varied between adjacent areas from freshwater to slightly brackish at maximum regression. This variation was brought about by the stronger influence of freshwater river input in some areas. This situation led to the coexistence of freshwater invertebrates with brackish water *Cerastoderma*. Salinity in the western basin was relatively higher than in the eastern central depression although absolute values have not been determined.

Nikolaev (1991) confirmed that the last "medium sized" regression occurred about 600 years B.C. and that, furthermore, the maximum transgression of the Aral Sea was probably at 4800-3600 years B.C.

The final conclusion could be that several periods of transgression of this lake are known. In prehistoric times the changes of level and salinity happened because of natural climate transformation. During the wet climate phase, the Syr-Dar'ya and Amu-Dar'ya were full of water and the level of the lake was high and salinity was low. In opposition to this, during dry climate phases, both rivers had little water and the Aral Sea level was low, and salinity high. In historic times, since the appearance of the Horezm Kingdom till now, the changes of level start to depend mainly on irrigation activity in the region along the Syr-Dar'ya and Amu-Dar'ya rivers. During prosperous development phases of the local countries, the irrigated fields expanded and large quantities of water were withdrawn from both rivers. As a result, the level of the Aral Sea was low and salinity high. During unsuccessful phases of local countries (wars, revolutions, salinization of lands, etc.), the irrigated fields usually collapsed and rivers were again full of water. Hence, the level of the lake was high and salinity was low.

References

Andrianov, B.V. & Kes, A.S., 1967. Hydrographic net and irrigation development on the plains of the Central Asia. In: Problems of the Nature Enhancement in the Central Asia. Moscow: 38-45. [in Russian]

Blinov L.K. Hydrochemistry of the Aral Sea. - Leningrad, "Gidrometeoizdat", 1956, 252 p. (in Russian).

Epifanov, M.I., About the Aral Sea terraces // Trudy Soyuznoy geologo-poiskovoy kontory (Moscow), V.2, 1961 (in Russian)

Fedorov, P.V., About some problems of the Aral and Caspian Seas Holocene history.// In: Oscillations of the Aral Sea Region humidity in Holocene. Moscow.: 1980, p.p.19-22. (in Russian)

Fedorov, P.V., Some problems of the Aral and Caspian Seas in late pliocene and pleistocene. // In: [Palaeogeography of the Caspian and Aral Seas in kainozoi. Part I. Moscow.: 1983, p.p.19-22. (in Russian)

Fedorovich, B.A., 1970. [About age and structural types of vales of Tien Shan.] Geomorfologiya, 2: 55-56. [in Russian].

Fedorovich, B.A., Ancient rivers in the deserts of Turan. // Materialy po chervertichnomu periodu SSSR, V.3, 1952, p.p. 93-100. (in Russian)

Gramm, M.N. Stratigraphy of Kainozoic molasses of Fergana and their comparing with tertiary continental sediments of some neighboring regions. Abstract of Doctoral thesis, University of Moscow, 1962 (in Russian)

Hondkarian, S.O. Transgressive fazes of development of the Aral Sea basin in Holocene. // In: Oscillations of the Aral-Caspian Region humidity in holocene: Abstracts of Conference. Moscow, 1977, 34p. (in Russian)

Khrustalev, Yu. P., Reznikov, S.A. & Turovskiy, D.S. Lithology and geochemistry of the Aral Sea bottom sediments. Rostov-on-Don.: 1977, 205p. (in Russian)

Kes, A.S. . Nizovya Amudaryi, Sarykimysh, Uzboi istoriya formirovaniya i zaseleniya. // Materialy Horezmskoy ekspeditsii. 1960.Vyp. 3. Moscow. (in Russian)

Kes, A.S. Main stages of the Aral Sea development. // In: Problems of the Aral Sea. - Moscow.: 1969,160-172. [in Russian]

Kes, A.S. The Aral Sea palaeogeography in late Pleistocene and Holocene. // In: Palaeogeography of the Caspian and Aral Seas in kainozoi. Part II. Moscow.:1983, 103p. (in Russian)

Korobkova, G.F. & Yusupov, H.Y. Discovery of new encampments of the Stone Age on upper Uzboy. // Izvestiya AN TurkSSR. Seriya obschestvennykh nauk, 5.1976 (ii Russian)

Kvasov, D.D., 1976. [Reasons of stopping of the discharge by Uzboy and problems of the Aral Sea.] Problemy osvoeniya pustyn, 6: 24-29 [in Russian]

Kvasov, D.D. and Mamedov, E.D. Irrigation development and its influence on water balance. // History of Lakes Sevan, Issyk-Kul, Balkhashm Zaisan and Aral. Leningrad.:1991 227-230. (in Russian)

Kuznetsov L.A., Levitskaya K.I., Makarenko O.V., Pankratova I.V. On characteristic of the soils of sea-land contact line of the Darsakelmes island (Aral Sea). Proceed. of Zool. Inst., 1993, v.250. pp.154-173. (in Russian).

Maev, E.G., Maeva, S.A., Nikolaev, S.D. Transection of the bottom sediments of the Aral Sea central part.// Palaeogeography of the Caspian and Aral Seas in kainozoi. Part II. Moscow, 1983,119-133. (in Russian)

Micklin P. The water Management Crisis in Soviet Central Asia // The Carl Beck Papers in Russian and East European Studies, 1991, N 905, 120 p.

Nikolaev, S.D . The Aral development according to oxygen isotope data. History of Lakes Sevan, Issyk-Kul, Balkhashm Zaisan and Aral. Leningrad.: 1991246-249. (in Russian)

Pinkhasov, B.I. Neogen-quaternary sediments and recent tectonic of the South Aral Sea Region and Western Kyzyl-Kum. Tashkent.1984 (in Russian)

Rubanov, I.V. Salt accumulation in the Aral hollow. // In: History of Lakes Sevan, Issyk-Kul, Balkhashm Zaisan and Aral. Leningrad.:1991 p.p. 231-234.(in Russian)

Serebryanniy, L.R., Pshenin, N.G., Punning, Y.M [Tien Shan glaciations and the Aral Sea level oscillations. // Izvestiya AN SSSR. Seriya geograficheskayya, 2:1980, p.p. 52-65. (in Russian)

Shnitnikov, A.V. Century changeability on the components of general humidity. Leningrad. 1969 (in Russian)

Shnitnikov, A.V. The Aral Sea in holocene and natural tendencies of its evolution. // Palaeogeography of the Caspian and Aral Seas in kainozoi. Part II .1983 Moscow.: p.p. 106-118. (in Russian)

Sorokina, R.A. and Yagodin, V.N. Development of the Aral delta of Amu Darya in holocene. // Oscillations of the Aral Sea Region humidity in holocene. Moscow.:1980, p.p. 199-200. (in Russian)

Vainbergs, I.G. and Stelle V.Ya. Late Quaternary stages of the Aral Sea evolution and their connection with changes in the climate of that epoch. // Oscillations of the Aral Sea Region humidity in holocene. Moscow.: 1980, p.p. 176-180. (in Russian)

Vinogradov, A.V. Ancient hunters and fishers of the Central Asia rivers area. Moscow.1981, (in Russian)

Vinogradov, A.V. and Mamedov, E.D. Prehistoric Lyavlyakan. //Stages of ancient settling and pioneering. Moscow. 1975 (in Russian)

Vinogradov, A.V. and Mityaev, P.E. Excavation of the Tolstov's encampment. //Archaeological discoveries in 1978. Moscow. 1979, (in Russian)

Yanshin, A.L. Geology of the Northern Aral Region. Moscow, 1953, 643p. (in Russian)

Figure 1.

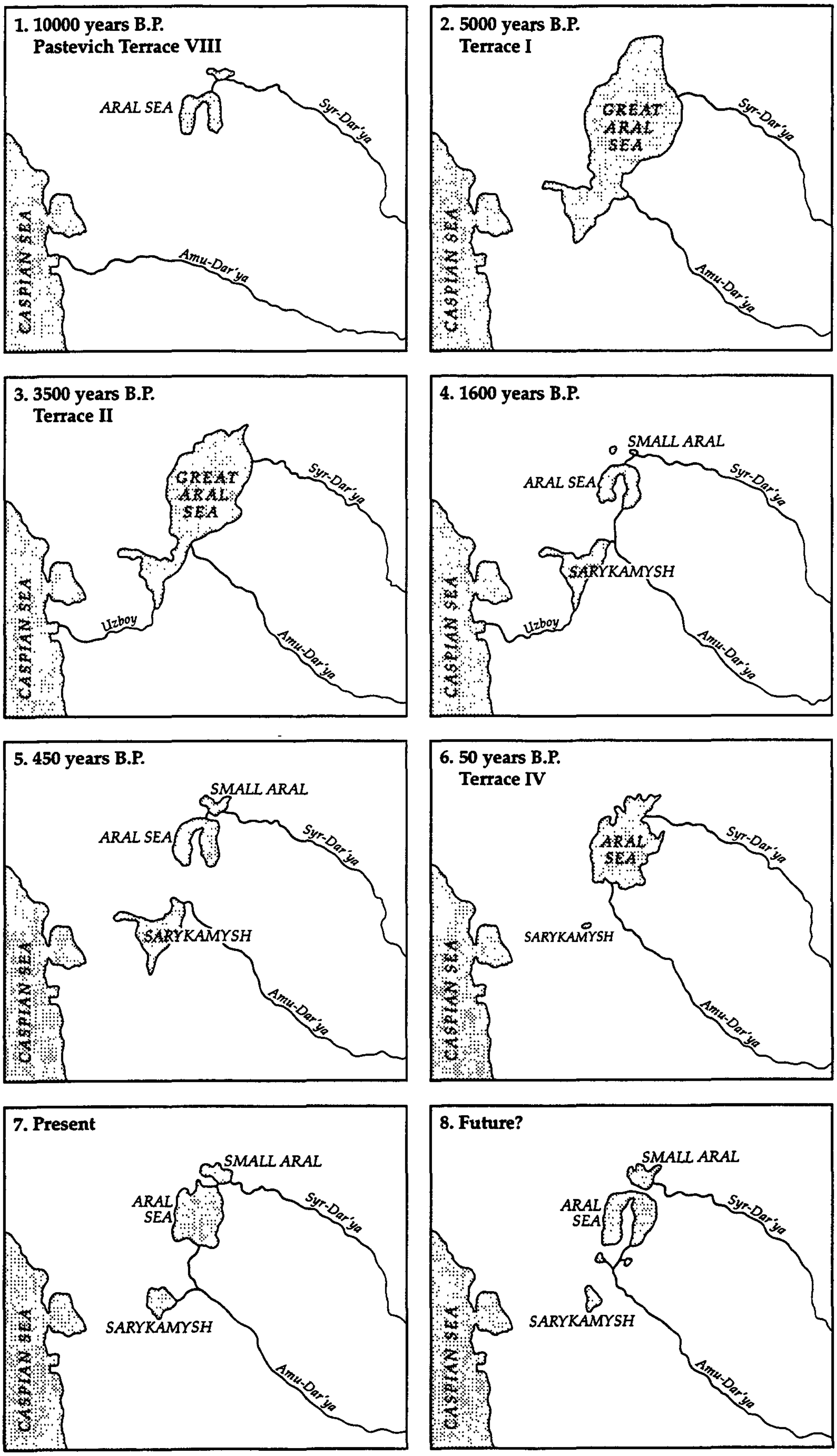

1. 10000 years B.P.
Pastevich Terrace VIII
ARAL SEA
Syr-Dar'ya
CASPIAN SEA
Amu-Dar'ya
2. 5000 years B.P.
Terrace I
GREAT ARAL SEA
Syr-Dar'ya
CASPIAN SEA
Amu-Dar'ya
3. 3500 years B.P.
Terrace II
GREAT ARAL SEA
Syr-Dar'ya
CASPIAN SEA
Uzboy
Amu-Dar'ya
4. 1600 years B.P.
SMALL ARAL
ARAL SEA
Syr-Dar'ya
SARYKAMYSH
CASPIAN SEA
Uzboy
Amu-Dar'ya
5. 450 years B.P.
SMALL ARAL
ARAL SEA
Syr-Dar'ya
SARYKAMYSH
CASPIAN SEA
Amu-Dar'ya
6. 50 years B.P.
Terrace IV
ARAL SEA
Syr-Dar'ya
SARYKAMYSH
CASPIAN SEA
Amu-Dar'ya
7. Present
SMALL ARAL
ARAL SEA
Syr-Dar'ya
SARYKAMYSH
CASPIAN SEA
Amu-Dar'ya
8. Future?
SMALL ARAL
ARAL SEA
Syr-Dar'ya
SARYKAMYSH
CASPIAN SEA
Amu-Dar'ya

Figure 2. Palaeohydrology of the region

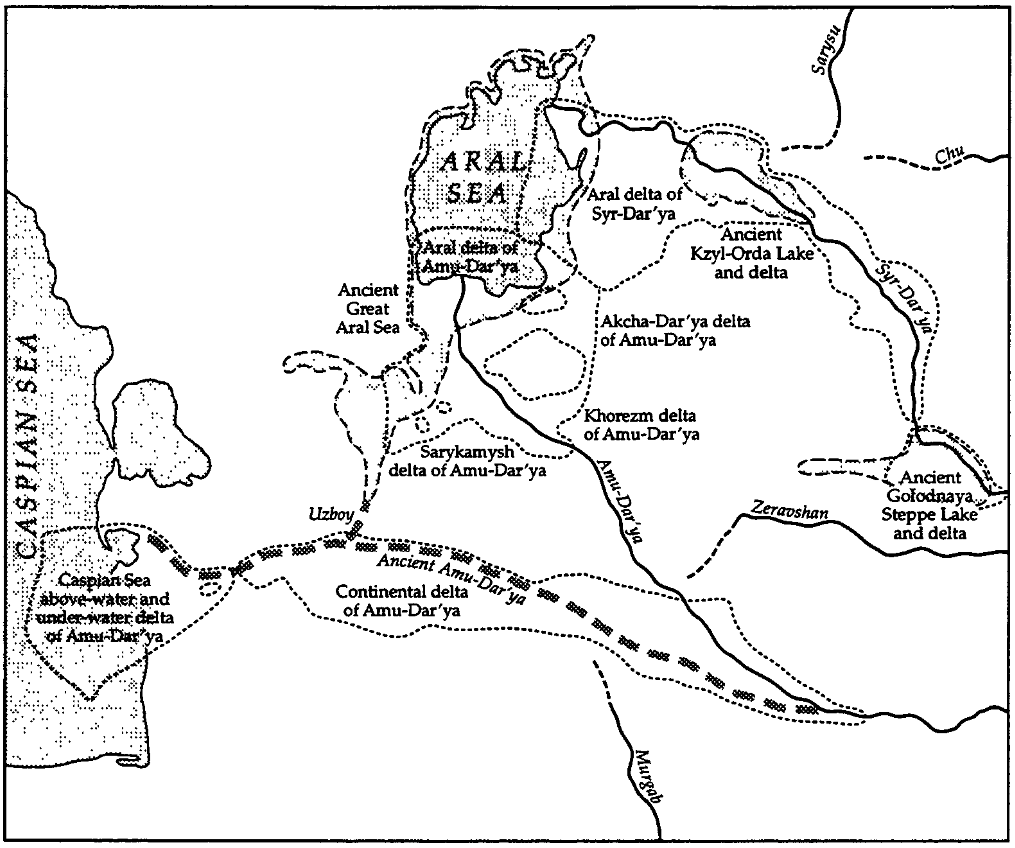


Figure 3. Development of irrigation zones

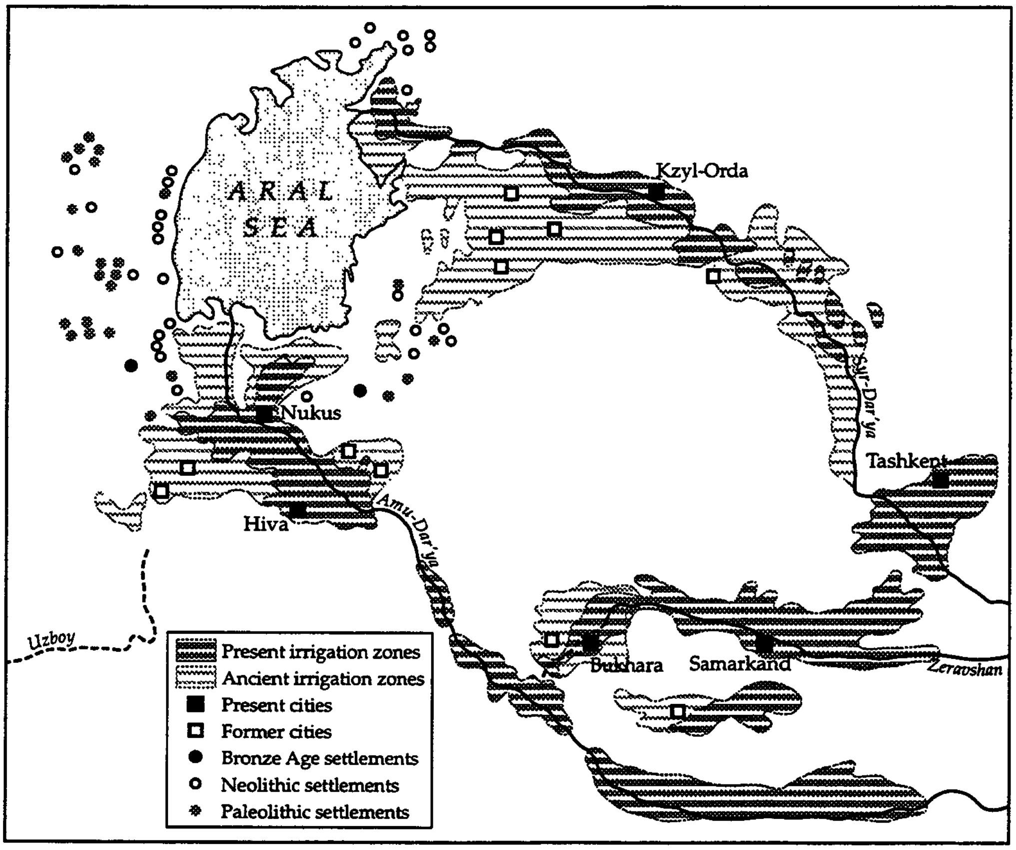
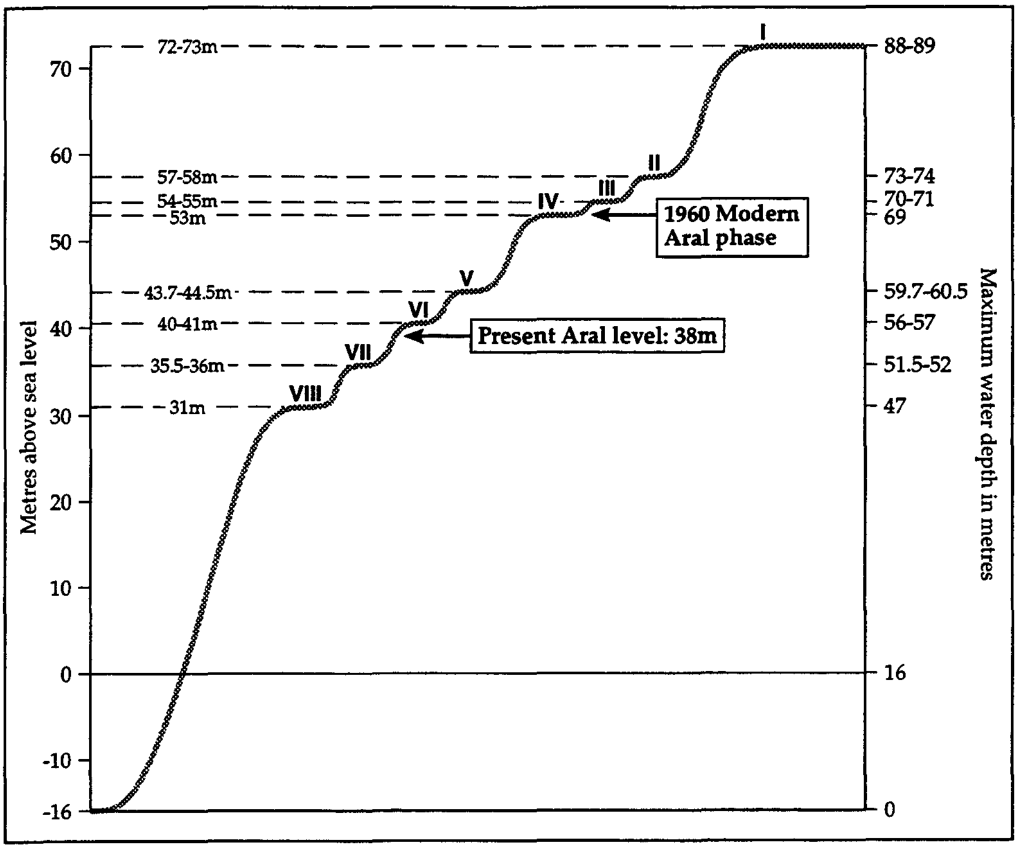


Figure 4. Terraces of the Aral Sea



Terrestrial habitats and vegetation cover

ASSESSMENT OF DESERTIFICATION PROCESSES IN NATURAL COMPLEXES OF THE SYR-DAR'YA DELTA

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The principal idea of the authors has been that the ecology of the present Aral Sea delta system should be evaluated from the point of view of the expansion, development and trends of the desertification processes in the region.

The research was conducted in the following directions:

- Study of the formation and functioning of the natural complexes in the desiccated bed of the Aral Sea. Modeling the dynamics of the movement of water-soluble substances in the soil exposed to desertification. Modeling the deflation-accumulation processes, which affect the natural complexes of the desiccated sea bed.
- Finding out and assessing the development patterns of the Syr-Dar'ya ecosystems.
- Combined ecological and economical evaluation of the natural complexes of the Syr-Dar'ya delta.

The mitigation of negative influences of human activities and stabilization of natural and anthropogenic processes in the Priaralie require measures which could be best be approached by systems analysis.

Over 30 years, the landscapes of the Kazakstan Priaralie developed on the background of desertification. Therefore, attention in the present research was focused on the processes developing on the desiccated Sea bed. Monitoring conducted from 1978 to 1994 has confirmed that the evolution of the affected territory is dominated by deflation-accumulation and halo-geochemical processes.

In the last years, the interest of scientists somewhat faltered in the study of the processes on the desiccated sea bed, although it could justly be seen as a unique natural laboratory, with no analogy to it anywhere in the world. This is probably connected with the many initiatives and discussions about the restoration of the Aral Sea and inundating the desiccated territory. However, sinking of the sea water level persists and every year new areas are added to the dried up sea bottom. Thus, we consider the formation of natural complexes at the desiccated sea bottom as the final link in the chain of anthropogenic desertification processes.

The natural complexes of the desiccated bed are, at present, fairly well understood as complex dynamic systems, which function and evolve following certain laws.

The landscape of the desiccated sea bottom develops under the action of contradictory processes of salinization and de-salinization, deflation and accumulation, biota

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activity and their waning into a passive state. By a system of mutual relationships, these opposed processes are integrated into the natural complexes, which evolve at the former sea bottom. Observations of eolian processes in the representative zone (Kaskakulan control profile) indicate that the landscapes tend to stabilize and, with time, the young natural complexes which develop on the desiccated sea bottom, become more and more like those of the continental zone.

Repeated surveys in the Kaskakulan zone (1978, 1980, 1994) made it possible to determine the general trends and intensity of deflation accumulation processes (Geldyeva, 1985). The highest intensity was observed on landscapes of medium lifetime, with continental development of 3 to 12 years. 3 year old natural complexes consist of inclined flat and slightly undulating surfaces (Fig. 1 - zone 6), consisting of fine sand with sparse vegetation on solonchak soil, the thickness of deflation slices being 1-3 cm/year.

The continental evolution of 5 to 6 year old natural complexes is marked by thinner slices of deflation, 1-1.5 cm/year, with parallel development of accumulative eolian processes. Repeated land surveying (1992-1994) has shown the local formation of accumulative eolian covers, 5-25 cm thick, superposed on the inclined, slightly undulating surfaces of fine sandy soil with clay fillings, overgrown by sparse vegetation. After 10-12 years, accumulative processes prevail, and the eolian cover thickens up to 25-30 cm. The structure of the natural complexes up to 14 and more years of continental evolution has still been determined by the morphology of the former sea bottom, which was marked by extended dunes ('barchans'). The sparsely overgrown or bare, slightly inclined solonchak landform move in South-Eastern and Southern direction, at an annual rate of 10-15 metres, the rate of progression of individual dunes attaining 20-25 metres per annum.

On the basis of satellite images, taken in 1990, and the terrestrial surveys of 1978-1994, landscape maps at scale 1:200,000 could be elaborated, with an indication of landscape-building processes (Figure 1). On the general background of desertification, the map illustrates well the dynamics of deflation-accumulation processes, shaping the surface of the former sea bottom. Three groups of natural complexes could be distinguished.

The most dynamic and short-lived are complexes which persist less than one year. These are marked by irreversible changes from aquatic to sub-aquatic landscape forms.

Considerable changes occur in complexes of medium duration (2-12 years), marked by morphological non-uniformity and intensive quantitative and qualitative changes of internal and external relationships.

Intermediate linkage between maritime and continental landscapes (the so-called 'buffer' zone) are landscape forms of long duration (over 12 years), which develop in conformity with zonal-regional influences. The internal relationships tend to stabilize, both in space and time, and the landscape evolves into a coherent entity.

Observations in the zone of the Kaskakulan control profile indicate that deflationary processes prevailed on the eastern shore, with sand and dust blown in a Southern and South-Eastern direction. In the zone of the Kaskakulan control profile, a 70-80 cm deep layer was eroded by wind in the period from 1978 to 1994. The depth of erosion was, however, less on surfaces at altitude 53 m (about 25-35 cm), which can be explained by the soil properties of deposits close to the former shoreline. Most active deflation processes were observed in 1980-1985, i.e. after some 8-12 years of continental existence of the former sea bottom. At the same time, intensive leaching (desalinization) took place on the top layers of the soil, with a change of plant species.

From 1990, however, a new phase of desalination processes started: deflation removes gradually the upper salty layer of the soil and thus creates better conditions for the vegetation to occupy the dry sea bottom.

The spatial and temporal changes of the desiccated sea bottom are reflected in the dynamics of water-soluble substances in the soil. For the forecasting of these, a prognostic model was elaborated for the Kaskakulan control profile, on the basis of statistical analysis of data, obtained by chemical analyses of soil samples, collected by the field investigations of the authors. By statistical analysis, the homogeneity of distribution had to be proved or, in the case of general non-homogeneity, the boundaries between homogeneous fields had to be established. The frequencies, represented in logarithmic scale on Fig. 2, show a bi-modal distribution, as a result of the superposition of two sets: the 'background' concentrations and the 'anomalies' - with increased concentrations (Table 1). Comparison of the same parameters in samples taken in different years show that the frequency distributions do not change significantly. This probably means that dynamic equilibrium has been established fairly quickly.

Close correlation (R=0.75-0.92) confirms a linear relationship between the parameters (Table 2). The data in the Table prove that the correlative links do not alter, from the top (up to 3 cm) to the lower soil layers (50-150 cm). The distribution of soluble substances in the soil remained practically unchanged during the observation period (Fig. 3a and 3b): sharp increase in the top layer (depth 5-20 cm), and fairly uniform distribution, with some fluctuations, underneath (to depth 300 cm). Along the length of the Kaskakulan control profile, salinity increases twice, from West to East, along a 26 kilometre-long line, from the water edge, to the original bank. One-dimensional distribution models of the components (Fig. 4, 5) show the dry residuum of HCO_3, Cl, in the top layer (5-20 cm) and deeper layer (50-250 cm) (Figures 4 and 5). The variability of salinity in both layers was also explored along the profile. The increase of total salinity towards the former Sea shore (of 1960) is, most likely, the consequence of lithology of bottom deposits and wave action.

The field expeditions of 1994 have confirmed the assumed trends towards stabilization, owing to the desalinization of the surface by deflation and simultaneous spreading of *Haloxylon aphyllum*.

At the beginning of the observations, in 1978, the morphology of natural complexes at the desiccated bottom was simple (bare solonchak plain, with a mosaic of wet and crusty solonchaks). By 1980, owing to the desiccation of the surface and deflation processes (wind erosion), the landscape morphology becomes more complex (Geldyeva and Budykov, 1987). Within 2-3 years, spots of *Haloxylon aphyllum, Halocemum strobilaceum* appear, provoking a slight accumulation of cohesionless soil in the wind shadow. The solonchak area decreases every year, due to the loss of salinity from the top layer, the contours slowly being overgrown by halophytes. By 1980, specimens of *Haloxylon aphyllum* were recorded and, up to 1987, they spread over a 4-4.5 km. wide belt, interrupted by bare spots of solonchak. By 1994, after 20-22 years of development in continental conditions, continuous growth of *Haloxylon aphyllum* could be observed, 5-5.5 km in width, covering 60-80% of the area, with good durability. The parts of the desiccated bottom at altitude 53 m. with higher salinity of the loamy sand and silty soil, are also exposed to deflation, though at a slower rate, and they become colonized by some typical desert plants, such as *Halostachys caspica, Calligonum aphyllum, Ammodendron bifollium, Lepidum* sp. (Fig. 6).

It can be concluded from the present processes at the Kaskakulan reach, that the following types of natural complexes develop on the former shallow water zones of Eastern Priaral:

a) inclined solonchak plains composed of fine-grained silty sand, with *Holocnemum strobilaceum, Halostachys caspica* vegetation (over former island ridges);

b) flat depressed solonchak plains with thin sand cover brought by wind, with *Haloxylon aphyllum,* and exposed to intermittent deflation-accumulation and salinization-desalinization processes;

c) inclined flat solonchak and takyr-like plains, with *Halostachys caspica* and *Holocnemum strobilaceum* vegetation, and slow prevalence of zonal desert species.

An important aspect of the research was to find out the organization patterns of the present ecosystems in the Syr-Dar'ya delta. Natural ecosystems are here called territorial complexes consisting of two basic parts: abiotic environment and biota, with external and internal cyclic fluxes of energy and matter (Tansley, 1935).

The actual Syr-Dar'ya delta is marked by a complex spatial structure of the ecosystems, generated by the physical and geographical features of the region, age-long agricultural land use and impacts of actual processes (Evstafiev and Rachkovsy, 1991).

The delta territory is located in the desert zone. Average annual precipitation is around 120-130 mm., the sum of positive daily temperatures reaches 4000°C, and annual evaporation from open water surface exceeds the amount of precipitation ten times.

The hydrogeological regime greatly affects the ecosystem. The heavily saline groundwater is close to the surface and the concave shape of the impermeable bed rock prevents the flow of groundwater towards the Aral Sea. The distribution and flow of the groundwater is strongly influenced by the limited discharge of the Syr-Dar'ya and water used for irrigation. Ecosystem dynamics are exposed to the impact of the sinking levels of the Aral Sea.

The arid climate, combined with the closed drainage area causes soil salinization in any part of the topography. Salt blown in by winds from the desiccating sea bottom also contributes to the positive salinity balance.

The main result of ecosystem studies is the ecosystem map, in scale 1:500,000. The map was prepared by using satellite imagery from "Landsat" (1993) and data obtained by terrestrial investigations in 1993-1995. The map comprises information on inventory and spatial structure of the natural ecosystems.

The mapping unit was the elementary ecosystem. The ecosystems are part of the landscape, and our main attention was given to the study of relationships between vegetation cover and topography. The map legend was compiled by regional-typological principles and comprises 26 items, structured in sections.

Specific feature of the territory is the combination of zonal (automorphic) and intrazonal (hydromorphic) types of ecosystems, which assume particular places in the topography.

In the legend, these were merged in ecosystem classes and divided into sections of first order: (I) ecosystems of inter-delta residual tableland; (II) ecosystems of delta plains; (III) ecosystems of relict shores and primal sea plains; (IV) agro-irrigation ecosystems.

Each ecosystem class is then subdivided into second order sections, according to the conditions of its genesis: by the meso-relief type and character of soil humidity. In the legend, the sections of second order sections are marked by letters (A,B,C,D). In each ecosystem type edaphic variants are defined, according to the mechanical structure, salinity and water regime of the soil. These factors are indicated by plant communities. In this way, the sections of the legend illustrate the correlations between the principal components of the ecosystem: meso- and micro-relief, vegetation and soil. The legend also indicates the present state of the ecosystem and, if applicable, the trends of its development: desiccation, desertifying, desert.

For irrigated agricultural land, which is no longer exploited, a series of ecosystems were used as mapping units. Each member of the series corresponds to a certain state of natural vegetation.

If, on a mapping unit, two or more ecosystems are present, their combination or overlapping is noted by the + sign. Doing so, the first number denotes the ecosystem which occupies more than 50% of the territory; the second number – up to 30%; and the third number – less than 10%.

Zonal types of ecosystems are present on elevations within the delta areas. They are affiliated to elevated well drained plains, created by accumulation (A) and are present as two sub-zonal types: on brown desert soils of the northern desert (1,2), and grey-brown soils in true deserts (3,4).

Dominating species on these areas are *Salsola orientalis, Kochia prostrata, Nanophyton erinacaeum* and *Anabasis aphylla*. For the landscape, *Artemisia terrae-albae* is important.

Besides the zonal types of ecosystems, automorphic ones occupy important areas on elevated eolian plains (B). Their spatial differentiation and biological diversity depend on the altitude of the rugged landscape (5,6,7). Plant associations are composed of psammophytic species (*Haloxylon persicum, Calligonum aphyllum, Ammodendron argentheum, Lyceum ruthenicum*). Ephemeral and ephemeroid species are abundant in early Spring (*Anizantha tectorium, Carex physodes, Poa bulbosa*). Subdominant species are Graminae (*Agropyron cristatum, A. fragile, Elymus giganteus*).

Automorphic ecosystems of the drained accumulative (A) or eolian (B) plains form habitats on homogeneous and mosaics on non-homogeneous landscapes, and combine with semihydromorphic ecosystems (C, D). The latter are confined to depressions (8,9,10) and sandy massifs with shallow groundwater (11).

Intrazonal (hydromorphic and semi-hydromorphic) ecosystems are represented by two classes: delta plains ecosystems (I) and ecosystems of relict shores and primal sea plains (III). They are differentiated by origin, formation and evolution.

Delta plains ecosystems are marked by spatial complexity and high dynamism. The main factor of their generation is the hydrological regime of their locality.

In low surfaces between river channels (A) meadow ecosystems develop on saline alluvial meadow soils. Reed vegetation associations (*Phragmites australis*) are significant for the landscape. Depending on ecological conditions of the habitat, different grass sorts and one-year varieties (*Salicornia europea, Suaeda salsa*) appear. Their floristic diversity is greatly restricted by salinization.

On elevated land forms halophytic meadows prevail (*Aeluropus litoralis, Pucinella distans*) with the participation of shrubs on meadow solonchaks (13) and hyper-halophytic semi-shrubs (*Anabasis salsa, Halocnemum strobilaceum*) and shrubs (*Tamarix hispida, Halostachys caspica*) on ordinary or secondary solonchaks (14, 15).

On natural levees of the Syr-Dar'ya and delta channels, tugai ecosystems (flood plain forests) are partly preserved, but lately severely restrained by lack of water supply (16, 17).

Low-lying parts of the delta plains are occupied by mono-dominant reed vegetation (*Phragmites australis*) on alluvial soils of swamp series (18).

The class of relict shore and primal sea plains (III) unites different types of new ecosystems, developing on the desiccated sea bottom. These are unstable in space and time and are of simple structure.

On newly dried-out parts of the sea bottom, in the beach zone (C), hyper-halophytic ecosystems develop, dominated by *Salicornia europea* and *Suaeda salsa*, on marsh solonchaks (24). They live a short time, maximum 5 years (Vuhrer, 1979).

In the former shore zones, 1960-1980, post-hydromorphic and hydromorphic accumulative and eolian ecosystems develop, on drying (B) and desertified (A) saline soils and solonchaks (19, 20, 21, 22). Vegetation cover is fragmented and represented by mono-dominant groups of one-year varieties (*Climacoptera aralensis, Petrosimonia triandra)* and shrubs *(Tamarix hispida, Halostachys caspica, Lyceum ruthenicum*).

On seaside sand, psammophytic shrubs start to grow (*Eremosparton aphyllum, Tamarix ramosissima, Nitraria schoberi).*

Patches of abiotic ecosystems without vegetation are scattered over the desiccated sea bottom. By ecological parameters, these are in extreme conditions of desertification, with pronounced destructive processes (desiccation and salinization of the soil, mobility of surface deposits). It is impossible to predict the duration of their existence or the type of vegetation which may develop. They combine with other ecosystems of the primal sea plain, and due to their small area, can not be shown on the map of the given scale.

Since a very long time (7th and 5th centuries B.C.), irrigated agriculture has been a powerful factor of anthropogenic transformation of the ecosystems of the Syr-Dar'ya delta. The recent agricultural land use with the application of extended irrigation network created ecosystems with irreversibly disturbed natural structure, dynamics and functioning. In the legend of the map, these are united in the class of agro-irrigated ecosystems (IV). Two types are distinguished among them: irrigated fields and farms (25), and waste agricultural land, with various states of restored soil and vegetation (26).

The map of the present status of delta ecosystems can be used as the basic map for presentation of assessments, forecasting and recommendations.

The ecological and economical assessment of the natural complexes in the delta should be approached through the analysis of land use patterns and their stability to anthropogenic impacts.

The landscape resource potential was assessed on the basis of the typological landscape map of the Kazakstan part of the Priaralye (scale 1:500,000), comprising the assessment of agricultural and water resources (Geldyeva et al., 1986). Special attention was given to the anthropogenic disturbance of landscapes (Table 3).

Agricultural fields occupy 54.3% of the total delta area, and are mainly situated on the accumulative-alluvial plains. Of the agricultural fields, pastures occupy 96.4%, arable land 1.9%, hay fields 1.7% (Table 4). The most productive pastures are located in the Syr-Dar'ya flood-plains. Compared to 1965, the productivity of pastures decreased 6.5 times, and in 1995 amounted to 150-200 kg/ha. Out of the 1,664,100 hectares of pasture land in the delta, 1,318,000 hectares are exposed to deflation (wind erosion), among which 1,000,300 hectares are most strongly affected, because of the light soils (sand and sandy loam soils occupy over 64% of the delta area). The largest surfaces endangered by deflation and salinization are situated on the accumulative-alluvial plains, with a total area of 1,465,100 hectares (Table 5).

Irrigated arable land in the accumulative-alluvial delta plain occupies 32,400 hectares. All irrigated land is exposed to secondary salinization, with medium and high level of salinity at 13,700 hectares. In 1993-1995, rice was cultivated on about 64% of the irrigated land, fodder on 28% and vegetables and fruits on 8%. The economic efficiency of rice cultivation in the Kazalinsk irrigation zone is questionable, owing to the ecological disturbance caused by shortage of water resources, deterioration of the soil, absence of drainage network (Fig. 7) (Skorintseva, 1992).

The development of agricultural land use from 1960 to 1995 is illustrated in Fig. 8. The area of hay fields and, from 1980, of arable land, show a decreasing trend, resulting in a general decrease of the agricultural land use from 1989 onwards. Field investigations have confirmed the trend of converting arable land and hay fields into pastures.

The ecological map (Fig. 9 and Table 6) was compiled on the basis of ecological and economical assessments. The disturbance of landscapes is subdivided into the following categories: 1. Critical - referring to accumulative-alluvial plains with deep and irreversible changes of the landscape and general deterioration of habitat; 2. Strained - generally attributed to landscapes of denudation-structural and accumulative-eolian plains; 3. Satisfactory - landscapes predominantly related to former marine (dried sea bottom) and new marine plains (Skorintseva, 1993).

The current desertification processes were marked on the map by a system of indexes, by using the following criteria: erosion, by the area affected by heavy erosion (20-40% of the total territory); depletion of pastures - by the loss of biological productivity and percentage of grass cover; deforestation - by forest cutting over the permissible rate, soil contamination by pesticides - by the transgression of permissible concentrations (decreed by the Ministry of Ecology of Kazakstan); soil contamination by heavy metals - by surpassing the critical Clark's content.

During many years, extensive one-crop cultivation was going on with the use of toxic chemicals, containing organic phosphorus and chlorine, highly toxic and stable compounds such as DDT, bidiphos, lindane, hexachloran, etc. Insecticides amounted to 15-25% of all chemicals used. Phosphor-organic pesticides such as ROGOR, Phazalon, Trichlorform, Dipteresx, represented about 6.3-8.5% of all pesticides. Residual content of DDT in the soils varied around 0.140-0.104 mg/kg and slightly decreased with the years (1960 - 0.168 mg/kg; 1995 - 0.166 mg/kg) and in many cases exceeded the permissible concentrations 3-5 times. In recent years, the use of pesticides tended to diminish. Many farms in the Kazalinsk district sharply reduced the use of rice herbicides. By 1989, on saline soils $ZnSO_4$ started to be used for rice and cereals. In soils of the Kazalinsk area, Cu compounds were found, which are highly accumulative and promote the growth of plants.

Excessive use of mineral fertilizers, over the standards for the regions, led to the deterioration of the Syr-Dar'ya water quality (Table 7).

The level of contamination by pesticides is highest in the lower Syr-Dar'ya. For instance, after field data of Kazhydromet, the permissible concentrations of DDD and DDT were surpassed 3 to 5 times downstream from Kzyl-Orda, and by Lindane and hexachloran 5 to 7 times, near Kazalinsk. Petroleum residues are among the harmful substances regularly present in the Kazalinsk reach of the Syr-Dar'ya. The average annual concentration of nitrates exceeds the permissible limits 1.1-3 times. High contamination by pesticides was found in the waters of Kamyshlybash lake (according to data of "Ecolas"). The total content of pesticides found in the water exceeded the permissible concentrations by 10 times.

Sanitary survey of the Ministry of Health of Kazakstan in the Kazalinsk region confirmed the impact of pesticides on the level of oncological and lung diseases, affecting the state of the immune system of humans. In the Syr-Dar'ya delta, high levels of enteric infections, oncological, cardio-vascular, gastric-intestinal and respiratory pathologies are typical. Morbidity and mortality of children of an early age are high. Pathological phenomena progress on the general background of ecological disturbances, of which the most hazardous are microbial contamination of drinking water, high salinity, increased pollution of water, air, and food by pesticides. Morbidity from typhoid fever has increased by 25 times in the last 15 years (in some years, 29 times), and reached in Kazalinsk region 120/0000; virus hepatitis morbidity increased 7 times, reaching 1427/0000 (in some districts 2542/0000). Over 60,000 people have suffered from the hepatitis virus and over 70,000 from intestinal infections, only in the last years (data of the Kazakstan Ministry of Health).

The totality of negative natural processes in the Syr-Dar'ya delta landscapes can be attributed to the anthropogenic desertification and increasing general aridity of this region. Ecological and landscape zoning is based on the qualitative and quantitative indexes of the current state of natural complexes in the delta area. Such zoning should be considered as the scientific basis for the assessment of evolutionary trends of natural systems, on the background of anthropogenic desertification. By such research, the level of permissible economical loading of different landscapes can be established.

The cartographic base for landscape-ecological zoning is the typological landscape map of Kazakstan, Priaralie part, at scale 1:500,000 (Geldyeva and Budnikova, 1986). This map reflects the spatial regularity of landscape structure in the Syr-Dar'ya delta (Table 8, Fig. 10).

The map of landscape-ecological zoning can be used for working out solutions of rational land use, taking into account ecological requirements and restrictions. It can be also used for the planning of terrestrial monitoring systems.

References

1. Geldyeva, G.V.: Eolean processes on primary marine plains of the Priaral *Izvestiya AN SSR, Geogr. series,* 1985, No. 5 (in Russian).
2. Geldyeva, G.V., Budnikova T.I.: Spatial and temporal aspects of the functionning of natural complexes at the dryed up part of the Aral Sea bottom, *Vestnik AN KazSSR, 1987,* No.3 (in Russian).
3. Tansley, A.G.: The use and abuse of vegetation concepts and terms, *Ecology, 1935, Vol.16,* N.3.
4. Evstafyev, Yu.G., Rachkovskaya E.I.: Laws of spatial differentiation of desert ecosystems, *Problems of desert reclamation,* 1991, No.3 /4 (in Russian).
5. Vuhrer, V.V.: Initial vegetation growth on dried up shores of the Aral, *Problems of desert reclamation,* 1979, No.3 (in Russian).
6. Skorintseva, I.B.: Development of farming on the Syr-Dar'ya Delta, *Proceedings, Institute or Geography,* Almaty, GYLYM, 1992, (in Russian).
7. Skorintseva, I.B.: Landscape-ecological level of farming in the Syr-Dar'ya Delta, *Proceedings,* Ashhabad, Ylym, 1993, (in Russian).
8. Geldyeva, G.V., Budnikova T.I.: *Landscape map of the Kazakstan part of Priaral,* Scale 1:500,000, 1986.

Table 1. Distribution of water-soluble elements (concentration mg/equivalent)

Element	Background	Boundary	Anomal series
Cl^-	1.2 - 1.3 (13)	1.8 (60)	2 - 2.2 (110)
SO_4^{2-}	0.9 (8)	1.2 (16)	1.5 (31)
Ca^+	0.4 - 0.6 (2.5 - 4)	0.8 (7)	1 - 1.4 (10 - 25)
Mg^{2+}	0.6 (4)	0.85 (7)	1.15 (14)
Na^+ + K	(1 - 1.5)	1.8	2.1

Table 2. Correlation between water-soluble elements

	PO	HCO_3^{2-}	Cl^-	SO_4^{2+}	Ca^+	Mg^{2+}	Na^++K
PO							
		0.256	0.838	0.847	0.789	0.824	0.885
HCO_3''	0.704						
			0.444	0.386	0.371	0.266	0.426
Cl	0.946	0.503					
				0.641	0.601	0.762	0.841
SO_4''	0.953	0.533	0.724				
					0.785	0.741	0.772
Ca	0.822	0.336	0.696	0.810			
						0.731	0.671
Mg''	0.834	0.455	0.793	0.805	0.730		
							0.758
Na''K	0.957	0.428	0.866	0.8	0.719	0.796	

z : 0-3

Upper part of the table - layer z = 0-3

Lower part of the table - layer z = 50-150

Table 3. Degree of anthropogenic disturbance of landscapes in the Syr-Dar'ya delta (January 01, 1995) (the table was composed by the authors according to data of the Kazakh State Institute of Land-use)

Class of anthropogenic landscapes	Type of anthropogenic landscapes	Area (km²)	Prevailing physico-geographical processes	Kind of modern land-use	Strengthening processes in conditions of modern land-use	Degree of disturbance of landscape (%)
1	2	3	4	5	6	7
I Assumed-natural landscapes	1. Landscapes of primary marine plains of relative unbroken	10319	Deflation, aeolian accumulation		Weathering, carrying away of sand and salts, takyr-formation	5
II Agricultural landscapes	2. Irrigated area (ploughed field)	314	Overhumidification accumulation of products of erosion	Raising of irrigated cultures	Salting, overhumidification, washing out of rich (fertile) layer of soils	90-100
	3. Hay fields	294	Salting, channel storage (accumulation)	Provision of feeding grasses and reeds and pasturing of cattles periodically	Salting	60-70
	4. Pastures of accumulative-alluvial flatten and lightly separated plains with halophytic vegetation *Halophytae*	14294	Deflation, salting	Pastures, cattle-driving ways, automobile roads populated sites	Degradation of soils and vegetation	80
	5. Salting pastures, low yielding solonchaks with cereals and halophytic plants on seaside aeolian plains in combination with pastures on meadow *Salsola* sp. +*Aeluropus littoralis*	1204	Sheet erosion, weathering, deflation	Pastures, cattle-driving ways, automobile roads	Salting weathering, local salting	40-50

1	2	3	4	5	6	7
	6. Pastures of denudation-structural rolling plains on gray-brown desert-steppe soils with takyrs and ephemeral, *Anabasis solsa* vegetation, strongly changed *Anabasis salsa+Ephemeroe*	1062	Deflation, takyr-formation along the margins of sand areas	Pastures, populated sites, roads	Degradation of vegetation	90-100
	7. Pastures of aeolian hillock plains strongly changed, with ephemeral, *Artemisia* vegetation *Artemisia terrae-albae*	961	Deflation, aeolian accumulation, takyr-formation	Pastures, populated sites, automobile roads	Deflation, degradation of pastures	70-80
	8. Waste lands with secondary salting and weedy grasses on salty soils *Suaeda* sp., Descurania sophia	1690	Salting, chemical pollution of soils	Particle pasture use	Salting	100
III. Forest landscapes	9. Cultural forest covers	24	Degradation of forests	Cutting of forests	Stoppage, structural rupture of forest and soils	80
IV. Transformed technogenic landscapes	Cities and villages		Deflation in margins of populated sites	Economical buildings, gardens, roads	Deflation	100
V. Road technogenic landscapes	Automobile roads, electric power lines, railway		Deflation, accumulation			100
VI. Aqueous landscapes	Lakes marshes, irrigation network		Salting, degradation of lacustrine systems	Irrigation, farm ponds	Chemical and biological water pollution	100

Table 4. Distribution of land found by landscape type in the Syr-Dar'ya delta (in 1995)

Natural-territorial complexes (NTC), forming in within:	Total area of land	Agricultural lands	of which		
			Ploughed fields	Hayfields	Pastures
	Thousand hectares	Th h	Th h	Th h	Th h
Total	3175.6	1725.9	32.4	29.4	1664.1
Accumulative alluvial plains	1540.9	1489.9	31.4	29.1	1429.4
Accumulative-aeolian plains	96.1	96.1	-	-	96.1
Denundation-structural plains	107.5	107.5	1.0	0.3	106.2
Solonchaks primary marine, accumulative-marine plains	1431.1	32.4	-	-	32.4

Table 5. Saline and deflation affected land in the Syr-Dar'ya delta

Natural-terretorial complexes (NTC), forming in within:	Total area of land		Saline		of which			Danger of deflation		of which		
					lightly	middle	highly			lightly	middle	highly
	Thousand hectares	%	Th h	%	Th h	Th h	Th h	Th h	%	Th h	Th h	Th h
Total	3175.6	100	1010.4	31.8	393.1	13.9	603.4	2045.4	64.4	-	352.5	1692.9
Accumulative alluvial plains	1540.9	4.5	577.1	37.4	370.5	11.5	195.1	888.0	57.6	-	323.7	564.3
Accumulative-aeolian plains	96.1	3.0	2.4	2.5	-	2.4	-	66.9	69.6	-	14.6	52.3
Denudation-structural plains	107.5	3.4	31.2	29.0	22.6	-	8.6	59.1	55.0	-	14.2	44.9
Solonchaks primary marine	1431.1	45.1	399.7	28.0	-	-	399.7	1031.4	72.0	-	-	1031.4

Table 6. Legend of map: "Ecological situation in the Syr-Dar'ya delta", Fig. 9

Type of landscape	Type of anthropogenic influences										Degree of anthropogenic transformation of landscape, %	Modern process of desertification	Ecological situation
	Ploughed field (1) km²			Hay fields, km² (4)	Pastures, km²								
	Total	From them			Lightly changed (5)	Middle changed (6)	Strongly changed			Saline (10)			
		Saline (2)	Waste (3)				Scoured (7)	Strongly scoured (8)	Overgrazed (9)				
Primary-Marine plain	–	–	–	–	–	–	–	–	–	–	less than 10%	Deflation (**L**) Accumulation (**M**) Carrying out of salts (**Q**)	Satisfactory
Marine plain	–	–	–	–	–	–	39	–	21	264	about of 20%	Accumulation (**M**) Deflation (**L**)	Satisfactory
Aeolian plain	–	–	–	–	–	44.0	52.1	–	–	–	about of 50%	Accumulation (**M**) Degradation of pastures (**H**)	Strained
Alluvial plain	314	126	296	291	1429	5718	–	2859	–	4288	more than 80%	Degradation of hay fields (**Hi**) Degradation of pastures (**H**) Salination of soils (**N**) Pesticides pollution (**E**) Heavy metals pollution (**Ei**)	Critical
Denudation-structural plain	10	8	–	3	–	–	637	106	219	–	about of 50%	Degradation of pastures (**H**) Pesticides pollution (**E**) Heavy metals pollution (**Ei**)	Strained

(12) – Sands and solonchaks of the formed shore zone of Aral Sea. **(13)** – Sands. **(14)** – Solonchaks. **(15)** – Takyrs

Table 7. Surface water contamination expressed in multipliers of the permissible concentrations (after data of Kazhydromet for 1 January 1995)

Ingredient	Permissible concentrat. mg/l	Aral Sea	Kamyshly-bash lake	Syr-Dar'ya river		
				Moderately-contaminated (before Kazalinsk) mg/l	Dirty (from Kazalinsk to Amanotkol) mg/l	Contaminated (from Amanotkol to mouth) mg/l
1. Cu	0.001	8	10	1.5	2	2
2. Zn	0.01	7	12	1	2	2
3. Phenols	0.001	4	3	1.2	1.6	1.5
4. Pesticides DDD	0.01	4	4	2	5	3
5. Pesticides DDE	0.01	6	3	1	4	2
6. Pesticides DDT	0.01	6	4	3	5	4
7. Hexacloran	0.01	6	8	2	6	3
8. Lindane	0.01	4	9	3	5	4

Table 8. Legend of landscape-ecological zoning map of the Syr-Dar'ya delta, Fig. 10
Desert landscape zone of moderate belt. Land: Turan-Pribalkhashia. District: Priaralia-Syr-Dar'ya.
Province: Prisyr-Dar'ya desert. Vicinity: Syr-Dar'ya.

Region, area (km^2)	Subregion	Dominant type of landscape	Prevailing absolute altitude (m)	Annual precipitation (mm)	Type of economical activity	Modern processes of desertification
I. Primary-Aral, 1031.9		Primary marine plain, small hillock-sands, barchans, flatten urotshistshes added by sand, loamy sand, loam. Vegetation:- *Halostachys caspia*+ *Halocnemum strobilaceum*, *Suaeda acuminata* +*Atriplex fominii*, *Tamarix hispida*, *T.laxa* on marshes, crust-plump solonchaks, seaside soil with drifted cover, sand soils and takyr-forming solonchaks	164-190	126-170		Deflation, accumulation, salinization of soils
II. Bugun' 1215		Accumulative marine inclined plain added by sand, clays. Vegetation: *Salsola orientalis*+*Artemisia arenaria*, *Poa bulbosa*+*Artemisia terraealbae* on gray-brown desert soils	165-172	130-168	Pasture cattle breeding	Deflation, accumulation, vegetation degradation
III. Syr-Dar'ya 9404	1. Akkol	Accumulative alluvial inclined flatten plain added by sand, loam with gravel and shingles. Vegetation: *Atriplex cana*+ *Anabasis salsa* *Artemisia pauciflora* on gray-brown desert salty soils with solonchaks	72-98	185	Provision of feeding grasses, production of rise, cucurbit cultivation, pasture cattle-breeding	Water pollution, accumulation, deflation, salinization of soils, vegetation degradation as a result of excess of Limited-Allowable Loads on pastures

III. Syr-Dar'ya 9404 (cont)	2. Kamyshly-bash	Accumulative alluvial inclined flatten plain added by sand, loam with gravel and shingles. Vegetation: *Peganum harmala+Euphorbia seguierana+Phragmites australis, Aeluropus littoralis* on alluvial-meadow desert like soils	72-85	178	Production of rice, provision of feeding grasses, cucurbit cultivation summer pasture cattle breeding	Deflation, accumulation, chemical pollution, salinization of soils, vegetation degradation as a result of excess of limited-allowable loads on pastures
	3. Koygoshkent	Accumulative alluvial with erosion separation plain added by sand, loam with gravel and shingles. Vegetation: *Calamagrostis epigeios Aeluropus littoralis, Salsola* sp. on takyr-like solonchaks, marshed soils	63-88	165	Production of feeding grasses, pasture cattle-breeding	Wind erosion, accumulation, soil degradation
	4. Bozkol	Accumulative alluvial inclined flatten plain, added by sand, loam. Vegetation: *Aeluropus littoralis, Phragmites australis, Mixto-herbae, Phragmites australis, Aeluropus litoralis, Salsola* sp., *Tamarix* sp., on alluvial-meadow desert-forming soils with meadow and typical solonchaks	74-78	165	Production of rice, provision of feeding grasses, cucurbit cultivation, pasture cattle-breeding	Wind erosion, accumulation, salinization of soils, soil and vegetation degradation
	5. Kazalinsk	Accumulative alluvial inclined flatten swamping plain added by sand, loam with gravel and shingles. Vegetation: *Peganum harmala+Phragmites australis, Aeluropus littotalis* on alluvial - meadow desert-forming soils with meadow and typical solonchaks	63-84	178	Production of rice, provision of feeding grasses, cucurbit cultivation pasture cattle-breeding	Water pollution, accumulation, wind erosion, salinization of soils, soil and vegetation degradation

IV. Sarykuma 1576		Denudation structural inclined low-rolling plain added by dislocated clays, aleurolites, sand, shingles. Vegetation: *Anabasis aphylla+Artemisia terrae-albae, Anabasis salsa; Atriplex cana; Anabasis salsa + Artemisia pauciflora* on brown desert-steppe, gray-brown soils with debris and salty soils and typical takyrs	84-87	154	Summer pasture cattle-breeding	Deflation, soil and vegetation degradation
V. Urazbay 2680		Accumulative aeolian middle-hillockplain,. Vegetation: *Artemisia terrae-albae +Agropyron fragile, Ephemerae +Mixto-herbae* on hillock sand	85-126	170	Summer pasture cattle-breeding	Deflation, accumulation vegetation degradation
VI. Kuvandar'ya	6. Sabelak	Accumulative aeolian middle-hillock plain with dried lake depressions. Vegetation: *Agropyron fragile, Artemisia terrae-albae, Agropyron fragile, Ephemerae+Mixto-herbae, Salsola orientalis* on hillock sand and sand ridges	70	145	Summer pasture cattle-breeding	Deflation, accumulation, vegetation degradation
	7. Ayak-kuduk	Accumulative alluvial-proluvial separated plain with aeolian reprocessing added by sand, loam, loamy sand with gravel and shingles. Vegetation: *Artemisia terrae-albae, Agropyron fragile* on sand, typical takyrs in depressions	71-95	176	Summer pasture cattle-breeding	Deflation, accumulation, vegetation degradation of Haloxylon forests

Figure 1. Landscape map of the dried out bed of the Aral Sea with leading relief-forming processes

Legend

Rank of landscape: Primary Sea plain

Rank of urotshistshe, short-term state:

1. Inclined flat plain composed of fine-grained sand, aleurolites, with *Salicornia europae* + *Suaeda salsa*, armoured by thick salty crust, on marches solonchaks, with intensive leaking salinization, small mounds, drying cracks and slight fluvial processes.

2. Inclined slightly dissected plain composed of aleurolites with addition of fine-grained sand, with *Salicornia europae* + *Suaeda salsa*, armoured by thick salty crust, on marches solonchaks, with intensive leaking salinization, drying cracks and slight fluvial proesses.

Rank of uratshistshe, middle-term state:

3. Inclined flat plain composed of big aleurites with rare *Atriplex fominii* + *Suaeda acuminata*, armoured by thick salty crust with small mounds, on coastal solonchaks, with local deflation and intensive leaking salinization - (0.3-1.0 cm).

4. Inclined slightly rolling plain, composed of big aleurite, fine-grained sand, with rare *Suaeda acuminata*, *S. salsa* on coastal solonchaks, with area deflation, original stages of accumulative relief forms and little desalinization - (1.0-1.5 cm); + (5.0-25.0 cm).

5. Inclined slightly concave plain composed of fine-grained sand, with *Suaeda acuminata* + *Atriplex fominii* on coastal solonchaks, with slight deflation-accumulation processes, desalinization - (1.0-3.0 cm); + (25.0-50.0 cm).

Rank of urotshistshe, long-term state:

6. Inclined flat plain composed of fine-grained sand, with *Suaeda acuminata* + *Atriplex fominii* on coastal soils armoured by salty crust, with area deflation and leaking salinization - (0.5-1.5 cm).

7. Inclined slightly dissected plain composed of fine-grained sand, with *Tamarix hispida*; *Atriplex fominii* + *Suaeda acuminata* on coastal slightly salty soils, with thin drifted sheet, with area deflation and accumulation - (1.5-3.0); + (50.0-70.0 cm)

8. Inclined dissected plain composed of fine-grained sand, with *Tamarix ramosissima*, *T. laxa* on coastal soils with drifted sand sheet, with local deflation-accumulation processes - (1.0-2.0 cm); + (70.0-150.0 cm).

9. Slightly inclined dissected barchan plain composed of different grain sand, with *Tamarix laxa* on coastal soils with drifted sand sheet, with active accumulation (150.0-250.0 cm).

10. Inclined dissected ridge-barchan plain composed of different grain sand, devoid of vegetation on coastal soils with thick drifted sheet, with aeolian processes + (250.0-300.0 cm).

11. Slightly dissected concave low barchan plain with *Haloxylon aphyllum* on coastal soils with drifted sand sheet in combination with crusted solonchaks, with accumulation-deflation and desalinization - salinization processes + (70.0-150.0 cm); - (2.5-3.0 cm).

12. Flat plain with *Tamarix laxa*, *Halostachys caspica* on crusted plump solonchaks in combination with coastal soils with drifted sand sheet, with deflation-impulverization processes - (0.5-1.0 cm).

13. Dissected hillock plain composed of different grain sand, a lot of shells, with *Tamarix laxa*, *Calligonum aphyllum*, *Ammodendron bifolium*, *Stipagrostis pennate* on sandy soils, with accumulation - deflation processes + (1.0-1.5 cm); - (0.3-0.5 cm).

14. Dissected low-hillock plain composed of fine-grained sand, with *Halocnemum strobilaceum* on crusted-plump solanchaks with deflation-impulverization processes - (0.3-1.0 cm).

15. Flat concave in places plain composed of fine-grained sand, with *Halostachys caspica* on crust-plump and crust solonchaks with deflation-impulverization and desalinization-salinization processes - (0.5-1.0 cm).

16. Slightly rolling flat plain composed of fine-grained sand with Haloxylon aphyllum on crust solonchaks in combination with coastal soils with drifted sand sheet, with deflation-accumulation and desalinization-salinization processes + (1.0-1.5 cm); - (3.0-5.0 cm)

17. Flat concave plain composed of fine-grained salty sand, devoid of vegetation with crust-plump solonchaks, with deflation-impulverization processes - (0.3-0.5 cm).

18. Inclined flat plain composed of fine-grained sand with *Tamarix laxa*, *T.elongata* on coastal soils in combination with sandy soils with slight deflation - (0.5-1.0) cm.

19. Slightly inclined concave plain composed of fine-grained sand, loamy sand, with *Phragmites australis*, *Salicornia europaea* + *Suaeda salsa* on wet solonchaks, with processes of hydromorphizm + 0.0.

Figure 2a. Histogram of density distribution of SO_4^{2-} (in log scale)

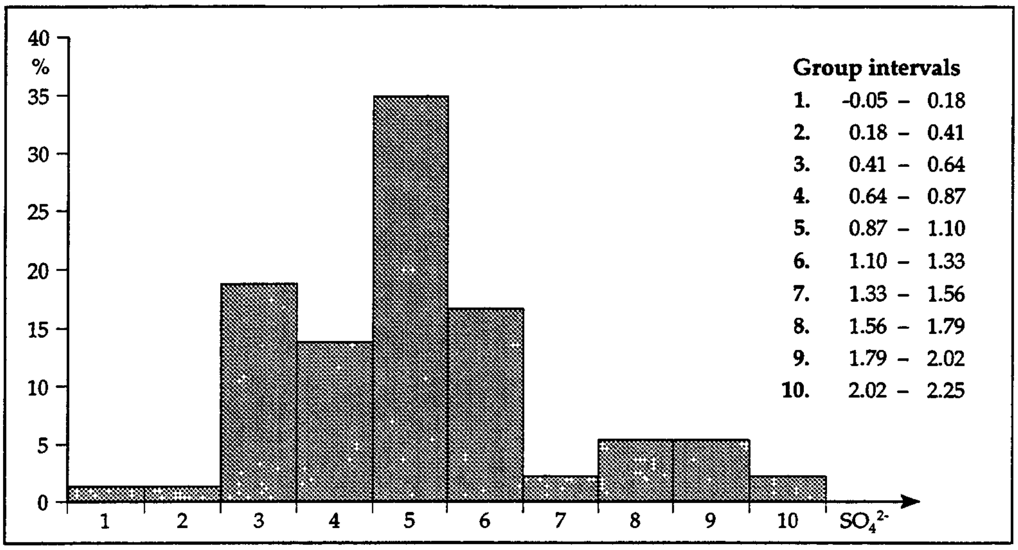


Figure 2b. Histogram of density distribution of Mg^{2+} (in log scale)

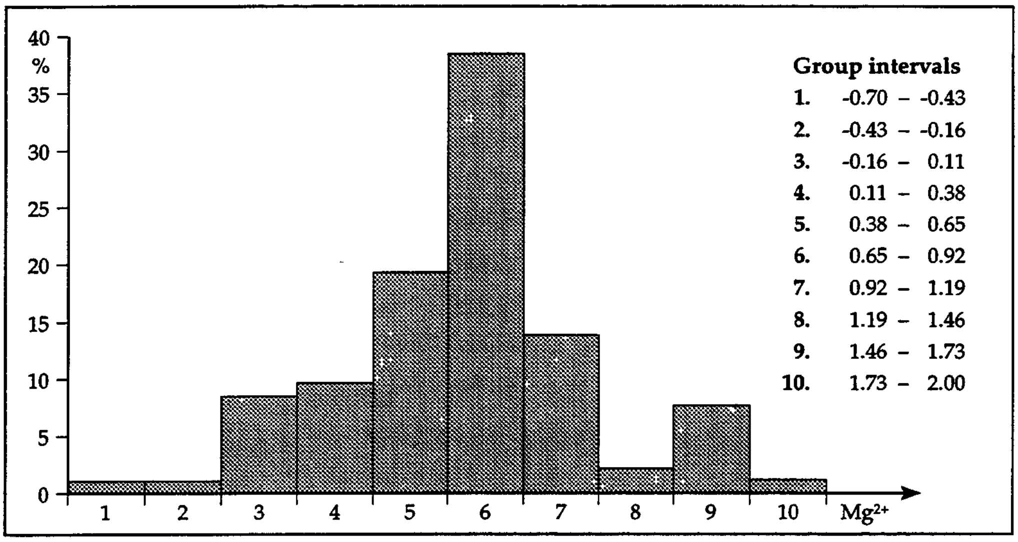


Figure 3a. Vertical distribution of hard remnants (%) in layer 0-300 cm

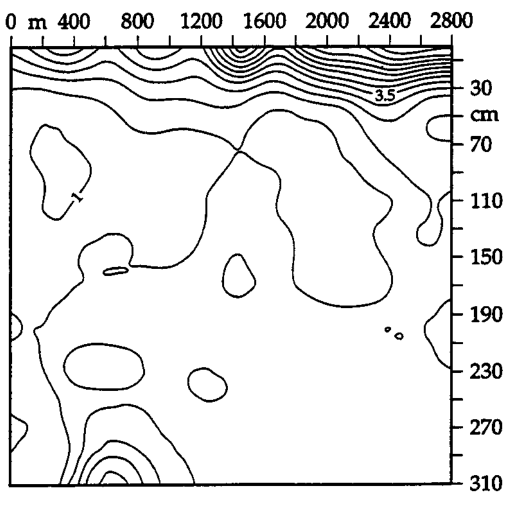


Figure 3b. Vertical distribution of hard remnants (%) in layer below 20 cm

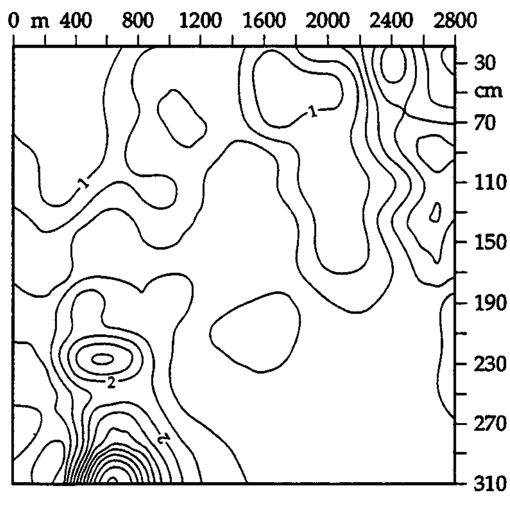
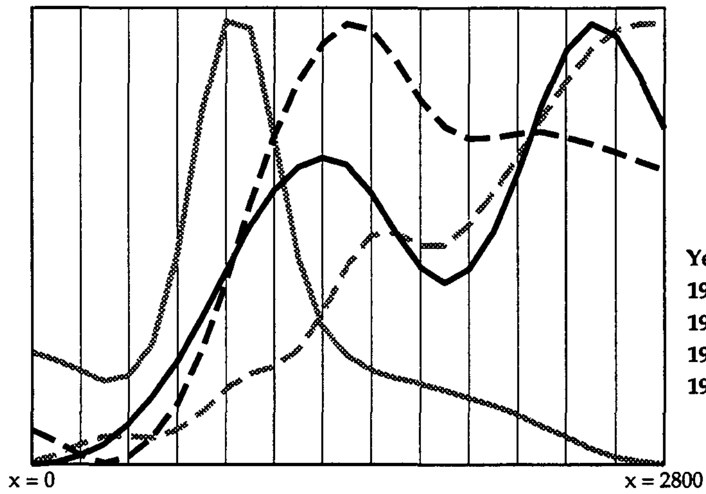
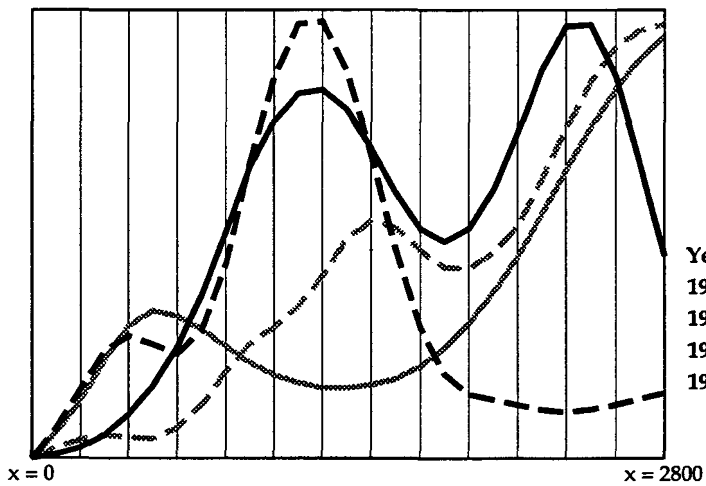


Figure 4. Distribution of hard remnants



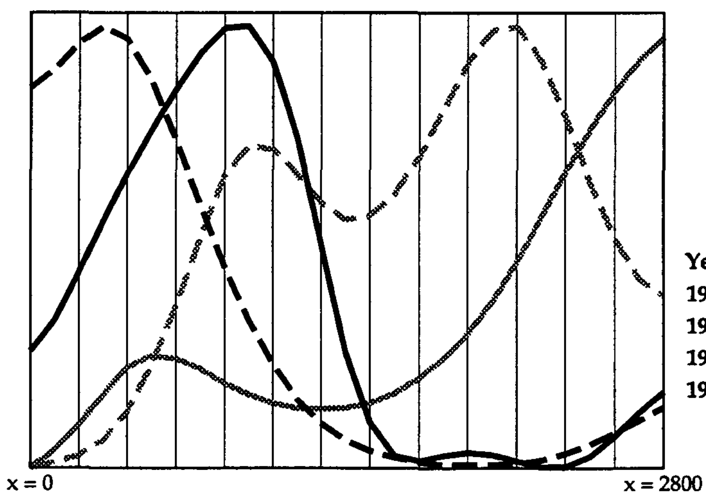
Year	Min	Max	Mean
1977	1.903	4.098	2.771
1978	0.376	0.881	0.502
1980	0.895	2.218	1.601
1981	1.002	2.734	1.829

Figure 5a. Distribution of HCO_3^{2-}



Year	Min	Max	Mean
1977	16.295	32.055	22.198
1978	13.825	32.639	19.915
1980	14.755	20.402	16.146
1981	9.393	19.176	14.330

Figure 5b. Distribution of Cl^-



Year	Min	Max	Mean
1977	0.233	0.296	0.258
1978	12.361	27.203	16.728
1980	0.473	7.174	2.407
1981	0.211	0.253	0.218

Figure 6. Fragment of landscape profiles of the Kaskakulan control zone

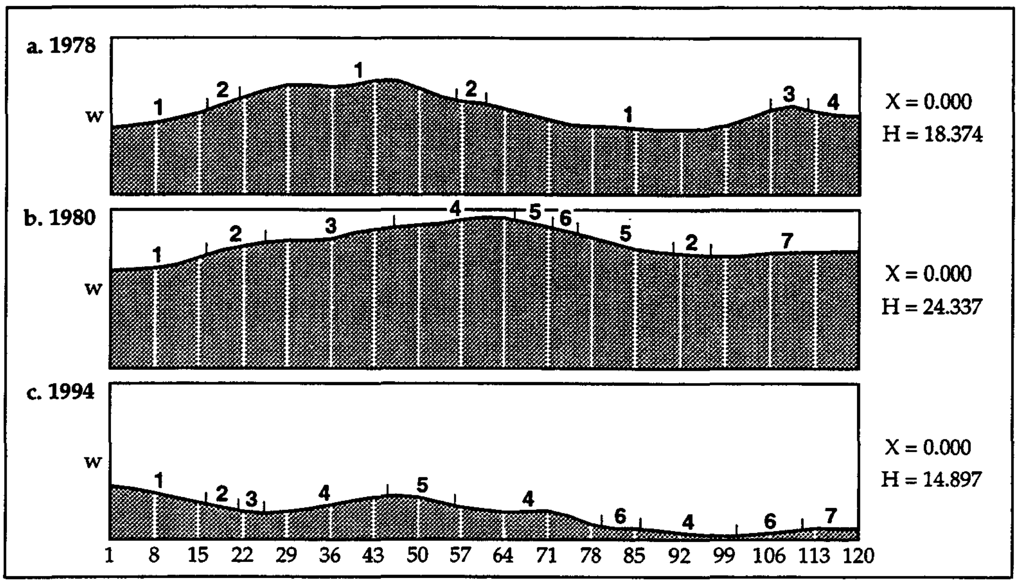


Figure 7. Rice production in the Kazalinsk irrigated area

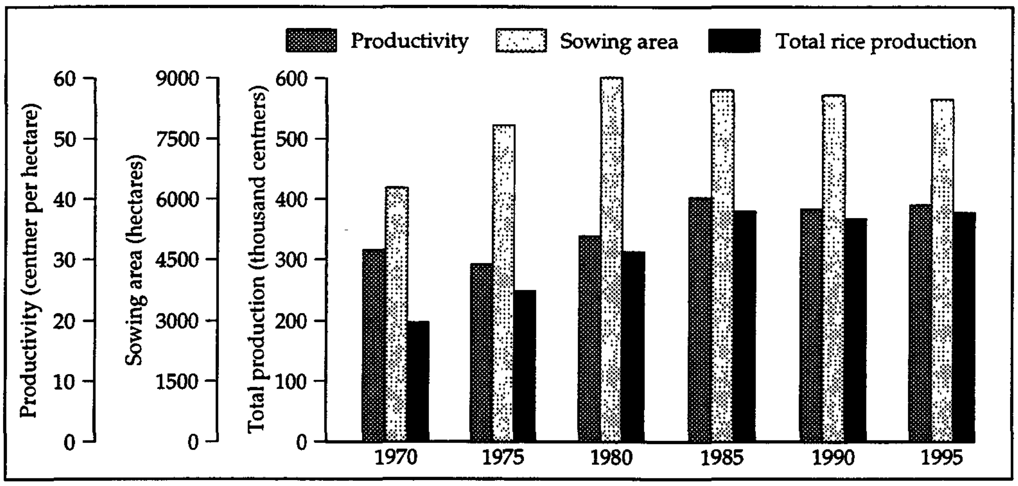
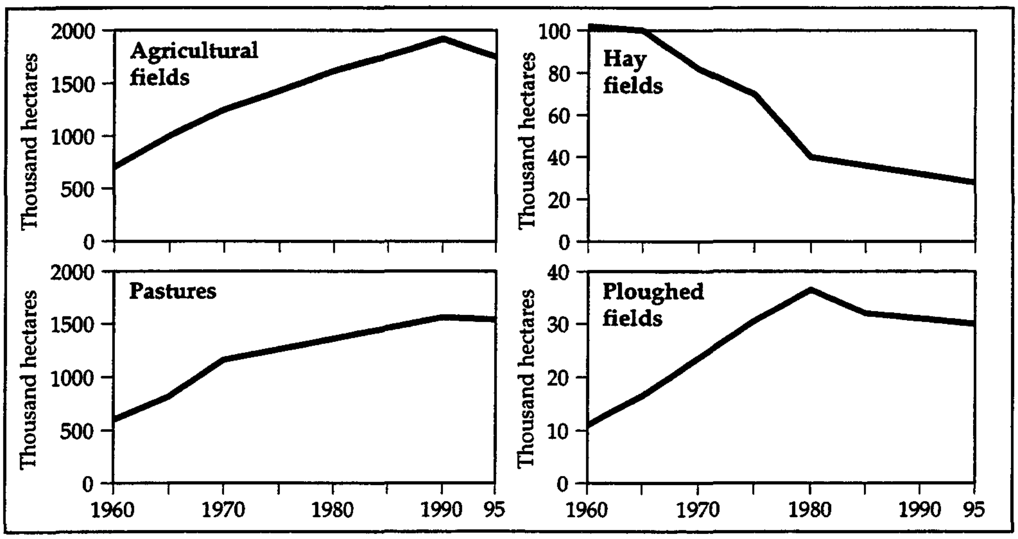


Figure 8. Changes in agricultural structures in the Syr-Dar'ya delta



Legend for Figure 6

1978 Primary sea inclined plain

1. Crust-plump concave plain with solonchaks, composed of fine-grained sand with silt, devoid of vegetation, with intensive leaking regime of salinization and process of sor deflation.

2. Crust-plump plain with solonchaks covered by "shell pavements" composed of fine-grained sand with silt, single shrub of *Holocnemum strobilaceum*, with intensive leaking regime of salinization and sor deflation.

3. Crust-solonchak plain composed of fine-grained sand with single plant of *Atriplex*, with leading regime of salinization and sor deflation.

4. Plump-solonchak slightly concave plain, composed of fine-grained sand, loamy sand, loans, devoid of vegetation, with leading regime of salinization and sor deflation.

1980 Primary Sea inclined plain

1. Crust-plump concave plain with solonchaks, covered by "shell pavements", composed of fine-grained sand, devoid of vegetation with intensive leaking regime of salinization and sor deflation

2. Crust-plump slightly concave plain with solonachaks, covered by "shell pavements", composed of fine-grained, sand single *Haloxylon aphyllum* (0.8-1.5 m height) with leaking regime and sor deflation.

3. Crust-solonchak slightly concave plain covered by "shell pavements" fragmentary, composed of fine-grained sand, devoid of vegetation, with first stages of develoment deflation-accumulation forms of relief.

4. Crust-solonchak slightly inclined plain covered by "shell pavements" fragmentary, composed of fine-grained sand, with embryonic forms of aeolian accumulative relief and single *Peganum harmala*.

5. Solonchak slightly inclined plain with drifted sand sheet, composed of fine-grained sand, with embryonic barchans at different sites of 0.6-0.7 m height, devoid of vegetation and processes of unconsolidated substrate accumulation.

6. Solonchak slightly inclined plain composed of fine-grained sands, devoid of vegetation, with area and limited (local) deflation.

7. Crust-solonchak slightly concave plain composed of fine-grained sand, loamy sand, loans, devoid of vegetation, with processes of sor deflation and first stage takyr-forming.

1994 Primary Sea inclined plain

1. Crust-plump fine-hillock solonchak plain covered by "shell pavements" composed of fine-grained sand, with *Holocnemum strobilaceum* (40% of total projective cover) and leaking regime of salinization and sor deflation.

2. Crust plump slightly inclined solonchak plain covered by "shell pavements" composed of fine-grained sand, with *Haloxylon aphyllum-Halocnemum strobilaceum* (30% of total projective cover) and limited sor deflation.

3. Crust-plump slightly solonchak plain covered by "shell pavements", composed of fine-grained sand, devoid of vegetation, with intensive leaking regime of salinization and sor deflation.

4. Solonchak slightly inclined plain, composed of fine-grained sand with *Haloxylon aphyllum* (2.0-2.5 m height, 50-60% of total projective cover) and area sor deflation.

5. Crust-solanchak fine-hillock plain covered by "shell pavements" fragmentary, composed of fine-grained sand, with *Haloxylon aphyllum-Halocnemum strobilaceum* (70% of total projective cover) and area deflation.

6. Crust-plump fine-hillock solonchak plain composed of fine-grained sand, with *Halocnemum strobilaceum-Haloxylon aphyllum* (50% of total projective cover) and limited deflation.

7. Crust-solonchak concave plain, fragments of crust solonchaks, composed of fine-grained sand, loamy sand, loams, with *Halostachys caspica-Halocnumum strobilaceum* (30% of total projective cover) and areas and limited sor deflation and process of takyr-forming.

Figure 9. Ecological situation in the Syr-Dar'ya delta

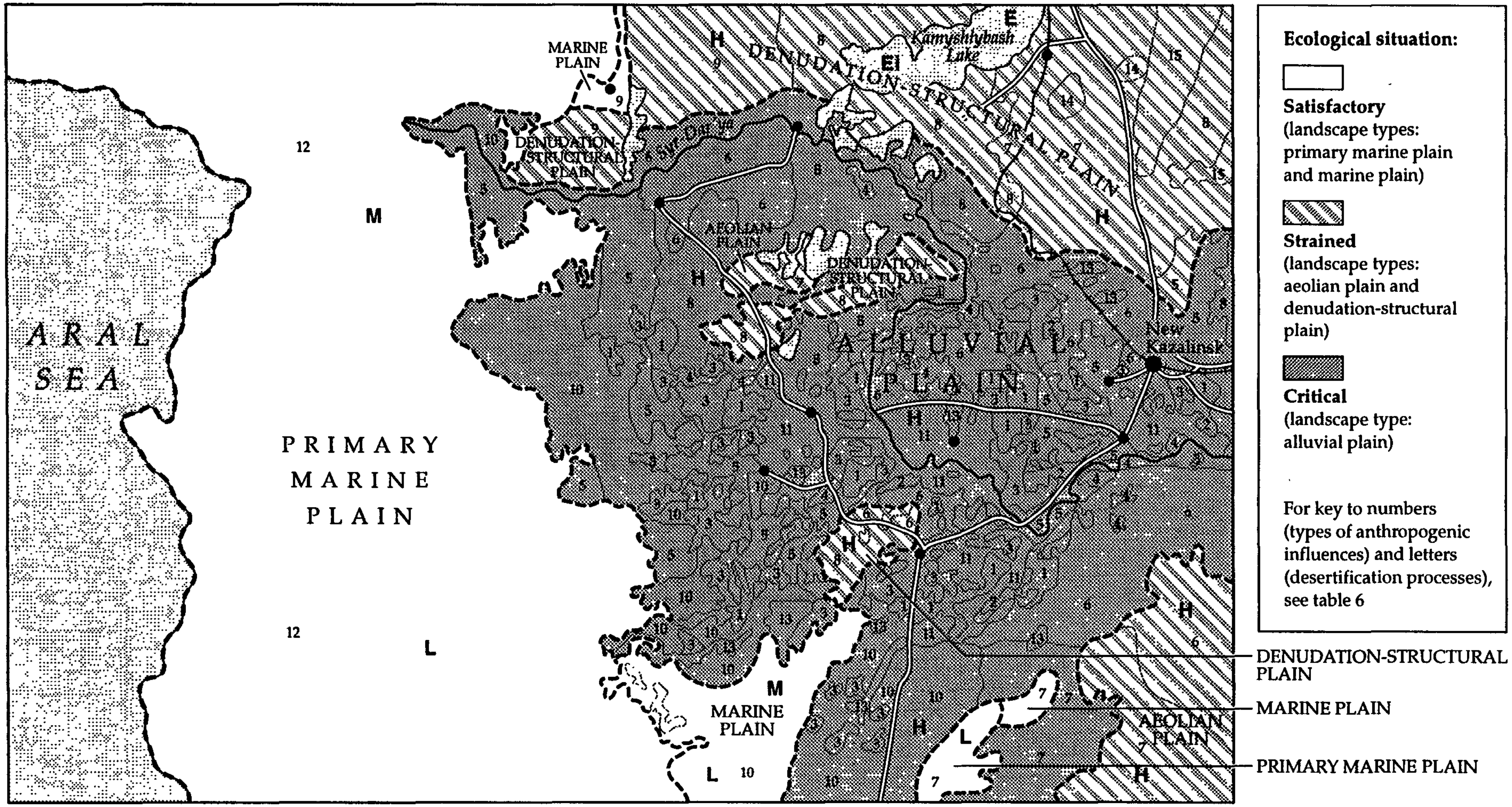
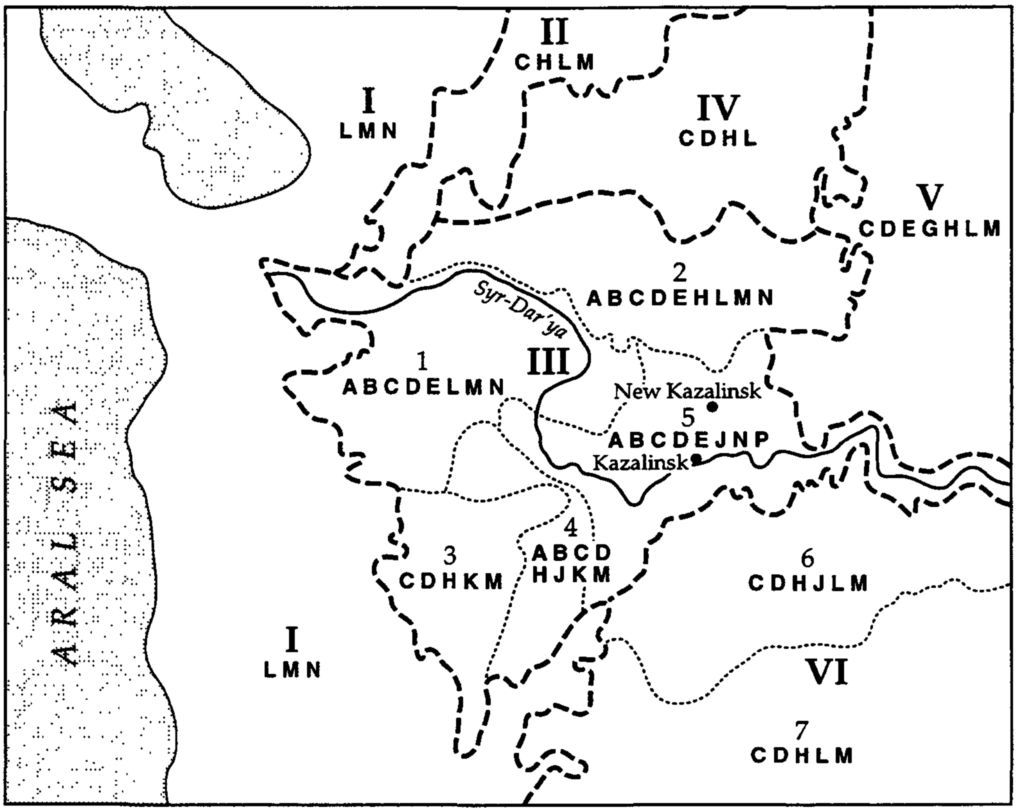


Figure 10. Landscape-ecological zoning of the Syr-Dar'ya delta

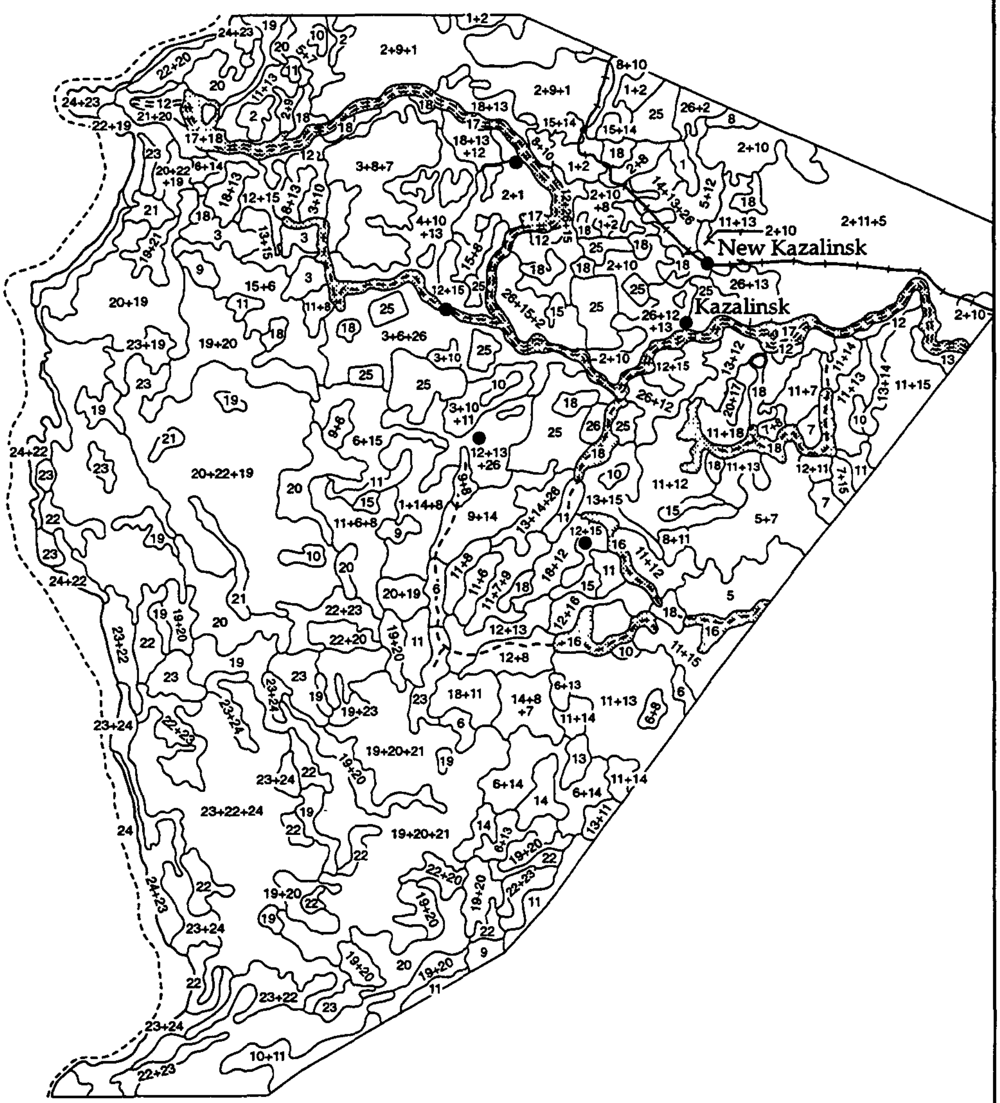


Region		Subregion		Dominant type of landscape
I	Primary Aral			Primary marine plain
II	Bugun'			Marine plain
III	Syr-Dar'ya	1 2 3 4 5	Akkol Kamyshlybash Koygoshkent Bozkol Kazalinsk	Accumulative-alluvial plain
IV	Sarykuma			Denudation-structural plain
V	Urazbay			Denudation-structural, accumulative-aeolian plains
VI	Kuvandar'ya	6 7	Sabelak Ayakkuduk	Accumulative-aeolian plain

Ecological factors:

- **A** Irrigation
- **B** Use of toxic chemicals
- **C** Cattle pasture
- **D** Cattle breeding farms and complexes
- **E** Water pollution
- **F** Exhaustion of fish reserves
- **G** Forest degradation
- **H** Vegetation degradation
- **J** Soil degradation
- **K** Erosion
- **L** Deflation
- **M** Accumulation
- **N** Salting of soils
- **P** Chemical pollution of soils

Map of ecosystems of modern Syr-Dar'ya delta, 1995 (reduced and simplified version)



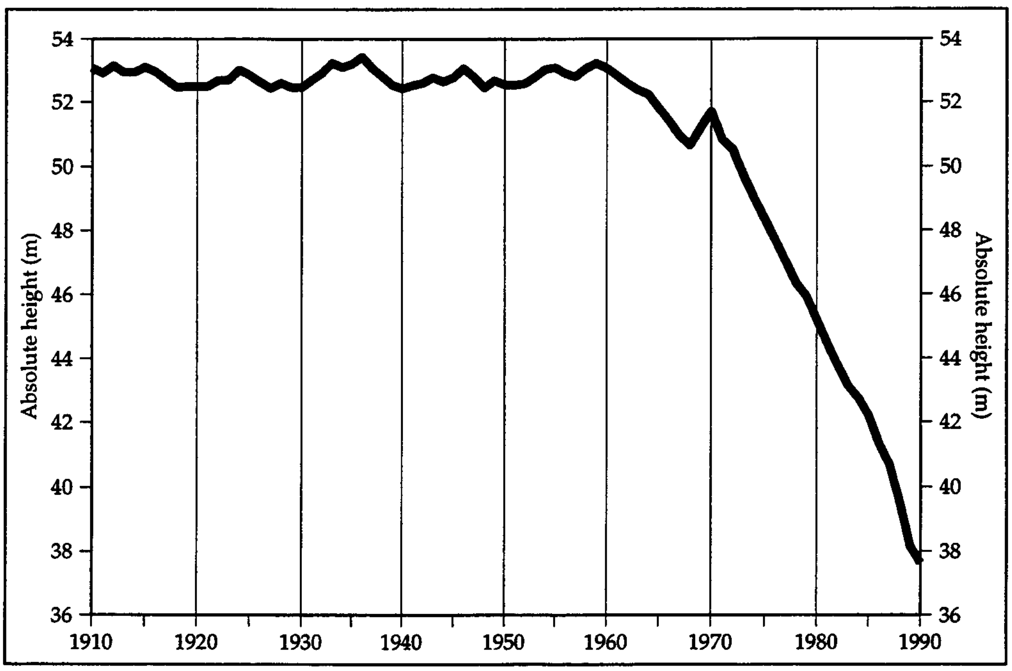
Refer to page 41 for explanation of numbers

Distribution of ecosystems throughout the relief type and water regime

Ecosystem class	Conditions of formation → Relief conditions / ↓ Water regime conditions	Aggraded plains: High well-drained plains	Aggraded plains: Closed weakly drained lowlands	Aggraded plains: Weakly drained and undrained plains	Alluvial and lake-alluvial plains: Depressions between river beds	Alluvial and lake-alluvial plains: Low flood plains and delta's plains	Eolian plains: Dissected plains	Eolian plains: Slightly dissected and graded plains
Interior parts of delta and cut-off lobes	Automorphic	1, 2, 3, 4					5	6, 7
	Semihydromorphic (half-boggy)		8, 9	10			11	
Delta	Hydromorphic				12, 13, 14, 15	16, 17, 18		
Relict offshore and primal sea plain	Posthydromorphic desertificated within the area of relict offshore			19				20
	Posthydromorphic hydromorphic desiccating within the shrinkage area of 1960-1980 ties			21, 22				23
	Marshes within the area of active strand			24				
Agro-irrigated	Flooded, waterlogged and desiccated	← 25, 26 →						

Figures refer to ecosystems map

Diagram of changes of Aral Sea level



PRESENT STATUS OF THE TUGAI FORESTS IN THE LOWER AMU-DAR'YA BASIN AND PROBLEMS OF THEIR PROTECTION AND RESTORATION

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Introduction

In recent decades, great importance has been attached to the conservation, restoration and upgrading of the bio-productivity of tugai forests. The reasons for such interest are the general shrinking of the tugai area and the specific structural-functional features of the highly vulnerable tugai ecosystems.

The lowering of the Aral Sea water level and the regulation of the Amu-Dar'ya flow caused considerable changes in the formation of the vegetation cover in its lower reach. These are associated with the reduction of water and sediment input, changes in the groundwater level, increasing mineralization of river and surface waters.

The ensuing environmental changes affected the various ecological types of vegetation differently. The most significant changes can be observed in the tugai forests, such as the deformation of their ecosystems, disturbance of their structural and functional organization and general degradation, manifested in the simplification of their structure, impoverishment of the floristic composition, reduction of the vegetation and animal biomass, vegetation community successions, leading often to the domination of xerophytes and halophytes.

The definition of tugai vegetation

Tugai (Desertsilveta) are the desert floodplain forests, typical for the bottomlands and river deltas in the arid zone, the main indicators being xeromesophyll and mesothermal trees, large bushes and tall grass of long duration over the vegetation period (with different features of adaptation to the arid climate).

The main biological determinants, which distinguish the tugai from other forest vegetation, are:

- their capacity to endure very wet soil and very dry air;
- a high intensity of transpiration;
- resistance to drought and salts;
- the growing of adventitious roots of different biomorphemes, typical for vegetative propagation of grass vegetation.

Tugai vegetation types and their dynamics

Increasing anthropogenic impacts, intensive use and agricultural developments led to catastrophic reduction of the area under tugai forests. At the beginning of our century, the tugai forests occupied over 350 thousand hectares in the lower reach and delta of the Amu-Dar'ya river. Nowadays, this area is less than 22 thousand hectares. Thus, the total area of tugai forests was reduced by 90% in the past 80 years (Fig. 1).

The tugai forest vegetation can be divided into three main groups: ligneous, bush and tugai grass vegetation. Due to ecological conditions and developments in the inhabited areas, significant changes occurred in the types-edificators as shown below:

Ligneous tugai vegetation	Bush tugai vegetation	Grass tugai vegetation
	1960s	
Populus ariana *P. pruinosa* *Salix songarica* *S. wilhelmsiana* *Elaeganus angustifolia*	*Tamarix ramosissima* *Tamarix laxa* *Halimodendron halodendron* *Lyceum ruthenicum*	*Phragmites australis* *Calamagrostis dubia* *Typha laxmanii* *Apocynum scabrum* *Glycyrrhiza glabra*
	1990s	
Populus ariana *Elaeganus angustifolia*	*Tamarix ramosissima* *Tamarix hispida* *Halostachys caspica*	*Phragmites australis* *Karelinia caspica* *Aeluropus littoralis* *Alhagi pseudoalhagi*

According to records of forest meliorations at the beginning of the century, the following members dominated the tugai flora:

Populus ariana and *P. pruinosa* - 62%
Salix songarica, S. wilhelmsiana - 20%
Eleagnus angustifolia - 18%.

In present days, tugai species are represented differently:

Populus ariana and *P. pruinosa* - less than 51%
Salix songarica, S. wilhelmsiana and *Eleagnus angustifolia* together - less than 14%.

On the other hand, different shrub species enlarged their positions:

Tamarix hispida, T. pentandra, T. laxa - 28%
Halostachys caspica - 7% (Fig. 2).

The change of vegetation cover of the Amu-Dar'ya delta was evaluated by comparing the ecological period of the associations occupying the territory in the early 1960s and in 1995.

The state of the delta as it was in the early 1960s could be appraised from data found in references (Vernik and others, 1964; Ashirova, 1971, 1976; Vegetation cover...1973) whereas data for 1995 were obtained by our own field research. The following types of habitat were designated:

- flood lands - abundant water supply every year, subsoil water at depth 0.5-1.5 m;
- higher flood lands - periodically flooded by river water, subsoil water at a depth below 1.5 m;
- desert habitat - the upper soil does not get river water, subsoil water at depth 1.5-3.5 m;
- saline lands - contain high percentage of salinity (over 2%) in the soil solution around the roots.

Comparison of the data showed that, while in the 1960s associations adjusted to flood-lands made up 35%, by 1995 they were reduced to 15%. The number of associations situated on higher flood lands also decreased, while at the same time, associations of saline habitat increased up to 40%, against only 4% in the 1960s. The relative position of desertification has also changed (Fig. 3).

These data show that in consequence of the aridisation and anthropogenic factors, the number of associations typical for flood-lands decreased, while the number of associations of desertified and saline habitats increased. An explicit tendency of degradation and desertification of the tugai communities can clearly be noted.

Responding to the flow regulation of the Amu-Dar'ya and its tributaries, and also to local influences of man on the flood plains, the vegetative cover transformed itself through a number of multi-variant directions. For the majority of associations, the directions of successive stages were defined as:

- xerohalogeneous - its origin is linked to the decrease of periodical flooding and increase of soil salinity;
- hydrogenous - induced by irrigation and rising groundwater levels;
- halogenous - induced by a complex of changes, including overgrazing, without ground-water level changes;
- xerogenous - connected with acute reduction of flooding, without increased salinization, etc.

The analysis of the present state, structure and dynamics of the tugai communities in the lower reach of the Amu-Dar'ya brings to light three categories of the state of tugai forests: degraded, desertified and comparatively well preserved (mainly on reserved territories). However, despite the differences in their state, all of them are exposed to direct or indirect anthropogenic impacts.

Before the flow regulation of the Amu-Dar'ya, the dynamic changes of the tugais were caused by the incessant modifications of the hydrographic network, which determined the spatial-temporal development of the vegetation, from its beginning to its dying off. In present days, the actual formation and development of tugai communities take place on the basis of the altered and very unstable hydrological regime of the Amu-Dar'ya, leading to successive stages of desertification, which could be ascertained for all described associations.

The main anthropogenic factors affecting tugai dynamics are: uncontrolled cutting, fires, pasturing, ploughing-up and technogenic loads. Depending upon the character and strength of the anthropogenic impact, gradual or sometimes very rapid changes in the composition and structure of communities take place, as well as their partial, or often complete replacement.

The direct anthropogenic impact of felling trees and grazing, in a very short time (through a few stages) transforms the tree-shrub communities into pasture ecosystems. Succession changes caused by fires in favourable hydrological conditions may restore the tugai communities, which would become, however, more halophytic compared to the preceding ones. Fires in desertified land damages the tugai communities forever. Irrigated agriculture in direct contact with tugai zones raises the groundwater levels critically (less than 1m below the ground), which leads to the death of the tugai forest. The above described signs indicate that at present all tugai forests in the lower reaches of the Amu'Darya are subjected to active anthropogenic impacts.

The same pattern of degradation can be observed on all tugai territories in Central Asia. Yet, tugai forest ecosystems are of exceptional ecological value, because they offer refuge to numerous representatives of flora and fauna, including rare and disappearing species, which are preserved owing to the specific ecology of the tugai vegetation. Moreover, in the present ecological conditions of the Southern Priaralye, tugai ecosystems become extremely precious, because they retain salt, dust and other harmful substances which arrive from neighbouring degraded areas.

As a rule, tugai communities develop only on the Amu-Dar'ya flood plains, which are regularly flooded. Tugai communities were not observed around shallow, fresh-brackish or saline water lakes, except for some scant, fragmentary sites. On such wetlands, water-swamp type vegetation appears.

The evolutionary pattern of tugai dynamics is presented in Table 1, which indicates in what conditions stable tugai communities exist and what happens when these conditions are disturbed.

In order to test the above-described development trends, additional investigations were conducted on sites long since deprived of vegetation, exposed to anthropogenic pressure. These sites were located in Konlikul region, "Kizil-Djar", and Akalinsk area in the Muinak region - formerly all covered by tugai forests. The analysis of the data obtained by the stationary observations and routine geobotanical investigations, made it possible to predict the development for 20 years ahead, taking into account the hydrological conditions and anthropogenic impacts.

Geobotanical surveys and ecological investigations were conducted annually, over the last ten years on selected permanent sites in the tugai belt. These investigations allowed us to check the accuracy of the predicted developments. Predicted and observed data differed considerably in different conditions. The predicted characteristics were closer to the observed ones in the case of sharper contrasts between present and former moisture of the natural tugai complexes. On one hand, there are tugai communities growing on comparatively moist sites, in more or less stable soil and groundwater conditions, and, on the other hand, there are tugai communities in greatly changed ecological conditions of inhabited sites, where natural propagation of vegetation is very decelerated or non-existent. Tugai communities in advantageous ecological conditions are distinct by their great species diversity and complex vertical and horizontal structure and, under anthropogenic impacts, modifications occur, with the domination of different types of tugai forests. However, such communities are rare in the lower Amu-Dar'ya basin and river delta, so that their total effect is not significant for the development of tugai forests.

Productivity of tugai vegetation

As shown on Table 2, ecological changes from 1960 to 1995 greatly affected the tugai biomass. Since the growth of aerial phytomass is stimulated by abundant moisture, the share of roots in the tugai phytomass increased appreciably in 1995, due to the deterioration of water supply and higher soil salinity. This proves once more that soil-groundwater conditions are the most important ecological factors which influence the formation and growth of tugai vegetation.

Functioning of tugai forests

Tugai communities are important components of the environment: they create a microclimate which enables the plants to survive in conditions of high temperature and short supply of active moisture. Our investigations on the topoecological profile have shown that under the cover of turangoi tugai, at three levels relative to the ground (at a depth of 10 cm, at ground level and at 50 cm above the surface), the air humidity is higher and air temperature lower by 1-2 degrees, than in the brushwood of *Tamarix ramosissima, T. hispida* and in desertified grass tugai, with *Alhagi pseudalhagi*. Daily temperatures and humidity variations are smoother in the ligneous tugai, than in scrub and grass tugais. The change of micro-climate inside the cenoses plays an important role in the progression of desertification and halophytization, by destroying or reducing the vitality of dominant, determinant species. So, in the tugais (*Populus ariana*), more xerophylleous, or drought-resisting types start to appear on the glades being formed by the disappearance of trees.

The landscape-stabilizing and landscape-forming role of vegetation is of paramount importance. It protects against erosion by water and wind, contributes to soil-forming, profile-forming, improving the water regime, etc. Practically all plants on the delta flood plains, being adapted to silts, contribute to the accumulation of alluvium during flooding. The annual silage may amount to 15 cm/yr. Ligneous-brushwood tugais reinforce the stability of river banks and restrain the migration of river channels. While desertification weakens these functions, the anti-deflatory role of vegetation becomes even more important: sand and dust transport was practically absent on areas covered by reed (*Phragmites australis*) or turangoviks (*Populus ariana*). They not only block possible sources of sand-dust, but also intercept sand and dust being blown in from other places. Dust drift was repeatedly observed in Muinak city, wherever the soil was not fixed, as in tugai areas, or with *Phragmites australis*.

By their high transpiration, tugais evacuate part of the water seepage from the river bed and affect the groundwater regime in the surrounding area, lowering its level in the vegetation period and preventing its critical rise during floods. Natural tugai vegetation affects not only the regime, but also the mineralization of the groundwater: turangovniks of tugai forests, owing to their biological properties, serve as powerful biological drainage. They consume significantly more water for transpiration than would evaporate from free water surface. Transpiration depends also on the age of the plants: an increase was observed from 9, 12 or 15 t/ha (stock of trees), to 24.08, 28.2, 31.5 t/ha (undergrowth on glades).

Alluvial-meadow tugai soils are generally located on accrued parts of the relief and are marked by intensive salt accumulation, owing to the climate and lithology. Recent alluvium in Autumn can already contain up to 0.15% of salts. While alluvium covered by undergrowth contains easily soluble sands up to 1%, young tugai lands may contain 3.5% of salts. Most of the salt accumulates around the depth of 1.5 m. In the lower Amu-Dar'ya basin, the humus content of soils is comparatively low (1-3%). With increasing salinity, the humus becomes intensively mineralized, and the soils become less humic.

The shrinking of the forest area and the degradation of tugai forests leads to the floristic impoverishment of the tugai communities. At the present time, many valuable wild varieties are on the brink of disappearing.

On the basis of literature and our own investigations, a list has been made of types of tugai plants, which are about to disappear. The preservation of their genetic fund in natural conditions is of great importance for the national economy as well as for science, allowing us to study the history of flora in the region, their appearance and further evolution.

Among the rare and disappearing types of flora growing in the tugai forests, are the following (Treshkin, 1994):

1. *Sacharum spontaneum*
2. *Erianthus ravennae*
3. *Typha laxmanii*

4. *Apocynum scabrum*
5. *Glycyrrhiza glabra*
6. *Salix wilhelmsiana*
7. *Salix songarica*
8. *Populus pruinosa*
9. *Populus ariana*
10. *Populus diversifolia*
11. *Elaeagnus turcomanica*
12. *Sphaerofisa salsula*

In the past, tugai forests were largely present in Central Asia. Yet now, in consequence of their exploitation and cutting out, they have been preserved only incompletely (Table 3).

Cultivation of tugai forests and planting of tugai trees

Our investigations and studies led to the conclusion that forestry practices in this region are obsolete and neglect the ecological changes that occurred in the last decades.

The restoration of tugai by means of artificial afforestation in the lower reaches of the Amu-Dar'ya is negligible, compared to the scale of forest damage in the region: for each thousand hectares of cut-down forests, only 30 hectares are replaced by plantations, of which annually 50% are written off as dead. Tugai forests could be restored by eliminating (which is not possible) or, at least, mitigating the anthropogenic impacts.

Pasturing is an important factor of the degradation of tugai vegetation. It leads, not only to the depletion of the community structure, but also to the increase of soil salinity and the lowering of sward density, from 70% to 30%, and sometimes even to 1-3%. Moreover, in many cases, pasturing damages the shoots of trees, completely or partially. In such conditions, the young tugais are doomed. Nevertheless, in spite of the totally unsatisfactory state of tugais, we noted their renewal (mainly vegetative) in almost all tracts. The density of shoots is variable (from 400 to 3,500 per hectare), depending upon the degree of disturbance and ecological conditions. Hence, in the framework of general protection of tugai forests, particular attention should be given to the protection of young shoots of arboreal species, or else they are doomed to disappear. Regrettably, nothing has been done so far about this.

The construction of collector drains contributed to the formation of small young tugai forests, but due to the lack of surface flooding, they could not stabilize and can already be considered as desertified forests.

As it is, the reforestation of tugai takes place thanks to the renewal of scrub. The best time for sanitary cuttings, which contributes to scrub regeneration, is the Autumn-Winter period (November-January). After such cuttings, the subsequent scrub renewal increased 1.5-2 times, in comparison with the preceding March-April season.

In the arid climate, soil structure and properties influence significantly the growth and development of ligneous-brushwood tugai types. The water regime of the soil is decisive in this respect. According to the study of soil-water relationships, the basic soil varieties of the lower Amu-Dar'ya region may be divided into three groups:

Group 1 Alluvial-meadow soils – which can store high levels of moisture, and thus are the most apt for reforestation.

Group 2 Residual-meadow-tugai soils – which allow the normal development of ligneous types of tugai, but require measures for the accumulation and preservation of soil moisture.

Group 3 Desertified meadow-soils and saltworts – in which specially selected, most salt-resistant ligneous-brushwood types can grow in irrigated areas, but need protection.

Table 4 lists the local flora types which are recommended for reforestation on the above defined soil groups.

For planting ligneous types admitted in forestry, the following pattern is recommended: inter-row spacing 3 m wide, with 0.–1.0 m distance between the plants in a row; however, other patterns are also possible. In the work plan, both pure and mixed forest cultures should be foreseen. It is advised to fence the sites in the first year of life of the forest cultures, and to set up permanent pilot fields for systematic observation of adaptability, growth, root system development and fruit bearing of the trees. In acute water shortage, preference should be given to artificial afforestion, and it is timely now to establish tree nurseries for this purpose.

The survey of forest area distribution by land category proves that there is still sufficient space available for the implementation of artificial afforestation in the lower Amu-Dar'ya basin (Table 5).

In the lower Amu-Dar'ya basin, forests occupy only 3% of the total basin area. The forests are mainly located on the flood plain of rivers, anabranches, abandoned channels. Therefore, forests can be planted on all the land not used for agriculture.

The successful implementation of such measures would expand twice the present area of tugai forests, which would contribute to the improvement of the microclimate and hydrology in the region.

Conclusions

Our research and the experience of other countries show that a scientific approach is indispensable for the successful conservation and restoration of tugai forests. Our recommendations are the following.

Establishment of a specialized research station. Its main attention must be directed to solving practical problems for the restoration of natural forests, with a minimum of theoretical studies. The main scope of research would concern: organization of arboreta and planting of young trees, selection of best arboreal species of highest quality, adapted to the prevailing local conditions, stabilization of sand, water conservation and forest amelioration.

Taking into account the prevailing ecology of the lower river reach and the Amu-Dar'ya delta, the most important issue of protection and restoration of tugai forests is the organization of reserves and specially protected territories. It should be underlined that, according to our investigations in the Baday-tugai reserve, agriculture in the neighbouring areas also strongly affects the reserve. Therefore, measures have to be worked out on how to limit and minimize these effects. Accordingly, local nature protection (organization of reserves and specially protected areas) can be effective only in combination with rational nature management of the whole territory of the lower Amu-Dar'ya basin.

On the territories of reserves and best preserved tugai patches, standard landscapes should be designated for subsequent study of their genesis and evolution, including vegetation and wild animal population.

Biological protection and restoration methods of tugai biocenoses have to be introduced actively. The essence of these measures is the development of multilayers with complex forest configuration. This will raise the ecological stability and bio-production of tugai as well as provide a better habitat for animals.

The protection of vegetation (herbs, rare species, valuable meadow lands) must be organized in combination with continuous control of the complex environmental protection measures during their implementation and maintenance.

On heavily disturbed patches, where the process of natural self-reproduction in tree-shrub tugai communities is impossible, it is necessary to speed up their degradation, with simultaneous phyto-meliorative works for the organization of pasture culture.

Along the course of the Amu-Dar'ya in its lower reach and especially in the delta, as well as along large canals, it is necessary to set up riparian water-protection zones. The width of such zones must be determined in function of the length and significance of the streams, taking into account the density and self-reproducing potential of the tugai vegetation. According to our research, this can be from 300 to 1,500 metres, and more. In this zone, all construction works, as well as discharge of polluted waste water, must be prohibited. All phyto-meliorative works in territories adjacent to these zones must be correlated with the tugai vegetation development and with the cycles of protected, hunted and other animal species. In this zone, annual flooding of the land must be provided by means of special canals or powerful pumps.

References

1. A.A. Ashirova 'Vegetation of Valley and Deltas of the Amu-Dar'ya and its Economic Use' - Book 1. - Ashkhabad, 1970 - 312p., Book 2 - Ashkhabad, 1976 - 212p.
2. A. Bahiev, S.Y.Treshkin, Sh.V.Kouzmina 'Formation and development of tugai vegetation of Middle Asia under man's impact'// Journal(Vestnik) of Karakalpak Department of Uzbekistan Academy of Science, Nukus: FAN, 1992, No. 3, pp.8-15.
3. A. Bahiev, S.Y.Treshkin, Sh.V.Kouzmina. Karakalpakia 'Present State and Protection of Tugais' Karakalpakstan Publishing House, Nukus, 1994. 72 p.
4. R.S. Vernic, Z.A. Mailun, I.F. Momotov 'Vegetation of Valley and Deltas of the Amu-Dar'ya and its Rational Use'. Tashkent: FAN. 1964. 212p.
5. S.E.Treshkin, Sh.V.Kouzmina, 'Structure of the tree-shrub tugai of the Amu-Dar'ya delta'//Journal (Vestnik) of Karakalpak Department of Uzbekistan Academy of Sciences, Nukus: FAN, 1989, No. 4, pp.35-39
6. S.Y.Treshkin, Sh.V.Kouzmina. 'Present condition of flood-plain forest ecosystems of Amu-Dar'ya and Sumbar-river under the human activity'/ 'Problems of Desert Development' Ashkhabad:Ylym, 1993, No. 2, pp.14-19
7. S.Y.Treshkin. 'Changes in the species diversity of the Tugai communities in the valley of the Amu-Dar'ya River in connection with anthropogenic desertification' //'International symposium on global change in Asia and the Pacific Regions', August 8-10, 1994, Beijing, China. 1p
8. Vegetation Cover of Uzbekistan. Tugai of Vegetation. Tashkent: FAN, 1973. pp. 303-375.

Table 1. Evolution patterns of tugai vegetation in lower Amu-Dar'ya basin

Stage	Soil	Moisture regime	Tugai types
1	Alluvial-meadow tugai soils (non-saline)	Hydromorphous bottomland-alluvial Ground water level (GWL) 0,5-2 m, with light salinization (less than 1g/l); Periodical flooding	Typical tugai groups (*Populus ariana, Salix son garica, Eleagnus angustifolia, Tamarix ramosissima, T. laxa, Phragmites australis, Typha laxmanii)* Anthropogenic impact insignificant; Seed propagation happens
2	Alluvial meadow halophytic soils	Semi-hydromorphous GWL 2-5 m, with mineralization higher than 1g/l Soil salinity penetrates whole profile (over 1%) Bottomland regime destroyed	Desertified tugai groups (*Populus ariana, Eleagnus angustifolia, Tamarix ramosissima, T. hispida, Halimodendron halodendron, Aeluropus littoralis, Alhagi pseudoalhagi)* Significant anthropogenic impact Seed propagation not present
3	Meadow-takyr halophytic soils	Semi-automorphous GWL below 5 m with mineralization 1,7-2 g/l Soil salinity reaches 5%	Halophyte tugai groups (*Populus ariana, Eleagnus angustifolia, Tamarix ramosissima, T. hispida, Halostachys caspica, Salsola dendroides)* Heavy anthropogenic impact; Hydrological regime completely changed
4	Plump saltwort	Automorphous GWL below 7m Mineralization over 2% Soil salinity attains 12%	Halophyte vegetation only *(Tamarix hispida, Halostachys caspica)* Propagation of tugai vegetation impossible

Note: typical tugais change into vegetation dominated by halophytes within 20 years, in the present hydrological conditions and anthropogenic impacts of the lower Amu-Dar'ya Basin.

Table 2. Average characteristics of the main productivity of tugai communities in the lower Amu-Dar'ya and its delta

Tugai type	Ligneous	Bush	Grass	Ligneous	Bush	Grass
Year:	1960			1995		
Phytomass t/ha	91.5	43.6	35.0	69.7	44.2	15.0
Green mass t/ha %	12.4 14.0	6.7 15.0	10.0 29.0	10.7 15.0	5.3 12.0	3.2 21.0
Lignin t/ha %	29.6 32.0	9.1 21.0	0 0	19.8 28.0	8.8 20.0	0 0
Roots t/ha %	49.4 54.0	27.7 64.0	25.0 71.0	39.2 57.0	30.1 68.0	12.0 79.0

Table 3. Expansion of tugai forests in Central Asia

Region of propagation	Total forest area 10^3 hectares
Lower reach and delta of Amu-Dar'ya	33.0
Middle reach of Amu-Dar'ya	30.0
Valley of the river Vaksh (Tadjikistan)	35.0
Delta of the rivers Murgaba and Tedjena	5.3
Basin of the river Atrek with tributaries Sumbar and Chandir	3.1
Valley of the Zeravshan river	3.0
Valley of the rivers Chu and Ili	2.6
Delta of the Syr-Dar'ya	4.5
Delta of the river Tarim (China)	2.5
Gobby (Mongolia)	0.5

Table 4. Recommended types of flora for different soil groups

Type	Soil Group			
	Alluvial-meadow	Residual-meadow	Desertif.-meadow	Saltworts
Salix songarica	+	-	-	-
S. wilhelmsiana	+	-	-	-
S. alba	+	-	-	-
Populus arianus	+	+	-	-
P. alba	+	+	-	-
P. nigra	+	+	-	-
P. bachofenii	+	+	-	-
Ulmus pumilia	+	+	-	-
Elaeagnus angustifolia	+	+	+	-
E. orientalis	+	+	-	-
Tamarix laxa	+	+	+	-
T. ramosissima	+	+	+	-
T. hispida	+	+	+	+
Halimodendron halodendron	+	+	+	+

Table 5. Forest area distribution by land category in the lower Amu-Dar'ya basin

	Actual forest area	Forest steppe	Burned out forest	Cutting out	Forest clearing	Total	Potential forest area
10^3 ha	21	3.4	1.7	1.1	5.0	12	33
%	63.6	10.3	5.2	3.3	17.6	37	100

Figure 1. Reduction of tugai forest in the Amu-Dar'ya delta

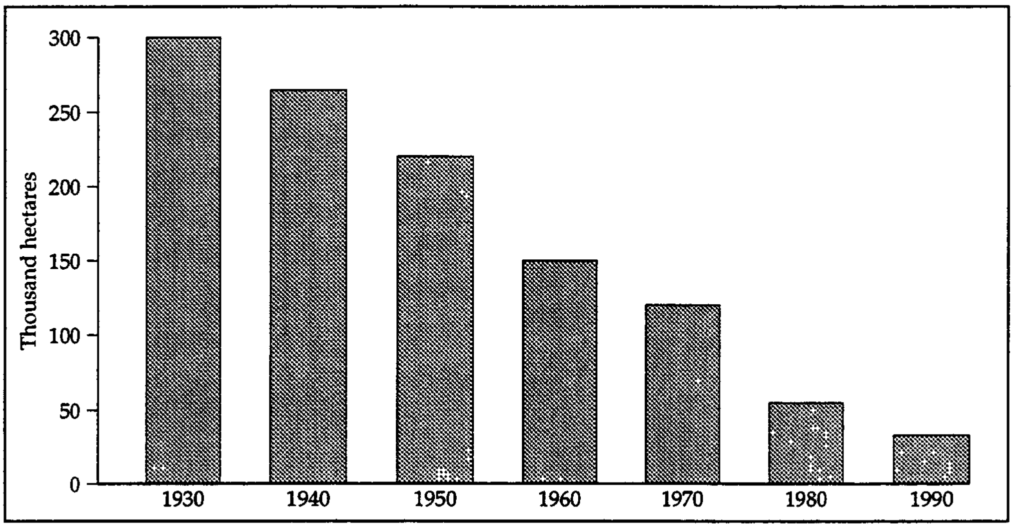


Figure 2. Change in the main forest-forming vegetation and trees in the tugai forests of the Amu-Dar'ya delta

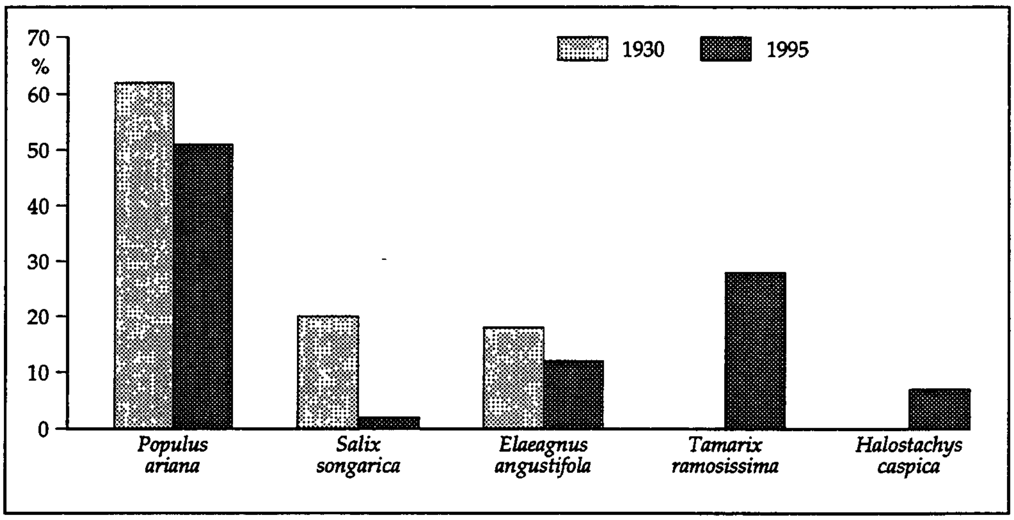
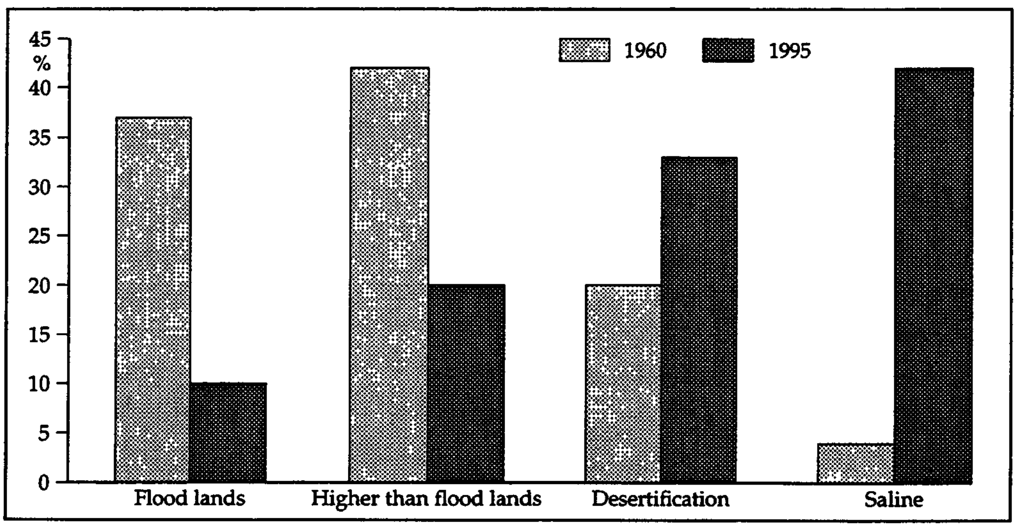


Figure 3. Change in the spreading vegetation of the Amu-Dar'ya delta



CONTEMPORARY PLANT AND SOIL COVER CHANGES IN THE AMU-DAR'YA AND SYR-DAR'YA RIVER DELTAS

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Introduction

The rational use of natural resources and the protection of biocomplexes of river basins are two of the most pressing problems of a scientific-practical nature. Numerous international meetings have been devoted to this subject during the last three years (La Cross, Wisconsin, USA; Togliatti, 1994; Vienna, 1995; UK, 1995 and others). Several international projects were also executed by UNESCO (Ecotones Research Project) in 1980-1990: e.g. Protection of riparian ecosystems in the Murray and Darling river basins, Australia; Aquatic-Terrestrial Ecotones at the River Danube – Inventory of biodiversity and organisation of monitoring in the Danube basin, and others.

The rational use of natural resources in the deltaic plains of the rivers Amu-Dar'ya and Syr-Dar'ya is one of the central problems of the Aral ecological crisis. The study of soil-vegetation complexes and their changes is a fundamental task, of great practical importance, as it is essential for water resources management decisions in the Aral region. Soils and vegetation are the most important components of the tugai biocomplexes. The prospects of the use of the unique tugai ecosystems for hay-making, pastures, as a source of industrial crops and herbs, and the productivity of agrocoenoses depend on the their preservation. Besides, in the severe natural dynamics of the deltaic landscapes, the soil-vegetation complexes have an important stabilising function, smoothening the sharp changes of environment, which is the main condition for the stable development of nature and economy in this region.

Changes in vegetation and soils of the deltaic plains in Priaralia have been thoroughly studied and described in many scientific publications and dissertations (Bachiev, 1985; Bakhiev and others,1977; Borovsky, Pogrebinsky, 1958; Zhollybekov, 1993; Kabulov, 1990; Kievskaya and others, 1980; Kurochkina and others, 1991; Kust, 1993; Mamutov, 1991; Mozhaitcheva, 1979; Novikova and others, 1981; Rodin, 1961; Treshkin, 1990; Chalidze, 1973,1974; Zaletaev, Novikova, 1995).

All the investigations on this theme were made, as a rule, separately and highlighted only the peculiarities of degradational changes in tugai biocomplexes. In our opinion, this process was completed in the middle 1980s and the formation of biocomplexes of a desert type began on the desertifying sites of the deltas of the Amu-Dar'ya and Syr-Dar'ya by the beginning of the second half of the 1980s, and on the dried bottom of the Aral Sea from the end of the 1970s.

Partial restoration of the deltaic plains watering, that began in the Syr-Dar'ya delta from the first half of the 1980s and in the Amu-Dar'ya delta in the mid-1980s, induced transformations of opposing character, some times resulting in the impoverishment of the state of degraded tugais and some times in the formation of

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new ones. Both processes demand studying and analysis for their management. Besides, the great mass of collected empirical data, makes it possible to apply more modern methods of operative control of change estimations and to create a more objective base for management decisions.

Objectives

The objective of this project is to assess the laws of changes in the soils and vegetation of the deltas of Amu-Dar'ya and Syr-Dar'ya, in order to sustain their stable development in conditions of aridisation and anthropogenic impacts. The tasks were as follows:

- to work out an information system which makes it possible to characterize the links and spatial-temporal changes of soils, vegetation and environmental factors by statistical analysis;
- to create a database of empirical data for characteristics of studied objects for collecting, storing and monitoring and working out the background of decision-making in water resources management;
- to work out principles and create a uniform classification of vegetation and identify the existing classifications of soils for the Amu-Dar'ya and Syr-Dar'ya deltas and characterize them; create models of the ecological-dynamic links of chosen taxons;
- to reveal the statistically meaningful indices of structure of vegetation communities independent from the sample volume;
- to observe the strategies of vegetation on the delta territory in conditions of changing watering;
- to reveal the character of direct anthropogenic impacts on the vegetation and soils;
- to give practical recommendations on nature protection actions and water management strategy in the deltas to support stable development of their bioresource potential.

Changes in the vegetation and soils of the modern Amu-Dar'ya and Syr-Dar'ya deltas depend upon regional and local factors:

- a natural evolution process of deltaic landscapes which leads to the replacement of hydromorphous complexes by climax communities of desert type;
- aridisation of the environment of Priaralia, anthropogenically conditioned, which increases the speed of natural changes in vegetation and soils;
- direct anthropogenic impacts which are able to intensify as well as weaken the influence of the regional factors mentioned above.

As in the destabilized environment of the Amu-Dar'ya and Syr-Dar'ya deltas, the change rate of edaphic factors is higher than the time of self-formation of soil-vegetation complexes, their transformations are considered as endo-ecogenetic. In this connection, the characteristic feature for the vegetative communities can be the destability of species composition, group or thicket composition, as they are in the process of constant succession, which changes directions.

In our research we used, with some modifications, the methodology and concepts proposed by G.S.Kust (1993) for the study of aridisation. We consider the aridity of climate or its aridisation as factors of change, various anthropogenic impacts – as agents of change which, together, bring about the elementary processes that condition the transformation of soils and vegetation. These processes in arid regions, in conditions of reduced water supply are: takyrisation, salinisation, psammophytisation of soils as well as xero-, halo-, psammogenic successions which condition the xerophytisation, halophytisation and psammophytisation of vegetation cover.

In this work, data are used from soil and geobotanical field research carried out by the authors in 1992, (Syr-Dar'ya delta); in 1993-1995 (Amu-Dar'ya delta), as well as data obtained by the authors on the territories of these deltas in previous years. Geobotanical descriptions and data on soil composition analysis from scientific publications are also included in our work.

Scientific innovation

- For the first time, an information system for ecological-geographical studies was created which is able to expand the data field and enlarge the field of observations. A computerized data base was set up for the territory of the Amu-Dar'ya and Syr-Dar'ya river deltas.

The methodology of data interpretation has been worked out, with the help of the application programme system.

- The principles and taxonomic classification of vegetation communities, with consideration of the environment dynamics, have been worked out.

A uniform classification was applied to the Amu-Dar'ya and Syr-Dar'ya deltas and a model was developed of ecological-dynamic links of selected taxons:

- Statistical analysis of the communities' structure and environmental factors showed that the most significant are: medium index of species diversity of community, medium and maximum indices of relative soil units and density of sward. The species composition is more rich when the salinity of soils is lower and the density of sward is higher. These indices are recommended as diagnostic when determining the territories for reservations.

- For the first time, the changes of the structure of vegetation communities in dynamic sequence of vegetation successions of tugai type were statistically evaluated.

- We have established that species diversity is minimum in extreme environmental conditions – excessive moisture and high level of soil salinization. A maximum number of species in the community and maximum diversity of communities are detected when the ground water level was 2-4 metres below the ground on the soils with medium salinity – 0.5-2%.

Practical results

The main practical result of the project is the setting up of an Ecological-Geographical Information System and Database. Its description and manual (ready for publication) is being handed over to the UNESCO/BMBF Project, for future use as the co-ordinating and organizing system for the organization of research, data storage and analysis by statistical methods, in the framework of the Aral Sea Project.

- A computerized version of the database stored in the process of work, with descriptions of methodology of vegetation and soils monitoring, is being passed on to the Government of the Karakalpakstan Republic, for monitoring the state of vegetation communities and making decisions on their protection and improvement.

The second concluding material is a methodological manuscript ready for publication, containing all research results of the project. It includes: outline of vegetation classification principles; characteristics of recent changes in vegetation and soils in the Amu-Dar'ya and Syr-Dar'ya deltas; methods of statistical analysis of botanical, geographical and soil data; methods of data interpretation, their retrieval from the database, with the help of application programme systems EXEL, ECOL, to be used for biodiversity study on the level of species and communities and their scientific analysis.

- Evaluation of the contemporary dynamic state and tendencies of further vegetation and soils development in the deltas.

- Elaboration of the diagnostic scheme for determining the environment aridisation grade.

- Practical recommendations on the strategy of environmental water management in the deltas, as well as environment protection measures for sustaining biodiversity.

- Description of the vegetation of the lakes in Tashaus region of Turkmenistan and their role in forming the water quality.

Research results were reported at several scientific symposia and conferences and were submitted to the scientific journals for publication. The list is attached at the end of this report.

Information system and ecological-geographical database

An information system and system of databases of ecological-geographical trend (BD) have been worked out for the Sub-project, for storing and processing empirical data for the Amu-Dar'ya and Syr-Dar'ya deltas.

The main data source has been the field research carried out from 1978 to 1993 by the Laboratory of Dynamics of Terrestrial Ecosystems of the Water Problems Institute, Russian Academy of Sciences, together with data from scientific publications and archives from the years 1947-1994.

BD includes several correlated blocks – special data bases: geographical, botanical, soil, hydrogeological, hydrological, climatic. These blocks are operated by the informational-inquiry system.

In December 1995: 745 geobotanical descriptions on the Amu-Dar'ya and Syr-Dar'ya deltas were made – 300 of them comprise data on the chemical composition of soils and 270 descriptions with groundwater characteristics. The continual information on the 433 species encountered in the Amu-Dar'ya and Syr-Dar'ya deltas was included.

Analysis of available data showed that this information is not sufficient for representative description of 7 formations in the Amu-Dar'ya delta and 6 formations in the Syr-Dar'ya delta, to reflect the present situation at the sea bottom in the Amu-Dar'ya delta, and to characterise the biodiversity of some deltaic regions. It is thus necessary to supplement the information about the recent state of vegetation and soils in the Syr-Dar'ya delta. A separate study is being made on the state of wild vegetation and soils on the territory of oases.

The database was designed by Ms. N.M. Novikova and Ms. G.U. Trofimova. Ms. J.V. Kuzmina took part in designing the botanical block and prepared the input of data from literature sources for the Amu-Dar'ya delta. The database structure and application programmes system were worked out by Ms. G.U. Trofimova.

Classification of vegetation

Classification of vegetation communities is an important part of our research. The classification system of vegetation communities in the Amu-Dar'ya delta, made by J.V. Kuzmina and G.U. Trofimova in 1994, on the basis of interpretation of more than 400 geobotanical descriptions defined in the period 1947 to 1993 has been entered into the ecological-geographical database and was used for analysis. The same principles were used for the classification of vegetation for the Syr-Dar'ya delta. 72 associations belonging to 21 formations, were selected in the Amu-Dar'ya and Syr-Dar'ya deltas (Table 1). Classification principles are described in the paper of J.V. Kuzmina (published in 1995) and in the latest report, which is ready for publication.

The model of ecological-dynamic links of the selected taxons has been made, using the information on their ecology (Fig. 1).

Classification of soils and their dynamics

Soils of the Amu-Dar'ya and Syr-Dar'ya deltas and their dynamics are fully described in the works of B. Jolibekov (1991), R.H. Kievskaya et al. (1980) and others. As scientists from different scientific schools used different terms for soil classifications, we worked out a uniform classification scheme which reflects the transformation processes (Table 2, authors – G.S. Kust, S.A. Avetian, S.U. Rozov and V.D. Deruzginskaya).

Statistical analysis of vegetation communities' structure and environmental factors

The parameters of the vegetation communities structure and their dependence on environmental factors, were determined by statistical analysis. It was necessary to find out the degree of dependence of communities structure from the number of described sites[4].

In estimating the average quantity of species on the site for each formation, the arithmetical mean (Number of species$_{av}$) as well as the median mean (Number of species$_{med}$) was calculated. These two calculated values were practically equal when rounded up to a whole number (Table 3, col. 5,6).

One of the most representative and significant characteristics of communities biodiversity – the total number of species in the plant formation (Number of species$_{sum}$) was tightly connected (Correlation coefficient 0.8599) with the number of sites which represented the formation (Table 4). Tight correlation (0.4645) was found between the number of descriptions used (Number of sites) and the maximum number of plant species met on each site in each formation (Number of species$_{max}$). It follows that as the number of descriptions increases, (number of sites), the total floristic list of formation grows as well, till they attain an absolute maximum of vegetation species met on the sites.

Among the geographical factors considered, the most dependent from the volume of samples are: anthropogenic impact, (this factor was estimated by its presence or absence (Tables 3, 4 – col. 21) and also values of the ground water level. Weak correlation between the sample volume and value of GWL is revealed for mean values (GWL_{av}, GWL_{med}; correlation coefficients are 0.5019 and 0.4411, respectively) (Table 4, col. 11,12).

[4] A site means here a patch of land 10x10 metres

Of the statistical floristic characteristics, relatively independent from the quantity of samples (Number of sites), was the medium value of the species number on the formation sites (Number of $species_{av}$, Number of $species_{med}$ – (Table 4, col. 5, 6), as well as the absolute minimum value of vegetation species met on the formation sites (Number of $species_{min}$ – Table 4, col. 4) (correlation coefficients 0.1405; 0.1534; -0.3854, respectively). Thus, the above-mentioned statistical parameters (Number of $species_{av}$, Number of $species_{med}$, Number of $species_{min}$) can be considered as the most important for determining the correlation with the other (not floristic) characteristics of community structure and environmental factors.

Among other analysed characteristics of community structure and environmental factors fairly independent from the sample volume of were the medium and maximum values of soils and sward density:

$Soil_{max}$, $Soil_{av}$, $Soil_{med}$, $Density_{max}$, $Density_{av}$, $Density_{med}$; (Table 4, col. 14, 15, 16); correlation indices: 0.1693; -0.2755; -0.2196; 0.3671; -0.2227; -0.1275, respectively.

In that way, the obtained mean values of community structure characteristics and environmental factors for formations of the lower course of Amu-Dar'ya prove the objectivity of data obtained during the preliminary interpretation of the material.

The statistical analysis of ecological-geographical database confirmed the traditional thesis (Ashirova,1971;1976; Mailun, 1973) about tugai communities being extremely poor floristically. So, the mean number of species on the sample sites in the lower course of Amu-Dar'ya, was less than 12 plant species.

As expected, the mean number of species on the sample site decreases from tugai to solonchak vegetation, varying in the range 7-11 and 3-7 plant species, respectively (Table 3, col. 6).

This conclusion is supported by the strong negative correlation between the species numbers in formations and soil characteristics. The strongest correlation is detected with medium soil indices ($Soil_{av}$, $Soil_{med}$). So, when the relative soil indices are lower on the sites of each formation, more species are met. Relative soil indices increase with increasing solonchak process [(grey-brown desert soils (111-115)⇒sandy desert soils (211-214)⇒takyrs (311-313)⇒takyrlike soils (411-415)⇒meadow-tugai soils (511-533)⇒meadow soils (611-643)⇒bog soils (711-763)⇒solonchaks automorphous (811-825)⇒solonchaks hydromorphous (911-965)]. Thus, a maximum number of species is characteristic for typical tugai communities spread on less saline soils: *Populeta arianae, Elaeagneta angustifoliae, E. turcomanicae, Halimodendreta halodendrii, Glycyrrhizeta glabrae.*

Tugai formations of *Populeta arianae* (97), *Tamariceta ramosissimae* (89), *Glycyrrhizeta glabrae* (56) and *Alhageta pseudalhagii* (53) are the most representative floristical formations in the Amu-Dar'ya delta (Table 3, col. 7).

The floristic biodiversity of communities on solonchak deserts sharply diminishes (Fig. 2). Formations with minimum number of species are: *Salicornieta europaea* (8), *Climacoptereta aralensis* (10), *Halocnemeta strobilacei* (21). The biodiversity of formations of solonchak deserts, as a whole, is lower than that of formations of tugai vegetation.

Graphical (Fig. 2) and correlation (Table 4) analysis of statistical data on community structure displayed negative correlation (-0.498) between minimum values of species numbers on the site and the maximum characteristics of the soil cover. It means that on meadow and desert soils, as a rule, minimum indices of species on the site are lower than on automorphous and hydromorphous solonchaks.

When the salinization increases in the upper soil layers, many plant species disappear from the communities. This phenomenon leads to impoverishment of communities.

Graphic analysis and data of double correlation revealed the tight positive correlation between medium indices of density of sward ($Density_{av}$, $Density_{med}$ – Table 4, col. 19, 20) and medium indices of number of species (Number of $species_{av}$, Number of $species_{med}$) in communities (correlation is from 0.52 to 0.63 respectively) and also with a minimum number of species met on the site (correlation from 0.64 to 0.70). Thus, when the density of sward is higher, the number of species is more. Besides, absolute minimum indices of species on the sites of each formation depend upon the medium density of sward to a large extent. The higher are the medium indices of plants' density in formations, the higher is the level of extremely small number of species that were met on the site. Meanwhile the high density of sward in community makes it possible to preserve more numbers of species in its composition (correlation is 0.7029 and 0.644 respectively).

Thus, analysis of our data shows that lowering of density of sward because of serial or transformational changes influences, not only the structure of community, but leads also to impoverishment of floristic diversity as a whole.

Passing of vegetation from tugai to solonchak is accompanied by a considerable lowering of medium density of sward: from 56-88% ($Density_{av}$) and 55-92.5% ($Density_{med}$) for tugais to 31-68% ($Density_{av}$) and 20-60% ($Density_{med}$) for solonchak vegetation (Table 3, col. 19, 20). Moreover, there are no considerable changes in absolute minimum and maximum indices of density of sward for tugai and solonchak vegetation.

Correlation analysis revealed medium-range negative correlation between density of sward ($Density_{min}$, $Density_{max}$, $Density_{av}$, $Density_{med}$) and indices of maximum relative indices of soils (correlation is: -0.537, -0.417, -0.521, -0.434 respectively), which also confirm the conclusions made before about the lowering of density of sward when passing to the communities on more saline soils.

Negative medium-range correlation is revealed for medium soil relative indices ($Soil_{av}$, $Soil_{med}$) and medium indices of ground water level (GWL_{av}, GWL_{med}), which are well presented on the picture (Table 4, Fig. 3). Thus, analysis of our data shows that more saline soils of the Amu-Dar'ya delta have, as a rule, more shallow ground waters. This conclusion, which corresponds fully to the dynamics of soil processes, confirms the objectivity and representativity of data which had been assumed as a basis for the ecological-geographical database.

Dynamics of vegetation and soils

The classification that had been worked out by using the concept of association as dynamic category (Sochava,1968) made it possible to create the scheme of natural dynamics of vegetation (Fig 1), which became the basis for the further evaluation of changes in vegetation. It became the model for vegetation changes in deltas directed to formation of zonal edaphic variants.

Changes of vegetation in the process of aridisation proceed from the scheme that reflects the changes of vegetation for the territory in the Amu-Dar'ya delta under the impact of aridisation, the modern dynamic state of vegetation can be estimated as the final stage of degradation of tugai vegetation and spreading of the takyr process. Changes went with different speed on different elements of deltaic relief and with different manifestation of the solonchak process, which depended on the speed of the lowering of the ground-water level.

At present, the wooden-bush tugai communities are well preserved on the natural levees of the main channel of the Amu-Dar'ya. Meanwhile, the degree of their degradation increases from the upper course to the lower course. In the upper course (region of Porlytau), communities of *Populus ariana-Tamarix ramosissima-Mixteherbosa* (*Glycyrrhiza glabra, Alhagi pseudalhagi, Aeluropus littoralis, Sphaerophysa salsula*) are preserved without artificial watering. The vitality of species is low – species are low, not all the plants are fruitful. Their territory shrinks because of annual death of trees and bushes on the outer edge of sites, followed by the death of tugai herbs.

On the natural levees of the shallow dry channels, the process of degradation of wooden-bush communities is more prominent. There are no tugai herbs, trees and bushes are dry up to 80%. Because of the death of tugai communities on the vast territories of natural levees, there is no vegetation because of the soil conditions and they are then subject to invasion of desert species.

Because of this, the invasion of the desert species – dwarf subshrub – *Ceratoides papposa* began. Its first communities were detected and described in 1990. They were monocoenoses. The height of *Ceratoides* plants was 80-130 cm; the number of plants on the site 10x10 m^2 was more than 40 plants. During these last years, the territory occupied by monocoenoses was about 10 km^2 on the left bank, as well as on the right bank of the river. Also found were *Phragmites australis, Alhagi pseudalhagi*.

On the natural levees, these entered the stage of desertification before the aridisation of the delta and passed through the solonchak stage, the process of psammophytisation of vegetation began with the formation of communities of salinization-proof species *Haloxylon aphyllum* with big psammophyle salinization-proof bush-tree *Salsola richterii* and psammophyle bush *Calligonum aphyllum*. This community changed the halophyle community of *Halostachys caspica* as the result of desalinization and destruction of salt crust and exposure of sand deposits under this crust. But the secondary salinization, because of watering caused by development of irrigation in this region, conditioned the death of the *Calligonum* population. The death of the whole community can be forecasted either because of further salinization, or because of ploughing of the territory.

Psammogenic succession on solonchaks can go through the accumulation of sand on their surface and further introduction of psammophyle plants. The initial studies of this process were observed on the right bank of the delta at a distance of several kilometers to the south from the Kazahdarya settlement. The sand deposited on the surface of the solonchaks was anchored by psammophyle ephemeres (*Eremopyron orientalis, Malcolmia* sp. and others) and by annual soliankas. Among halophyle communities of *Halostachys caspica*, the sites of mesophyle ephemeres appeared. Broadening of their territory and an increase of thickness of the sand deposits can lead to the formation of psammophyle communities.

The replacement of tugai vegetation in interchannel depressions went through the halophile stage. The widest distribution had halophile communities of tugai subshrubs *Tamarix hispida* and *Halostachys caspica*. Starting at the end of the 1970s, they became the landscape-forming communities on the coastal plains, on the natural levees slopes and in the interchannel depressions. At the end of the 1980s – beginning of the 1990s, together with the expansion of the takyr process, they were replaced by dwarf subshrub *Salsola dendroides*. A spreading of this species indicates the desalinization of soils and change in its chemistry – from magnesium-sodium to the sulphate calcic-sodium.

The takyr process is more developed to the north of the delta, on the slope of the natural levee of Ulkundarya, where the dwarf subshrub *Anabasis aphylla* is detected in place of the *Halostachys* community.

The process of soil salinization plays a great role in vegetation changes. As our research (done on the 200 base profiles made in 20 key sites of modern drying and ancient dried deltas of main channels and streams of the Amu-Dar'ya and Syr-Dar'ya) showed (Kust, 1995), dynamics of changes of the salinization degree and types of distribution of easy soluble salts on the profile of desertified soils of deltaic territories, are determined by three conditions: a) speed of the lowering of ground water level; b) time of drying of the territory; c) initial belonging of soils to various elements of relief. These laws of changes in the degree of salinization, of character of salts distribution on the soil profile and changes in the chemistry of salinization, determine the laws of changes in vegetation.

Changes of vegetation under conditions of additional watering

Filling the lake depressions with water permits the regeneration of hydro- and hygrophyle vegetation communities with dominant *Phragmites australis, Typha angustifolia* on the coastal sites and on the shallows, and of communities of *Tamarix* sp. on the coasts. The high productivity of these species is restored and in 2-3 years they reach such volume as to make it possible to use them as hay and pastures. Short flooding of wooden-shrub tugais increases their vitality, increases the diversity of herb species, emergence of plantlets of *Populus* and *Tamarix* of seed origin (Novikova, 1994).

Changes under direct anthropogenic impacts

The main forms of agricultural activity on the deltaic plains – haymaking, pasture, burning out, transport trampling down, ploughing, drainage and watering – change vegetation and soils directly. In conditions of constant press, they preserve the vegetation-soil complexes in a long-disturbed state. In conditions of single impact they can give the direction of digressive-demutation changes, which develop also in three main directions. Unpractical nature management can lead to degradation and complete redistribution of vegetation and soil covers. Irrigation may be such a factor. When preparing the territory for irrigation, the natural vegetation is replaced by agrocoenoses. Changes of environmental regimes take place, not only in oases, but far beyond their limits.

Pasture – one of the most ancient and most constant forms of anthropogenic impact on the floodplain ecosystems. According to the opinions of some authors, all existing floodplain vegetation, especially floodplain meadows, are long-disturbed communities, which are under the constant control of this anthropogenic impact. As a rule, when the water supply decreases, together with the drying of biotopes, the pasture load on the vegetation communities increase, which leads to sharp deterioration of the vegetation state and to its degradation (cattle trampling).

This process is not reflected in our database with sufficient volume for statistic interpretation, which is why analysis of the rate of communities' degradation was made with the help of relative indices of the Ramenskiy scales. For almost all communities in different periods, this differs in moistening the pasture digression estimated as weak (3-4 points). It can be explained because the estimation of the rate of degradation in these scales is based on the increase of the role of weeds and in conditions of strong press of environmental xerophytisation, either death of communities occur, or they are replaced by more drought-resistant communities.

We observed the process of degradation of vegetation communities under the impact of pasture 10 kilometers to the south of Muinak; communities of *Tamarix hispida+ T. ramosissima-Bolboshoenus maritimus-Aeluropus littoralis* are an example. A reduction of water supply of the biotope without pasture conditioned the disappearance of hygrophyle species *Bolboshoenus maritimus* from the community and a reduction of fertility of good fodder cereal *Aeluropus littoralis* from 516 in 1993 to 246 mg/m^2 in

1994 (Table 5). A deterioration of watering in 1995 in the Muinak region became the reason for pasturing in this area. In the Autumn the surface of the soil was disturbed by paths made by cattle and the fertility of *Aeluropus littoralis* decreased to 70 mg/m^2. The total volume of the surface phytomass also decreased.

The degradation of vegetation and soil develops with peculiar strength near the settlements because of cattle passing. Thus around Muinak, a settlement in the sovjoz Aral in the Amu-Dar'ya delta and near the settlement Karateren, in the Syr-Dar'ya delta, the migrating sands formed, bare of vegetation and soils at a distance of 1.5 kilometres. Such territories surrounding the settlements are a constant source of dust. They must become the objects of great attention and organization of special melioration measures.
Fires are a powerful agent of vegetation transformation. At present the old phytomass of reed is burned almost annually. It leads to further rejuvenation and an increase of growing of the surface green mass, when watered. The bushes are also burned out, but they are not restored if watering stops.

Phytomelioration is widely applied in towns and settlements as a means of improvement of environmental comfort. Meanwhile there is a positive experience of melioration (without watering) of the drying bottom of the Aral Sea in the region of Muinak. *Haloxylon aphyllum* was planted artificially. Now, the 15 year old trees are invaded by the natural phytocenoses of psammophyte *Salsola richterii* and a great part of the surface is covered by annual salsolas. Good reproduction of both wood species is detected.

The territory of the alluvial fan of the 1960s was, for a long time, a takyrish clay surface bare of vegetation. Sowing in the ploughed furrows of *Haloxylon aphyllum* and *Salsola richterii*, at a distance of 3 metres from each other, gave good results. The trees are now 3 metres high and their crown diameter is 2.5-3 metres. Reproduction of these species is detected under crowns of 2-9 plants. Between rows of *Salsola richterii* and *Haloxylon aphyllum* the "repairing" community of annual *Salsola paulsenii* formed. It is of high abundance (Cop 1-3) and density (40-50%). The presence of *Ceratocarpus arenaria* is detected in the community composition – the species, typical for ecosystems of sand deserts, is disturbed by pasture.

Irrigated agriculture influences directly and indirectly the soils and vegetation. The territories of irrigated lands in deltas constantly grow, in spite of the lack of water resources; salinized fields are abandoned and new lands are cultivated, while part of the old agricultural lands are transformed to the category of "disused". Thus the agrocoenoses and communities formed in the process of demutations on the "disused" lands, replace the relatively natural vegetation of deltas. This phenomenon is characteristic for most parts of the Kazalinsk delta of the Syr-Dar'ya.

With the aim of revealing the degree of participation of wild species in agrocoenoses, we explored in September 1993 and 1994 the crops of rice, cotton, sorghum and maize in the old-irrigated oases on the left bank (to the north of the town Hodjeyli) and on the right bank (sovjoz Voroshilov) of Amu-Dar'ya and on the new-irrigated fields in the Bozataus region, on its right bank. It appeared that in all variants the degree of participation of the wild plants, as well as weeds, is inconsiderable. Thus agrocoenoses can not be considered the refugees of tugai flora.

Transport highways. Changes in the vegetation cover caused by transport, have a destruction character. In conditions of quick environmental aridisation of deltas, they play the role of migration channels which encourage the settling of desert species on the disturbed sites of land which are bare of vegetation. The sides of the highways and slopes serve as good biotopes for the intrusion of newcomers. Long-term observations in the Amu-Dar'ya delta showed that, together with the introduction of the new desert species on the side of the highway, they became abundant on the desertified biotopes, bare of vegetation for 3-5 years. Thus the three waves of settling occured. The first plants of *Salsola dendroides* and *Haloxylon aphyllum* were detected on the sides of the highway Nukus-Muinak in 1982. Up to 1985, *Salsola dendroides* became the background species on takyrised meadow soils of a different rate of salinization and on the takyrized solonchak soils on the slopes of natural levees along the whole delta. *Haloxylon aphyllum* settled and formed a compact, 50 metres wide wooden belt along each side of the highway, over the distance of 100 kilometres from Kungrad to Muinak. The next wave of expansion is connected with the quick settling on the territory of the delta of the dwarf subshrub *Ceratoides papposa*. It was found for the first time in 1990 on the side of the highway Kungrad-Muinak on the 101st km in the thicket on the meadow-desertified soil, the upper clay crust of which was disturbed and the process of sanding began. In the same year, the wide spreading of its monocoenoses was detected along the highway Bozatau-Muinak. Up to 1993, *Ceratoides papposa* occupied wide areas of previously vegetation-bare desertified meadow soils on the left and right banks of the Amu-Dar'ya. It actively took root in such communities as *Alhagi pseudalhagi, Phragmites australis, Zygophyllum oxyanum.*

Analysis of species diversity in communities

Cluster analysis of species diversity on the basis of indices of Wiver-Shennon between vegetation formations of the Amu-Dar'ya delta with use of summary species abundance as well as frequency of species meeting in community, showed that the richest flora are formations of tugai vegetation: *Populeta arianae, Tamariceta ramosissimae, Alhageta pseudalhagii, Glycyrrhizeta glabrae, Tamariceta hispidae* as well as successionally near to the bush tugais formation of solonchak vegetation of *Halostahydeta caspicae*. Meanwhile, a formation of *Populeta arianae* is maximum rich in flora, including 49% of tugai and solonchak flora of the Amu-Dar'ya delta. Indications for choosing anthropogenically formed formations can serve not only high (more than 55%, Fig. 3) floristic likeness with other formations, but also weak differentiation of associations in the limits of proposed taxonomic units.

Statistic and cluster analysis of quantitative characteristics revealed that for the preservation of species diversity of tugai vegetation, it is important to preserve communities of *Populus ariana* and *Tamarix ramosissima*. Only successionally, near to them, communities of herb tugais of *Alhageta pseudalhagii* and *Glycyrrhizeta glabrae* can be the alternative, ecotonal reserves of flora under the anthropogenic liquidation of wooden massifs. The preference must be given to communities with higher density of sward as well as those situated on the less saline soils.

Strategies of vegetation communities in conditions of quickly changing environment

The strategy of vegetation communities was studied on the basis of data on the Amu-Dar'ya delta. For this aim, time intervals were selected, during which the watering of the delta differed considerably.

1st period: 1947-1952 – is considered to be standard; water supply and development of the delta was in natural regime. Active irrigation cultivation of the deltaic plain had local character.

1952-1965 – is characterized by the development of irrigation construction in the river basins, but a reduction in the water flow to the upper course of the deltas was not detected.

2nd period: 1972(74)-1977 – the beginning stage of active drying of the coastal part of the deltas, as a result of the construction of the Tahiatash and Kazalinsk hydro-electric stations in the upper course of the deltas and stopping of natural floodings in the Syr-Dar'ya delta beginning from 1972, and in the Amu-Dar'ya delta – from 1978.

3rd period: 1978-1983 – minimum water supply of delta, stage of automorphous development.

4th period: 1984-1989 – beginning of the new water supply from the drainage water flow and construction of local watering systems.

5th period: 1990-1993 – increase of river water flow to the upper ends of deltas, vast filling of dried lake lagoons by river water, restoration of the previous water supply up to 30% of the deltaic plain that existed before the 1960s.

For evaluation, we used the traditional ordination method of L.G. Ramenskiy, in conventional scales of moistening and salinization. These methods can give good quantitative results and a possibility for their ecological interpretation for large amounts of data.

Using the meaning of species according to scales of moistening and soil fertility which change in accordance with its phytocoenotic role (cop, sp, sol, un), we calculated the meanings for each formation included into the database. Then the "ordination fields" for all associations in limits of formations were created for selected periods.

On the basis of the data obtained, it can be concluded that the least-changed, are the "ecological ordination fields" of phreatophyte communities with deep root systems, as well as communities formed by species resistant to salinization. In the limits of one formation, the most stable appeared to be communities with diverse species composition and several dominants. Particular stability is natural for communities which had in their composition herb species using water from groundwater level.

The results describing the strategy of vegetation communities under conditions of changing water supply of the delta can serve not only for prediction but also as a scientific basis for the regulation of the delta water supply.

This research was conducted by T.V. Dikariova, G.U. Trofimova and N.M. Novikova using taxons collected by J.V. Kuzmina.

Vegetation of waterbodies of Tashauz region and Karakum canal

In conditions of water deficit and the ecological crisis caused by this phenomenon, the task of studying the water objects in the Aral Sea basin is very urgent. The Laboratory of Algology of the Botanical Institute of Turkmenistan has dealt with research on vegetation composition of waterbodies in Turkmenistan, with evaluation of water quality and with estimation of the fitness of water objects for fish-breeding for many years (1956-1994). In connection with work on the UNESCO/BMFT Aral Sea Project, U.E.Lubeznov, Head of this Laboratory, made nature observations during the three years and presented his results in a report and paper (Lubeznov, 1996).

The study of ecological groups of algae and high-water plants, of formation and distribution of bacteria and phytoplankton, of their functional peculiarities and productivity on the basis of hydrochemical and hydrophysical parameters, provided reliable information about the state of waterbodies, making it possible to evaluate the medical-ecological state and quality of water and to carry out ecological monitoring. Lakes of the Tahtin region of Tashauz province receive water from the irrigation net and groundwaters. They are shallow (3-4 metres) and water mineralisation is extremely high (5.68 – 13.4 g/l). The correlation is determined between the species diversity of algoflora and water mineralisation. The primary production is very high – 788-2681 kkal/m^2. These lakes are rarely used for fish-breeding, but calculation of their potential productivity shows the perspective of the increase in fish production (Table 6).

Shavat and Gazavat canals take water from the Amu-Dar'ya and are the main sources of fresh drinking water and irrigation in the Tashauz region of Turkmenistan. The quality of water is very low as it is highly mineralized (2214.6 – 3471.5 mg/l) and polluted through irrigation.

The ecosystem of the Karakum canal experienced the increasing anthropogenic impact, the consequences of which are – increase during the last years of the salt concentration in water to 1.5 g/l and a content of P and N and especially NO_3. Microbiological analysis also supports the idea of water contamination. The negative influence exerts the hydrological regime of silt load on the development of vegetation of the water ecosystems of the Karakum channel, where the algocoenoses and submerged high water vegetation are not developed. In lightened parts, the algocoenoses have high diversity and are well developed. Their quantitative indices are 1.5-3 times more than their indices in the 1970s.

Reed thickets in the canal occupy 1290-1520 hectares, with a phytomass of 55.6-72.0 thousand tons in dry weight.

During the observation period we encountered eight species of submerged high water plants: *Potamogeton perfoliatus* L., *P. nodosus* L., *P. pectinatus* L., *P. crispus* L., *P. lucens* L., *Najas marina* L., *Myriophyllum spicatum* L., *Batrachium rionii* (Lagg.) Nym. and one representative of horsetails – *Equisetum fluviatile* L. Flora of submerged high-water plants in Karakum channel can be compared with analogous flora in the water streams of the region. Among the named species, *P. nodosus* L. and *P. pectinatus* L. played the greatest role in bioproduction.

It is possible to improve the water quality in the water bodies. In the water bodies of Central Asia, water is polluted by agricultural wastes. This is why, under conditions of strong water pollution in irrigation systems, we studied the processes of their purification by communities of water vegetation. The best results were achieved when water flowed in the channel through the natural thickets of *Typha angustifolia* over a length of 400-500 metres, and plant density 25-47 plants/m^2. The concentration of chlororganic pesticides HCH, DDE, DDT and DDD was 1.289 mkg/l at the entrance of the natural biofilter, and at the exit – 0.121 mkg/l. Water salinity decreased by 9.7 – 16.2% in Spring, and by 5.5 – 12.2% in Autumn. The concentration of phosphates decreased by 30-50%, NH_4^+ – by 30-57%. The most significant decrease was marked for ammonia nitrogen. We determined the algae species (*Golenkiniosis parvulum* (Woronud.) Korsch., *Pediastrum duplex* Meyen., *Coelastrum microporum* Negeli. and others), resistant to the high salinity of waters in the irrigation system, thus having a perspective for use as filters of contaminants.

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Conclusions and recommendations

- The developed information system and database made on its basis proved their vitality. The classification of vegetation is worked out on its basis, and statistical analysis of communities' structure and monitoring of changes in vegetation and soils was made.

The developed information system and database can be recommended as an information and co-ordinating system for the organisation and execution of research in the Aral Sea Basin.

- Modern vegetation of the Amu-Dar'ya delta is represented by 191 species belonging to 56 associations and 21 formations. Tugai species are most completely represented in the formation Populus.

- Statistical analysis of the communities' structure and environmental factors showed that the most significant are: medium index of species' diversity of community, medium and maximum indices of relative soil units and density of sward. The species composition is richer when the salinity of soils is lower and the density of sward higher. These indices are recommended as diagnostic when determining the territories for reservations.

- Analysis of species diversity of vegetation revealed as most valuable and prospective for preservation the formations: *Populeta arianae, Tamariceta ramosissimae, Alhagieta pseudalhagii, Glycyrrhizeta glabrae.*

- Over most of the territory of the Amu-Dar'ya delta the typical bog, meadow, meadow-tugai and solonchak soils were replaced by their takyrish variants. The new environmental conditions are characteristic for typical desert communities. They define the wide spread of repairing communities of *Salsola paulsenii* and expansion of *Ceratoides papposa* and *Haloxylon aphyllum*.

- Renewal of watering of the lake depressions promotes the development of bog, meadow and solonchak processes in soils and regeneration of tugai communities: with dominants *Typha* sp., *Phragmites australis, Tamarix hispida.*

- Straight anthropogenic impacts affect the soil-vegetation complexes on the local scale and often condition the degradation processes.

Taking into consideration that in the greater part of the Amu-Dar'ya delta, the environmental conditions changed to arid to such an extent that they are now not good for tugai communities, the following is necessary.

- Double the attention to preserve tugai coenoses and maintain their preservation through laws giving them the status of: "natural heritage" reserve, national park, which necessitates keeping an inventory; for example – the region with regulated watering by river waters: Kipchakdarya branch and the coasts of Mezgdurechenskoe, Shege, Maliy and Bolshoy Zakirkol lakes.

- On the desertified areas where the communities of desert type formed (*Ceratoides papposa, Haloxylon aphyllum*), it is necessary to sow desert ecology fodder plants, such as *Kohia prostrata* and others.

- Territories adjacent to the settlements, in a radius of 1-2 km, as the most degraded and dangerous sources of dust, must become the object of special attention and organization of special activities of complex melioration.

- Pasture in tugai communities must be controlled, as it is one of the strongest agents of the degradation process.
- It is recommended to the Commission of Ecology of the Karakalpakstan Republic to use the database for the monitoring of vegetation and soils.
- Algae *Golenkiniosis parvulum* (Woronud.) Korsch., *Pediastrum duplex* Meyen., *Coelastrum microporum* Negeli. are resistant to the high salinity of drainage waters and have good prospects for use as a filter against contaminants.

References

Ashirova A.A. 'Vegetation of the Amu-Dar'ya Valley and its uses'. Ashkhabad: Ylym. Book 1 – 1971. 230 p., Book 2 - 1976. 322 p.

Bahiev A.B., Butov K.N., Tadjitdinov M.T. 'Plant communities dynamics at the south of pre-Aral region in connection with the hydrological regime of the Aral Sea basin change'. Tashkent: Phan. 1977. 84 p.

Bahiev A.B. 'Ecology and changes of plant communities in the downflow of the Amu-Dar'ya river'. Tashkent:Phan.1985.192p.

Borovsky V.M. , Pogrebinskyi M.A. 'Ancient delta of the Syr-Dar'ya and North Kyzylkum'. Alma-Ata: Publ. of Academy of Sci Kazakch SR. V.1. 1958. 514 p.

Chalidze Ph.N. 'Plant communities dynamics in the levees and river bodies of the ancient and contemporary Syr-Dar'ya river delta' // Ecology. 1973. N 3. P.24-30.

Chalidze Ph.N. 'Plant communities changes in the interriver lowlands in the ancient and contemporary river delta of Syr-Dar'ya' // Ecology. 1974. N.3. P. 29-34.

Kievskaya R.Ch., Nekrasova T.Ph., Mojaitzeva N. Ph. 'Halogeochemical processes in the Syr'Darya delta under aridization / Problems of the desert development'. 1980. N 6. pp. 23-28.

Kabulov S.K. 'Desert phytocoenoses changes under aridization'. Tashkent:Phan. 1990.230 p.

Kurochkina L.Ja., Vuchrer V.V., Makulbekova G.B., Dimeeva L.A. 'Vegetation of the desiccated sea-shore and bottom' / Izvestija of the USSR Academy of Science. Sere of geography. 1991. P. 76-81.

Kust G.S. 'Desertification and soil evolution in the arid land'. Dissertation. Moscow. Lomonosov MSU. 1993.50 c.

Kust G.S. 'Main tendencies in soil salinization of the Amu-Dar'ya and Syr-Dar'ya deltas under present day strong desertification / Pochvovedenie. 1996 (under publication).

Mailun Z.A. 'Tygai vegetation – Potamophyta' / Plant cover of the Uzbekistan.V.2. 1973.P. 303-375.

Mamutov N.K. 'Meadow vegetation transformation in the Amu-Dar'ya river delta under aridization'. PhD These. Moscow Pedagogical Inst. 1991. 18 p.

Mojaicheva N. PhD. 'Landscape evolution under desiccation in the eastern Aral sea-shore / Problems of the deserts development'. 1979. N3. P. 18 -25.

Novikova N.M., Markova L.E., Bachiev A.B., Jalgasbaev J. 'Contemporary plant cover and its changes in connection with river runoff regulating / Problems of the desert development'. 1981. N 5.P. 21-28.

Rodin L.E. 'Desert vegetation dynamics'. M-L.: Nauka. 1961. 277 p.

Treshkin S.E. 'Structure and dynamics of woody-bush plant communities of the tugai forests in the downflow of the Amu-Dar'ya river'. PhD . These . Moscow. 1990. 23 p.

Zaletaev V.S., Novikova N.M. 'Changes in Biota of the Aral Region as a Result of Antropogenic Impacts between 1950 and 1990'// GeoJournal. 1995. N 35.1. P.23-27.

Zhollybekov B. 'Soil cover changes in the sea-shore part of the Amu-Dar'ya river delta' Tashkent:Phan. 192 p.

List of publications

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Papers

1. Bahiev A.B., Novikova N.M., Kust G.S., Mamutov N.K., Treshkin S.E., Gladyshev A.I., Pak V., Kuzmina J.V., Avetyan S.A., Dikareva T.V., Kapustin G.A., Rosov Ju. S. The results of the ecological investigations in the Muinak International station // Vestnik of the Karakalpak department of the Uzbek Academy of Science. 1995. N 2 (140) .P. 16-25 (in Russian).
2. A.Bahiev, S.Y.Treshkin, Sh.V.Kouzmina. Karakalpakia Tugays Modern State and Protection. Karakalpakstan Publishing House, Nukus, 1994. 72 p. (in Russian).

3. Gladyshev A.I., Novikova N.M. The tugais in the Amu-Dar'ya – the problem of preservation // Priroda. 1994. N 3. P. 54-64 (in Russian).
4. Korshunova V.S., Novikova N.M. Changes in soils, vegetation and halogeochemical processes in the landscapes of the Amu-Dar'ya river delta under aridization / Proc. of International symposium " Advances in hydroscience and engineering"- ICHE. Beijing, China. March 1995. Beijing: Tsinghua University Press. Vol. II. Part B. P. 1345 – 1352 (in English).
5. Kust G.S., Zukova L.K. Methane emission from desertificated soils in Pre-Aral region // Problems of desert development. 1994. N 2. p.76-79 (in Russian).
6. Novikova N.M. International project "Aral sea" // Geography and Natural Resources. 1995. N 1. P. 197-200 (in Russian).
7. Novikova N.M., Trofimova G.Yu. Ecological system data base for the river territory in the arid regions of Central Asia // Problems of desert development. 1944. N 2. P. 76-79 (in Russsian).
8. Novikova N.M., Trofimova G.Yu. Ecological-geographical database system: Composition and structure / Proceedings of the First International Conference on Hydroinformatics. The Netherlands, Delft, September, 19-23, 1994. P. 617-620 (in English).
9. Novikova N. Water management for biodiversity conservation in the desertified delta plains of the Aral sea basin // Bordomer – 95, 6-10 Fevrier, Bordeaux, France 1995. Pages 84 – 88 (in English).

Abstracts

1. Kust G.S. Desertification /Land degradation map of southern and eastern pre-Aral region // Proc. of the Internat. conference " Quaternary deserts and Climatic Changes" Al Ain, United Arab Emirates, December 9-11, 1995 (in English).
2. Kust G.S. The main trends of soil evolution in the lower reaches of Amu-Dar'ya river/ Abstr. Internat conf. "Asian ecosystems and their protection". Ulaanbaatar 21-25 August, 1995. P. 148 (in English).
3. Kust G.S. The peculiarities of soil forming processes in conditions of present desertification in the deltaic regions of the Aral sea basin's rivers /Proceedings of the Transact. Conference young scientists Soil Science Faculty MSU. Moscow, 1994. P. 56-58 (in Russian).
4. Kust G.S., Camara Cordova. Natural and antropogenic evolution of wetland soils in deltaic zones of arid and humid regions / Proceedings of the Transact. International Congress Soil Science. Acapulco, Mexico, 1994 (in English).
5. Kust G.S.,Goryachev A.V. Clay minerals and their transformation in alluvial soils of the Aral sea region territories prone to desertification// Proc. of the Internat. conference " Quaternary deserts and Climatic Changes" Al Ain, United Arab Emirates, December 9-11, 1995 (in English).
6. Kust G.S., Novikova N.M. The natural and antropogenic changes of plants and soils in the delta plains of Turan region deserts./ Proceedings of the EGS International Symposium. Grenoble, France, March 1994 (in English).
7. Kust G.S., Rosov S. Yu. The present peculiarities of salinization and desalinisation of soils and landscapes prone to desertification in the Aral sea region./ Proceedings of the EGS International Symposium. Grenoble, France, March 1994 (in English).
8. Kuzmina J.V. Classification of vegetation of the Amudarya delta/ Abstr. Internat. conf. "Asian ecosystems and their protection". Ulaanbaatar 21-25 August, 1995. P. 32 (in English).
9. Kuzmina J.V., Novikova N.M., Trofimova G.Yu. Botanical databases in the system of ecological databases for the deltaic territory of the Aral sea Basin / Abstr. of IV th. Plant life of south west Asia symposium. 21-28 May, 1995. Turkey.P.127 (in English).
10. Novikova N.M. Evaluation of the changes in the vegetation of the Amu-Dar'ya and Syr-Dar'ya river deltas as a basis for rehabilitation and protection/ Abstr. Internat conf. "Asian ecosystems and their protection". Ulaanbaatar 21-25 August,1995. P. 150 (in English).
11. Novikova N.M. Theory and methods for studying changes in vegetation in the arid delta plains / Abstr. of IV th. Plant life of south west Asia symposium. 21-28 May, 1995. Turkey. P.19 (in English).
12. Novikova N.M., Trofimova G.Yu. Systems of the ecological databases for the Aral sea basin deltas /Proceedings of the Mathematical methods in the ecology, Russia, Novosibirsk, 21-23 June 1994.P. 64-65 (in Russian).
13. Novikova N.M., Trofimova G.Yu., Chrapunov D. O. Ecological geographical database system for Amudarya and Syrdarya river deltas // Abstr. of Global Changes and Geography the IGU Conference. Moscow, Russia. 14-18 August 1995. P. 255 (in English).
14. Novikova N.M., Trofimova G.Y., Kuz'mina J.V. Vegetation cover monitoring the Amudarya delta on the basis of the ecological-botanical-geographical database./ Proceedings of the EGS International Symposium. Grenoble, France, March 1994 (in English).

To be published

1. Lubesnov Yu.E. and others. Karakum Canal: hydrobiology and water quality/ Water resources. 1996 . N 2 (21 pages, incl. 4 tab. in Russian).
2. Lubesnov Yu.E. Algae for the drainage water purification / Vestnik of Karakalpak Department of Uzbek Academy of Sciences. (8 pages in Russian).
3. Kust G.S. Ionoselective electrodes for the evaluation of soil salinity status in the Pre-Aral region / Soil, 1996 (8 pages, in Russian).

4. Kust G.S., Avetyan S.A., Derjuzchinskaya V.D. Soil salinization of the different types of territories in the Pre-Aral region/ Pochvovedenie, 1996 (14 pages, in Russian).
5. Kuzmina J. Classification of the riparian vegetation (Amu-Dar'ya river delta as a sample) / Journal of Botany. 1996 (21 pages, in Russian).
6. Novikova N.M. The current changes of the vegetation in the Amu-Dar'ya river delta / Proc. of the Nato Symposium. (12 pages in English).
7. Rozov S.Yu. The peculiarities of the suspension effect within the ionometric analysis of soil salinity in the Amu-Dar'ya river's deltaic region/1996, Pochvovedenie, (12 pages in Russian).

Table 1. Plant communities classification for hydromorphic habitats in the Amu-Dar'ya and Syr-Dar'ya river deltas

Climatype	Edaphotype	Cenotype	Phytiums	Associations
Thermomesophytia	Potamophyta – flood-plain vegetation	Potamodendra wooden tugai	1. *Populeta arianae**	1. *Populus ariana - Tamarix ramosissima - Mixteherbosa (Glycyrrhiza glabra, Calamagrostis dubia, Aeluropus littoralis)** 2. *Populus ariana - Tamarix ramosissima - Aeluropus littoralis - Mixteherbosa (Alhagi pseudalhagi, Karelinia caspia, Trachomitum scabrum)** 3. *Populus ariana -Tamarix ramosissima - Aeluropus littoralis - Chenopodiosum (Bassia hyssopifolia, Atriplex tatarica, Chenopodium album)** 4. *Populus ariana - Tamarix ramosissima - Zygophyllum oxianum - Salsopoiosa** 5. *Populus ariana - Tamarix ramosissima + T. elongata - Capparis herbacea - Ephemerosa**
			2. *Populeta pruinosae**	1. *Populus pruinosa - Tamarix ramosissima - Mixteherbosa (Calamagrostis dubia, Glycyrrhiza glabra, Phragmites australis, Aeluropus littoralis)**
			3. *Saliceta songaricae*	1. *Salix songarica - Mixteherbosa* 2. *Salix songarica + Populus pruinosa - Elaeagnus angustifolia*
			4. *Elaeagneta angustifoliae*	1. *Elaeagnus angustifolia + Populus ariana - Tamarix ramosissima - Mixteherbosa (Phragmites australis, Glycyrrhiza glabra, Calamagrostis dubia)* 2. *Elaeagnus angustifolia + Salix songarica - Halimodendron halodendron - Calamagrostis pseudophargmites***
			5. *Elaeagneta turcomanicae**	1. *Elaeagnus turcomanica - Tamarix ramosissima - Calamagrostis dubia* 2. *Elaeagnus turcomanica - Tamarix sp.sp. - Mixteherbosa (Aeluropus littoralis, Phragmites australis, Calamagrostis dubia)**
			6. *Elaeagneta oxycarpaea***	1. *Elaeagnus oxycarpa - Gramineosa (Calamagrosits epigeios, Agropyron fragile)*** 2. *Elaeagnus oxycarpa - Zygophyllum brachypterum - Ephemerosa***
		Potamothamna – bush tugai	7. *Tamariceta ramosissimae*	1. *Tamarix ramosissima - Calamagrostis dubia + Phragmites australis** 2. *Tamarix ramosissima - Phragmites australis** 3. *Tamarix ramosissima - Alhagi pseudalhagi + Karelinia caspia** 4. *Tamarix ramosissima + Lycium ruthenicum + Halostachys belangeriana - Mixteherbosa* 5. *Tamarix ramosissima + Halimodendron halodendron** 6. *Tamarix ramosissima - Capparis herbacea + Zygophyllum sp.sp.** 7. *Tamarix ramosissima - Tamarix sp.sp. - Haloxylon aphyllum - Krascheninnikovia ceratoides - Mixteherbosa (Alhagi pseudalhagi, Limonium otolepis)***

			8. *Tamariceta hispidae*	1. *Tamarix hispida + Halostachys belangeriana - Mixteherbosa (Karelinia caspia, Phragmites australis, Aeluropus littoralis)* 2. *Tamarix hispida + Tamarix sp.sp. + Halosatchys belangeriana - Limonium otolepis + Alhagi pseudalhagi*** 3. *Tamarix hispida - Aeluropus littoralis - Karelinia caspia*
			9. *Halimodendreta halodendrii*	1. *Halimodendron halodendron - Mixteherbosa (Calamagrostis dubia, Leymus multicaulis, Phragmites australis, Aeluropus littoralis)*
		Potamopoia – herb tugai	10. *Ñalamagro stideta dubiae**	1. *Calamagrostis dubia - Mixteherbosa**
			11. *Ñalamagro - stideta epigeae***	1. *Calamagrostis epigeios - Mixteherbosa***
			12. *Ñalamagro - stideta pseudo-phragmiteae***	1. *Calamagrostis pseudophragmites - Mixteherbosa***
			13. *Phragmiteta australiae*	1. *Phragmites australis* 2. *Phragmites australis - Salsopoiosa - Ephemerosa* 3. *Phragmites australis - Alhagi pseudalhagi - Mixteherbosa (Karelinia caspia, Aeluropus littoralis)*
			14. *Alhageta pseudalhagi*	1. *Alhagi pseudalhagi - Phragmites australis** 2. *Alhagi pseudalhagi - Aeluropus littoralis with shrubs (Tamarix ramosissima, Halimodendron halodendron, Lycium ruthenicum, Halostachys belangeriana) participation* 3. *Alhagi pseudalhagi + Karelinia caspia**
			15. *Glycyrrhizeta glabrae****	1. *Glycyrrhiza glabra - Tamarix ramosissiama + Halimodendron halodendron - Mixteherbosa (Phragmites australis, Calamagrostis dubia, Aeluropus littoralis)**** 2. *Glycyrrhiza glabra - Tamarix ramosissima + T. bungei- Mixteherbosa (Karelinia caspia, Alhagi pseudalhagi, Bassia hyssopifolia)**** 3. *Glycyrrhiza glabra - Tamarix ramosissima + T. bungei - Suaeda salsa****
			16. *Karelinieta caspiae*****	1. *Karelinia caspia - Mixteherbosa (Aeluropus littoralis, Alhagi pseudalhagi, Limonium otolepis****
Thermoeuxerophytia	Halophyta – vegetation of solonchak deserts	Halothamna– bush, evkserophile of vegetation of solonchak deserts	17. *Halostachydeta belangerianae*	1. *Halostachys belangeriana - Phragmites australis + Karelinia caspia** 2. *Halostachys belangeriana + Tamarix ramosissima - Aeluropus littoralis - Limonium otolepis** 3. *Halostachys belangeriana + Tamarix hispida - Aeluropus littoralis + Mixteherbosa** 4. *Halostachys belangeriana + Tamarix ramosissima + T. hispida - Climacoptera lanata + Senecio subdentatus** 5. *Halostachys belangeriana - Salsola dendroides** 6. *Halostachys belangeriana - Haloxylon aphyllum - Salsola nitraria ** 7. *Halostachys belangeriana - Tamarix hispida - Halocnemum strobilaceum - Limonium otolepis - Aeluropus littoralis***

				8. *Halostachys belangeriana + Tamarix hispida + T. leptostachys - Kalidium sp.sp. - Petrosimonia brachiata*** 9. *Halostachys belangeriana - Climacoptera lanata* **
			18. *Nitrarieta schoberi***	1. *Nitraria schoberi*** 2. *Nitraria schoberi + Lycium ruthenicum + Tamarix sp.sp. - Limonium otolepis - Ephemerosa*** 3. *Nitraria schoberi - Krascheninnikovia ceratoides - Alhagi pseudalhagi***
		Halohemitamnisca – evxerophile low subscrub vegetation of solonchak deserts	19. *Salsoleta dendroidis**	1. *Salsola dendroides** 2. *Salsola dendroides + Alhagi pseudalhagi - Salsopoiosa (Salsola foliosa)** 3. *Salsola dendroides with Halostachys belangeriana participation** 4. *Salsola dendroides + Tamarix sp.sp. - Capparis herbacea + Mixteherbosa** 5. *Salsola dendroides - Anabasis aphylla*
			20. *Kalidieta caspici**	1. *Kalidium caspicum** 2. *Kalidium caspicum + Haloxylon aphyllum**
			21. *Kalidieta foliosae***	1. *Kalidium foliatum - Karelinia caspia - Climacoptera aralensis***
			22. *Kalidieta schrenkianae***	1. *Kalidium schrenkianum - Alhagi pseudalhagi - Anabasis aphylla with Tamarix sp.sp., Halostachys belangeriana participation***
			23. *Halocnemeta strobilacei*	1. *Halocnemum strobilaceum* 2. *Halocnemum strobilaceum - Suaeda salsa with Kalidium caspicum participation****
			24. *Anabasieta aphyllae*	1. *Anabasis aphylla + Salsola orientalis** 2. *Anabasis aphylla* 3. *Anabasis aphylla - Salsola sp.sp. with Haloxylon aphyllum participation*** 4. *Anabasis aphylla - Aellenia subaphylla - Ephemerosa*
		Halopoia – evxerophile herb vegetation of solonchak deserts	25. *Salicornieta europaea*	1. *Salicornia europaea* 2. *Salicornia europaea - Suaeda salsa* 3. *Salicornia europaea - Aeluropus littoralis****
			26. *Climacoptereta aralensis**	1. *Climacoptera aralensis - Phragmites australis** 2. *Climacoptera aralensis - Suaeda salsa*
		Halodendra – woody evxerophile vegetation of solonchak deserts	27. *Haloxyleta aphyllae****	1. *Haloxylon aphyllum* *** 2. *Haloxylon aphyllum - Halostachys belangeriana****

Table 2. Soils

N	Type	Index (in Russian)	Subtype	Species
1	Gray-brown desert	СБ	not divided, except facial diversity	typical, gypsed, solonchaked, takyr-solontzevatye, washed
2	Sandy desert	ПП	not divided, except facial diversity	typical, rest-meadow, degraded, rest-solonchaked
3	Takyrs	Т	not divided, except facial diversity	typical, rest-solonchaked, with aeolian sandy cover
4	Takyrlyke	ТВ	not divided, except facial diversity	typical, rest-meadow, rest-swamp, rest-solonchaked, with aeolian sandy cover
5	Meadow-tugai (alluvial-meadow-tugai)	ПТУГ	typical, layery	typical, salinized, coreded
6	Meadow (alluvial-meadow)	П	typical, swamp-meadow, low developed, layered, takyred	typical, salanized, takyred
7	Swamp	Б	peaty- swamp, mud-swamp, meadow-swamp, meadow- swamp-peaty, low developed layered, takyred	typical, salinized, takyred
8	Solonchaks (automorphic)	С	typical, takyred	typical, rest-meadow, rest-swamp, with aeolian sandy cover, takyred
9	Solonchaks (hydromorphic)	С	typical, swamp, meadow, watered, marshes, seashores	typical, rest-swamp, rest-meadow, takyred, with aeolian sandy cover

Table 3. Statistic indices of community structure and of edaphic factors in the formations of the Amu-Dar'ya delta vegetation

Plant formation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. *Populeta arianae*	1829	660	1	22	9.34	9	97	67	0.44	8.00	3.18	2.60	113	931	523	511	0	100	56	60	23
2. *Populeta pruinosae*	237	83	4	12	7.55	7	29	11	2.30	3.25	2.78	2.78	531	642	605	641	40	100	70	70	0
3. *Saliceta songaricae*	175	53	4	10	7.57	8	31	7	*	*	*	*	*	722	*	*	60	90	76	75	1
4. *Elaeagneta angustifolia*	175	52	9	11	10.40	11	22	5	*	*	*	*	*	*	*	*	70	100	89	93	0
5. *Elaeagneta turcomanicae*	361	126	6	23	11.45	10	44	11	1.50	3.00	2.42	2.50	412	931	565	511	15	100	71	70	3
6. *Tamariceta ramosissimae*	1383	459	2	16	7.78	8	89	57	0.80	10.50	3.57	2.90	214	961	520	512	0.5	95	59	63	8
7. *Tamariceta hispidae*	523	188	2	13	7.23	7	44	26	1.15	4.00	2.54	2.00	412	931	583	612	10	100	72	80	5
8. *Halimodendreta halodendrii*	365	118	4	15	9.83	10	35	12	1.00	3.35	1.75	1.50	211	631	586	631	80	100	88	90	0
9. *Calamagrostideta dubiae*	304	98	4	14	8.17	7.5	39	12	0.70	3.50	1.73	1.00	511	631	579	611	40	100	81	80	2
10. *Phragmiteta australiae*	294	94	1	9	4.27	4.5	38	22	0.31	6.00	2.39	2.00	412	922	660	731	10	95	61	75	5
11. *Alhagieta pseudalhagi*	968	315	2	17	7.88	8	53	38	1.15	5.50	3.43	3.50	212	643	453	412	15	100	59	55	0
12. *Glycyrrhiza glabra*	947	321	4	16	9.17	9	56	35	1.00	3.00	1.93	2.00	411	931	590	611	50	100	84	90	1
13. *Karelinia caspia*	353	116	2	11	6.82	7	26	17	1.75	3.50	2.73	2.98	412	931	635	612	20	100	73	70	1
14. *Halostachydeta caspicae*	862	291	1	12	5.32	5	43	56	0.60	5.50	2.65	2.60	414	934	811	911	0.5	100	39	38	11
15. *Salsoleta dendroidis*	376	131	1	13	5.70	4	49	23	1.80	8.00	4.98	3.50	212	922	516	414	3	90	43	40	2
16. *Kalidieta caspici*	176	63	1	13	5.25	4	31	12	1.30	1.50	1.43	1.50	114	965	808	824	7	65	32	20	1
17. *Halocnemeta strobilacei*	140	48	1	14	6.00	5	21	8	1.00	1.10	1.04	1.00	911	965	946	963	35	65	53	55	0
18. *Anabasieta aphyllae*	317	115	2	16	7.19	7.5	36	16	2.00	3.50	3.00	3.10	312	914	476	414	7	70	42	40	0
19. *Salicornieta europaea*	68	19	2	4	2.71	3	8	7	0.40	2.50	1.81	2.00	911	961	943	955	60	80	68	60	0
20. *Climacoptereta aralensis*	67	21	2	5	3.50	3.5	10	6	1.50	1.80	1.65	1.65	815	965	908	939	20	90	55	55	1
21. *Haloxyleta aphyllae*	194	75	2	13	6.25	5.5	39	12	1.80	2.00	1.90	1.90	113	965	334	312	0	70	35	35	4

* – no data

Column Table 3: 1 Sum of abundances. 2 Frequency of cross-coming. 3 Number of species minimum (min). 4 Number of species maximum (max). 5 Number of species average (av). 6 Number of species median (med). 7 Number of species sum. 8 Number of patches. 9 Ground water level minimum (min) cm. 10 Ground water level maximum (max) cm. 11 Ground water level average (av) cm. 12 Ground water level median (med) cm. 13 Soil minimum (min). 14 Soil maximum (max). 15 Soil average (av). 16 Soil median (med). 17 % density minimum (min). 18 % density maximum (max). 19 % density average (av). 20 % density median (med). 21 Anthropogenic load.

Table 4. Correlation of plant communities structure statistic indices and of edaphic factors (at the formation level)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
% density median (med)																				-0.132
% density average (av)																			0.966	-0.242
% density maximum (max)																		0.645	0.671	0.257
% density maximum (min)																	0.177	0.771	0.671	-0.496
Soil median (med)																0.331	-0.172	0.019	-0.014	-0.117
Soil average (av)															0.978	0.301	-0.257	-0.038	-0.095	-0.171
Soil maximum (max)														0.292	0.221	-0.537	-0.417	-0.521	-0.434	0.277
Soil minimum (min)													0.117	0.765	0.732	0.440	-0.129	0.247	0.213	-0.362
Ground water level median (med) cm												-0.407	-0.005	-0.479	-0.546	-0.449	0.296	-0.204	-0.209	0.159
Ground water level average (av) cm											0.886	-0.474	-0.035	-0.532	-0.592	-0.484	0.354	-0.179	-0.147	0.282
Ground water level maximum (max) cm										0.800	0.597	-0.469	0.017	-0.407	-0.397	-0.438	0.447	-0.064	0.032	0.589
Ground water level minimum (min) cm									-0.290	0.215	0.348	-0.137	-0.098	-0.327	-0.402	-0.132	-0.202	-0.195	-0.257	-0.460
Number of patches								-0.438	0.780	0.502	0.441	-0.458	0.169	-0.275	-0.220	-0.514	0.367	-0.223	-0.128	0.804
Number of species sum							0.860	-0.272	0.795	0.542	0.392	-0.656	0.051	-0.583	-0.551	-0.465	0.332	-0.103	-0.006	0.740
Number of species median (med)						0.392	0.153	0.040	0.204	0.126	0.168	-0.419	-0.447	-0.590	-0.545	0.355	0.531	0.631	0.633	0.101
Number of species average (av)					0.960	0.432	0.141	0.124	0.164	0.144	0.137	-0.453	-0.394	-0.592	-0.569	0.253	0.476	0.531	0.526	0.120
Number of species maximum (max)				0.763	0.634	0.714	0.464	0.050	0.305	0.274	0.251	-0.570	-0.095	-0.584	-0.596	-0.295	0.194	-0.013	0.022	0.416
Number of species minimum (min)			0.114	0.676	0.710	-0.195	-0.385	0.235	-0.268	-0.190	-0.115	0.060	-0.498	-0.248	-0.225	0.634	0.391	0.703	0.644	-0.327
Frequency of cross-coming		-0.237	0.615	0.348	0.354	0.927	0.946	-0.383	0.722	0.452	0.394	-0.486	0.087	-0.375	-0.337	-0.397	0.397	-0.068	0.012	0.806
Sum of abundances	0.9981	-0.226	0.603	0.349	0.362	0.925	0.950	-0.395	0.736	0.457	0.402	-0.481	0.066	-0.372	-0.332	-0.381	0.416	-0.049	0.029	0.781

Column Table 4: 1 Sum of abundances. 2 Frequency of cross-coming. 3 Number of species minimum (min). 4 Number of species maximum (max). 5 Number of species average (av). 6 Number of species median (med). 7 Number of species sum. 8 Number of patches. 9 Ground water level minimum (min) cm. 10 Ground water level maximum (max) cm. 11 Ground water level average (av) cm. 12 Ground water level median (med) cm. 13 Soil minimum (min). 14 Soil maximum (max). 15 Soil average (av). 16 Soil median (med). 17 % density minimum (min). 18 % density maximum (max). 19 % density average (av). 20 % density median (med). 21 Anthropogenic load.

Table 5. Changes in the structure of herb phytomass (in mg/m²) in communities of *Tamarix hispida+T. ramosissima - Bolboshoenus maritimus - Aeluropus littoralis* under the impact of pasture and reduction of watering

Year	Green mass	Dead mass litter + dry plants	Volume of surface phytomass	Green mass vs dead mass
1993	516	48	564	10.7
1994	246	180	426	1.4
1995	70	290	560	0.2

Table 6. Estimation of fish productivity of the lakes in Tashauz region

Name	Daily gross production	Annual primary production		Catch kg/ha	Potential fish production kg/ha
	$g\ O_2/m^2$	$g\ O_2/m^2$	kkal/m²		
Tekemchi	1.53	588	1897	29.2	87.6
Porsikel	0.91	332	1129	17.8	53.4
Hodgeili	1.24	454	1544	24.0	72.0
Chonakli	2.16	788	2681	40.7	122.1

Figure 1. Model of the dynamic links of formations on hydromorphic habitats in the Amu-Dar'ya delta

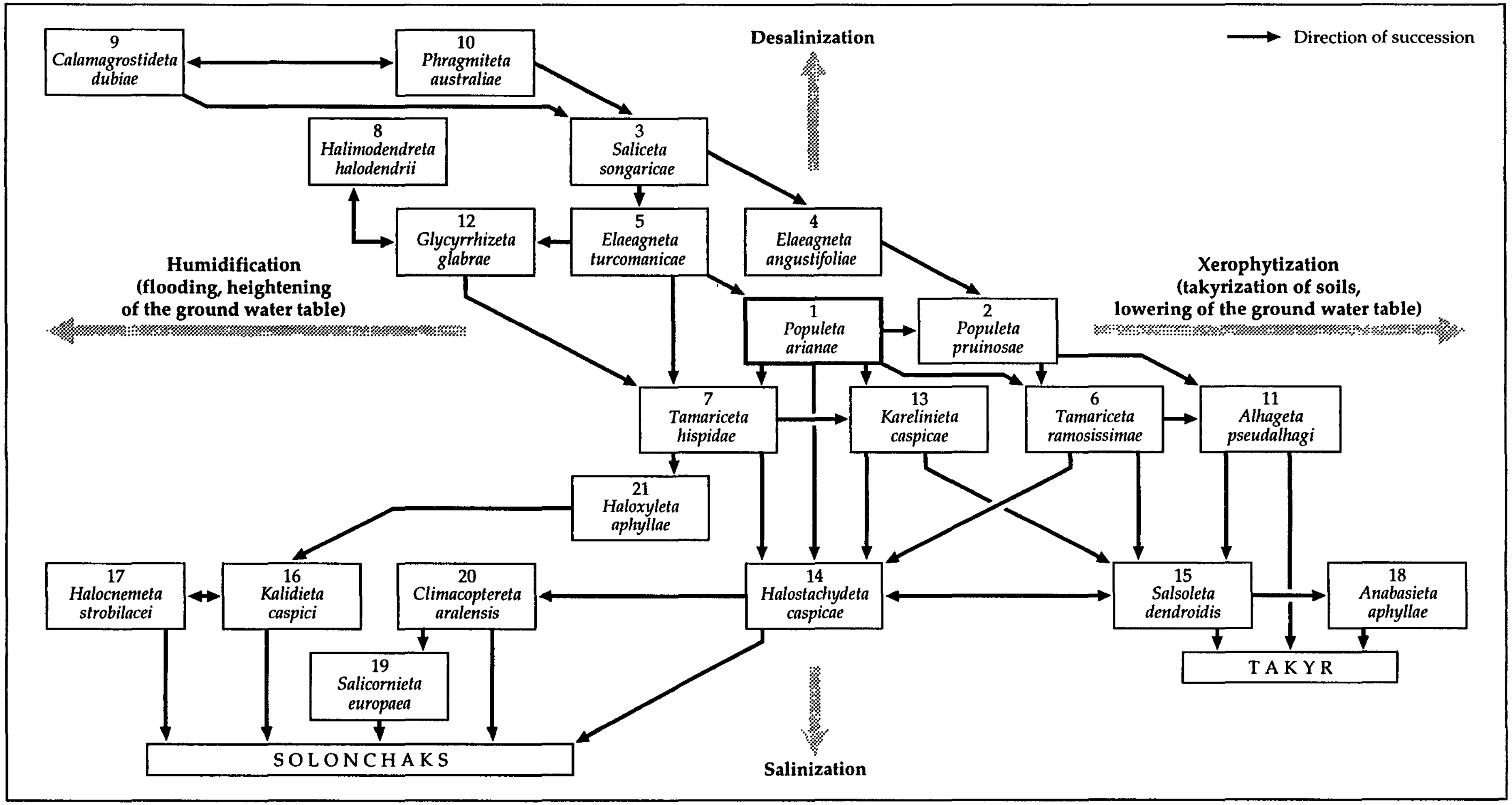


Figure 2. Statistic indices of communities' structure and of edaphic factors in the formations of the Amu-Dar'ya delta vegetation

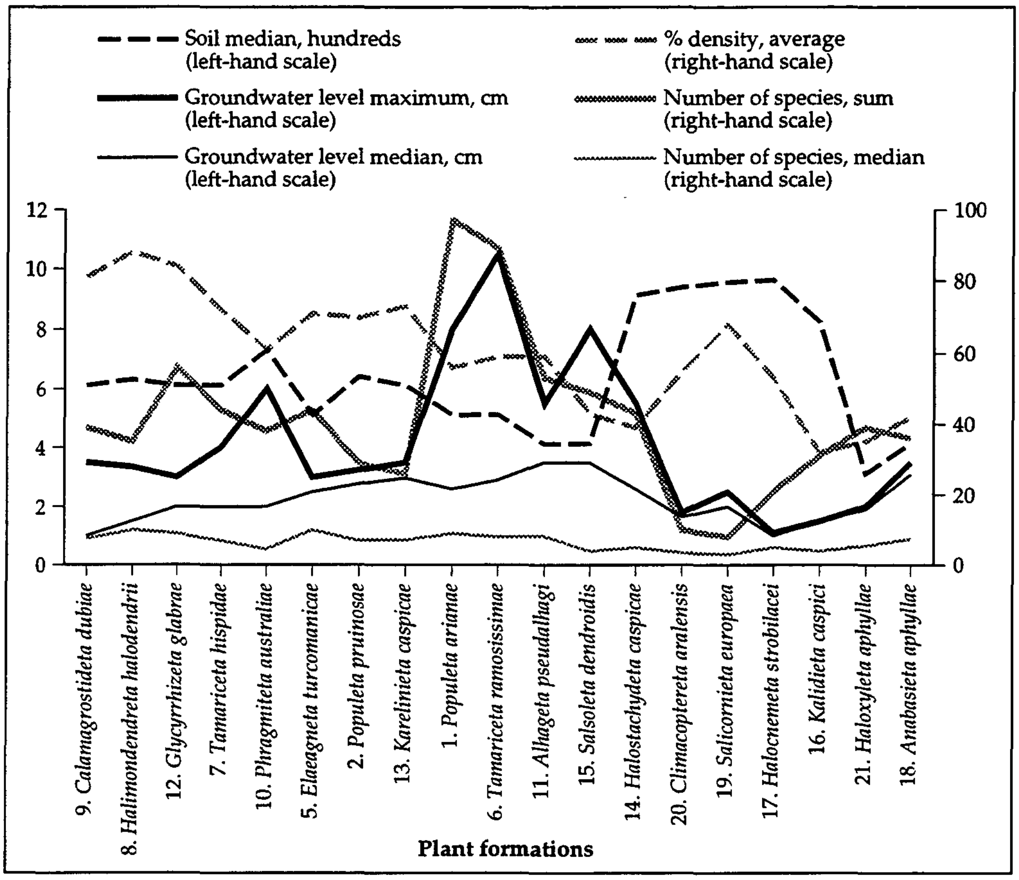
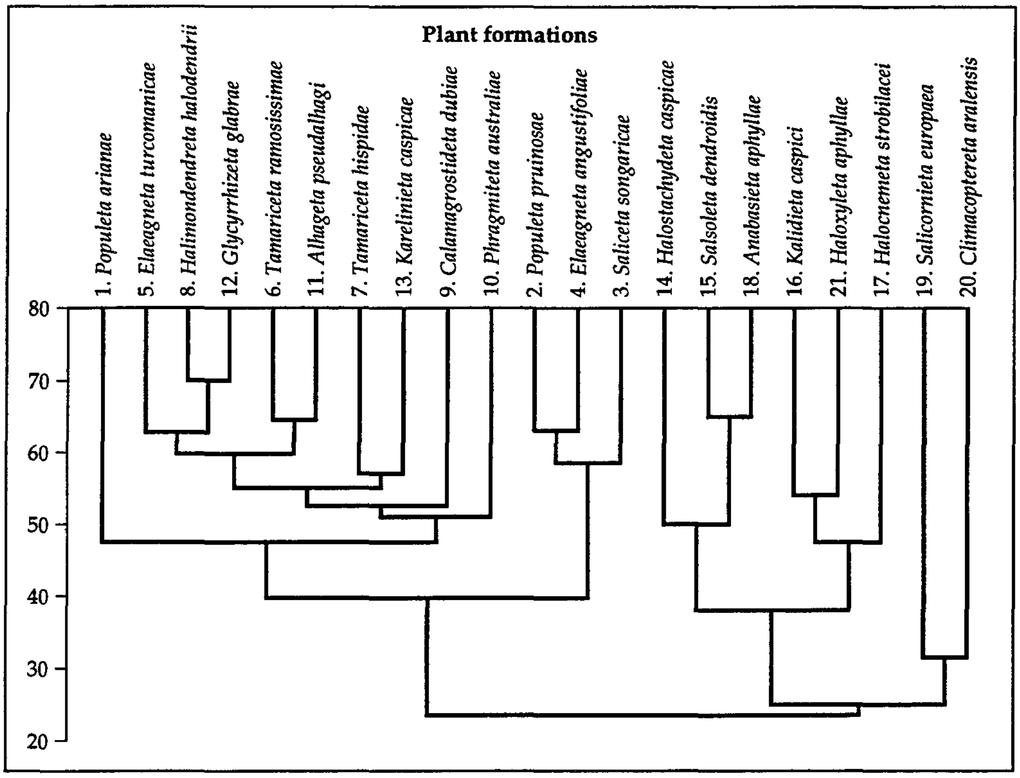


Figure 3. Cluster analysis of Sorensen of the Amu-Dar'ya plant formations



MIGRATION OF PESTICIDES IN TIME AND THEIR DISTRIBUTION IN THE SOIL-WATER-VEGETATION SYSTEM

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Introduction

Intensive use of pesticides has long been made in Uzbekistan. The utilization of pesticides is indispensable for intensive agriculture for greater farm production. However, their expanded use and proliferation of types leads to increased danger of biosphere pollution. Of the four landscape components (soil, water, air, biota), the first two are the most exposed to contamination.

Through farming activities, the soil, as an important element of the biosphere, is annually exposed to the action of pesticides and several times in each season exposed to accumulation and migration. An index of the behaviour of pesticides in the soil and other systems is the rate of their decomposition into non-toxic substances. The most persistent are chlorine-organic substances: for instance, DDT remains toxic for 144 months, and HCH for 18 months. Persistence is one of the main causes of their accumulation in the soil and its contamination. It is likely that traces of DDT detected recently, especially at former agricultural airfields, are residuals of applications from as early as 1983.

In 1995, research was conducted on six former agricultural airfields (three in Karakalpakstan, two in Khorezm province, Uzbekistan, and one in Dashkovus province, Turkmenistan), with the objective of determining the extent of contamination by pesticides of soil and water (surface run-off, drainage water and groundwater). A total of 430 soil samples and 31 water samples were collected in the course of the investigations.

One of the main objectives was to find out the effect of plants on the elimination of pesticides from the soil. For this purpose, the usually cultivated crops were planted on 14 sites selected on abandoned airfields, with different soil types and different groundwater levels.

Subjects for investigation

Pesticide migration was investigated in soil profiles, selected in 1993, at six abandoned airfields, belonging to different collective farms ("Khalkabad" in Kergeily district, "Kungrad" in Kungrad district, "Amu-Dar'ya" - in Karakalpakstan; "Ahunbabaev", in Koshkupyr district and "Khorezm" in Shavat district, - both in Uzbekistan; and "40 years of Turkmenistan" in Dashkovus region, Turkmenistan).

The extraction of pesticides by plants was tested on four former airfields - on the lands of farms: "Ahunbabaev", "Horezm", "40 years of Turkmenistan", "Khalkabad". The following crops were used: industrial crops - cotton, sunflower, tobacco, sorghum; cereals - wheat, rice, jugara, maize, beans; fruits - melon, water-melon, pumpkin; vegetables - carrots, tomato, cabbage; perennial grass - alfalfa; woods - Poplar; natural (wild) vegetation - *Salicornia*.

The samples were analysed for Cl- and P-pesticides in the chromatographic laboratory of the Research Centre for Water Management Ecology.

Investigation results

The investigations have confirmed that the territories of former agricultural airfields are still contaminated by pesticides to different degrees and, with time (1993-1995), their distribution in the soil profile changes in quanitity and composition (Table 1, Figures 1-4). The total quantity in the soil profiles did not change significantly during the three years of investigations and, in some cases, even increased annually, especially in the top layers, for instance, in the farm "Khalkabad" (Fig. 1, Section 28, near the former mixing site during the airfield use). This can be explained by the stability and weak dissolution of Cl-pesticides, and also, by the fact that the land of the former airfield is not irrigated non-cultivated land. Similarly, the land of the former airfield is not cultivated in the "Amu-Dar'ya" farm, in particular in Section 06 (mixing pit). Fig.1 shows an upward re-distribution of the pesticide content in the soil profile, which can be explained by the fact that in 1994, the land was prepared for rice, by the application of large amounts of water, but then rice was not sown because of the shortage of fresh water; in 1995, the pesticide concentrations almost reached the former level of 1993.

The behaviour of pesticides is different on irrigated land. Profile 01 (former pesticide store) at the former airfield located on the land of "Ahunbabaev" farm, Horezm district, is typical for irrigated soils. On this land, rice was cultivated over the last 6 years, hence displacement of pesticides towards the lower layers took place (Fig. 4). If the supply of such irrigation water quantities stops, the displacement will be reversed, because the groundwater is heavily contaminated, with concentrations largely over the permissible ones (Fig. 4).

Soil contamination is influenced by contaminated groundwater, as is particularly noticeable in the farms "Amu-Dar'ya" and "Khalkabad", where groundwater contamination is the highest. Where groundwater is insignificantly contaminated, a gradual decrease of pesticide concentrations is observable along the whole depth, as shown, for instance, on Section 19 (non-cultivated land), located at the take-off strip of the former airfield in the farm "Kungrad", Karakalpakstan (Fig. 2).

The high level of groundwater pollution is explained by the lack of drainage at the "Amu-Dar'ya" farm in the zone of the former airport, and by the unsatisfactory operation of the drainage network in the farm "Khalkabad". Water samples taken from drainage collectors show that leaching of pesticides continues from the territories of the former airfields (Fig. 5, Table 1). The trends shown by Table 1 and Figure 5 are generally for all abandoned agricultural airfields - lower at the beginning of the collector ditch than at its end.

Literature sources and our investigations confirmed that pesticides accumulate in heavy soils, in contrast to light, sandy soils. This can be seen from the analyses, summarized in Table 2. Nevertheless, plants cultivated on these soils contain DDT and its metabolites in concentrations which exceed the permissible levels.

The distribution of pesticides in the "soil-water-plant" systems is discussed below.

Pesticides are intensively absorbed from the soil and water by the plants in the stage of their active growth. The access of HCH, DDT and their metabolites increases during rain or watering. For instance, in the green mass of cotton sprouts, Cl-pesticides exceed the permissible concentrations 38-1000 times (Table 2). After watering, the intensity of taking up Cl-pesticides by cotton and other cultures depends on the soil properties and groundwater level. Whereas in sand or sandy loam, water filters easily, washing out the pesticide content, in loam and clay soils, the pesticides stagnate and continue to be absorbed by the plants. Thus, DDT pollution of heavy soils causes serious contamination of the plants. As the irrigation water itself also contains some Cl-pesticides, the groundwater becomes greatly contaminated, as well as both the seasonal and perennial crops.

The high pesticide concentrations in the groundwater lead to increased residual contents of these products in plants, the roots of which reach the groundwater level. This is confirmed by the high residual content of Cl-pesticides in crops on areas, where the groundwater is heavily polluted by these products, while their concentrations in the soil is below the permissible limits. (Table 2, Section 06). While young vegetation outside the irrigated zone (e.g. young poplar trees) contains low concentrations of pesticides, adult trees on contaminated soil and ground water intensively accumulate DDT and DDE in their stems.

When the groundwater level is high (less than 0.7 m below the surface), Halophytes – *Salicornia*, etc., – are excellent "absorbants", accumulating large quantities of chlorides, without any damage to themselves.

The dynamics of pesticide content in agricultural plants has its specific features.

In the course of growth, part of the pesticides, absorbed by young plants, is decomposed, and the other part is distributed in the plant's biomass. By Autumn, for instance, the content of pesticides in cotton stems is reduced by one or two orders of magnitude. The lower the pesticide content in Spring-Summer, the lower it will be in Autumn. The same rule is valid for other crops - cereals, vegetables, oil-seed, beans. It is important to underline that even small quantities of pesticides in the soil and groundwater will accumulate in the end product - the fruit, seeds, grain. The higher the pesticide content in the soil and groundwater, the higher it will be in the seeds. This is particularly so for cereals - wheat, maize, sorghum, rice. In these crops, isomers of Cl-pesticides also accumulate, in proportion with their biomass.

Cl-pesticides actively accumulate also in leguminous crops - mash, alfalfa. These crops are excellent for the reclamation of saline soils, because they absorb salts, including chlorides; but as they would, at the same time, also absorb pesticides, they must be grown on pesticide-free land, as the presence of pesticides is not permissible in fodder.

In melons, water melons and pumpkins, grown on loamy soils, the concentration of Cl-pesticides will surpass not more than 1-3 times the permissible level, if the pesticide concentration in the soil also exceeds the permissible level 1-3 times. In melons and water melons, grown on lightly contaminated sandy soil, no pesticide content will appear at all. In pumpkins, in particular, pesticides do not accumulate, even on heavily contaminated soils, which makes this a good fodder crop.

Conclusions

The problems of the Aral region go far beyond the borders of a country, they are of global importance and cause great concern.

Intensive irrigated agriculture, with consumptive use of the limited water resources, and industrial development in the southern Aral basin created a technogenic landscape, which practically conceals the natural landscape of the Amu-Dar'ya delta. The soil, vegetation and surface and groundwater, all are contaminated, at different levels.

In this context, we have proposed a project for the research of residual contents not only of pesticides, but also of heavy metals, in all the irrigated land of the Khoresm province of Uzbekistan and Karakalpakstan. The research was scheduled for 1996-1999.

Table 1. Selected results of chemical analysis of soil, groundwater and drainage water of samples taken from various farms in 1993, 1994 and 1995
units: soil - mg/kg; water - μg/l

Sample depth cm	Year	Alpha HCH	Gamma HCH	DDE	DDD	DDT	Butifos
Collective Farm Amu-Dar'ya, Hodjeily District, Karakalpakstan Soil Section N06, virgin land near mixing site							
0-25	1993	-	-	1.418	0.282	1.966	0.297
	1994	0.004	0.002	0.460	0.074	0.250	-
	1995	0.006	0.009	0.410	0.268	2.743	-
25-50	1993	0.004	0.015	0.023	0.007	0.015	-
	1994	0.005	0.056	-	-	-	-
	1995	0.003	0.009	0.009	0.003	0.037	-
50-75	1993	0.005	0.016	0.016	0.011	0.029	-
	1994	0.055	0.003	0.009	0.013	0.003	-
	1995	0.002	0.012	0.121	0.058	0.885	-
75-100	1993	0.002	0.019	0.008	0.010	0.024	0.226
	1994	0.001	0.002	0.050	0.180	0.990	-
	1995	-	-	0.015	0.008	0.099	-
100-150	1993	traces	0.013	0.007	0.006	0.009	-
	1994	0.001	traces	0.027	0.120	1.260	-
	1995	0.003	0.006	0.007	0.006	0.032	-
150-200	1993	0.002	0.008	0.013	0.010	0.007	-
	1994	0.003	0.002	0.006	0.033	0.059	-
	1995	0.012	0.005	0.006	traces	0.023	-
Collective Farm Amu-Dar'ya, Hodjeily District, Karakalpakstan Section N06, virgin land near mixing site Groundwater at 1.6 m depth							
1.6	1993	2.216	36.371	1.749	0.392	2.448	0.120
	1994	2.216	6.374	1.479	0.293	2.840	-
	1995	0.968	0.544	0.144	0.530	9.500	-
State farm Khalkabad, Karakalpakstan Soils section N28, virgin land, near mixing site							
0-25	1993	0.001	0.001	0.239	0.347	0.625	-
	1994	0.031	0.013	0.088	1.057	0.210	-
	1995	0.051	-	0.439	0.201	4.301	-
25-50	1993	-	-	0.047	-	0.078	-
	1994	0.010	0.005	0.005	0.066	0.007	-
	1995	0.036	0.041	0.071	0.025	0.456	-
50-75	1993	-	-	0.020	-	0.084	-
	1994	0.016	0.005	0.001	0.004	0.001	-
	1995	0.007	0.004	0.027	0.010	0.222	-
75-100	1993	-	-	0.014	-	0.031	-
	1994	0.006	0.001	0.002	0.013	0.002	-
	1995	0.002	0.004	0.026	0.011	0.211	-
100-150	1993	0.001	0.001	0.014	0.019	0.088	-
	1994	0.008	0.007	0.006	0.095	0.011	-
	1995	0.004	0.004	0.026	0.014	0.264	-
150-200	1993	-	-	0.015	-	0.076	-
	1994	0.007	0.003	0.004	0.042	0.005	-
	1995	0.001	traces	0.008	0.004	0.071	-

Sample depth cm	Year	Alpha HCH	Gamma HCH	DDE	DDD	DDT	Butifos
State farm Khalkabad, Karakalpakstan, soil section N28, underground water							
180	1993	1.240	-	0.219	0.075	0.278	-
	1994	1.224	0.085	0.219	0.091	0.287	-
	1995	1.008	0.048	0.482	0.264	3.616	-
State farm Khalkabad, Karakalpakstan, drainage water							
Beginning zone of influence	1993	-	-	-	-	-	-
	1994	0.037	0.043	0.035	0.031	traces	-
	1995	0.324	0.019	-	0.100	-	-
End zone of influence	1993	0.177	0.084	0.628	0.001	0.001	-
	1994	0.093	0.026	0.045	0.064	0.042	-
	1995	0.129	0.053	0.001	0.076	0.181	-
Col. farm 'Gungrad', Gungrad District, Karakalpakstan. Soil Section N19 (virgin land, take-off strip)							
0-25	1993	0.008	0.002	0.027	0.021	0.038	-
	1994	0.005	traces	0.014	0.027	0.015	-
	1995	0.002	traces	0.022	-	-	-
25-50	1993	0.005	0.002	0.028	0.043	0.116	-
	1994	0.006	0.002	0.082	0.034	0.062	-
	1995	0.005	-	0.060	0.028	0.027	-
50-75	1993	0.007	0.004	0.021	0.001	0.018	-
	1994	0.007	0.004	0.012	0.021	0.037	-
	1995	0.002	-	-	-	-	-
75-100	1993	0.017	0.008	0.720	0.013	0.118	-
	1994	0.016	0.009	0.490	0.023	0.121	-
	1995	0.003	traces	0.280	0.045	0.056	-
100-150	1993	0.003	0.002	0.025	0.008	0.033	-
	1994	0.004	0.002	0.003	0.001	0.004	-
	1995	0.002	-	-	-	-	-
150-200	1993	0.008	0.002	0.037	0.017	0.119	-
	1994	0.007	0.003	0.048	0.014	0.111	-
	1995 - Underground water						
Col. farm 'Gungrad', Karakalpakstan. Drainage water							
Beginning zone of influence	1993	0.176	0.092	-	-	-	-
	1994	0.083	0.006	0.054	0.089	0.044	-
	1995	0.195	0.142	-	-	-	-
End zone of influence	1993	1.821	0.821	0.151	-	0.362	-
	1994	3.674	0.503	0.047	0.077	0.044	-
	1995	0.270	-	0.430	2.056	0.362	-
Col. farm 'Gungrad'. Underground water. Soil section 19 h=1.8m							
180	1993	0.007	-	-	-	-	-
	1994	0.005	0.117	traces	0.001	traces	-
	1995	-	0.239	-	-	-	-
Col. farm 'Ahunbabaev' of district of Horezm region. Soil section N1 irrigation land (storage)							
0-25	1993	-	-	0.045	0.019	0.238	-
	1994	0.012	0.008	0.065	0.079	0.084	-
	1995	0.005	0.010	0.056	0.015	0.205	-
25-50	1993	-	-	-	-	0.033	-
	1994	0.007	0.003	0.019	0.009	0.016	-
	1995	0.003	0.004	0.003	-	0.008	-
50-75	1993	0.046	0.038	0.689	0.672	2.547	-
	1994	0.010	0.008	0.612	0.017	2.084	-
	1995	0.005	0.002	0.026	0.022	0.292	-

Sample depth cm	Year	Alpha HCH	Gamma HCH	DDE	DDD	DDT	Butifos
75-100	1993	0.008	0.003	0.068	0.070	0.424	-
	1994	0.005	0.004	0.086	0.070	0.374	-
	1995	0.005	0.006	0.062	0.141	0.272	-
100-150	1993	0.005	0.002	0.016	0.023	0.145	-
	1994	0.006	0.005	0.012	0.017	0.134	-
	1995	0.003	0.002	0.142	0.147	1.331	-
150-200	1993	-	-	0.014	-	0.058	-
	1994	-	-	0.014	0.017	0.053	-
	1995 - Underground water						
Underground water. Soil section N1							
H=2.5m	1993	0.148	0.075	0.090	0.180	0.080	-
H=2.3m	1994	0.121	0.111	0.107	0.156	0.092	-
H=1.5m	1995	0.156	0.142	0.088	0.172	0.078	-
Drainage water							
Beginning zone of influence	1993	-	-	-	-	-	-
	1994	0.030	0.115	0.230	0.509	0.124	-
	1995	0.218	-	0.052	0.223	-	-
End zone of influence	1993	0.360	1.763	0.630	1.217	0.530	-
	1994	0.687	0.230	0.309	0.598	0.104	-
	1995	4.368	1.489	0.449	0.789	-	-

Table 2. Pesticide content (in terms of multipliers of permissible concentration) in soils and crops of the former agricultural airfields

Soil type	Groundwater level m	DDT with metabolites in the soil	Crops	DDT with metabolites in the crops
Uniform loam	3.0	3.3	cereals (green mass)	5.7
Uniform loam	3.0	17.1	cereals (green mass)	8.0
Stratified loam	2.0-3.0	1-3	water melon	17.55
Stratified loam	2.0-3.0	1-3	water melon	1.5
Stratified loam	2.0-3.0	1-3	melon	1.65
Stratified loam	2.0-3.0	1-3	pumpkin	traces
Stratified loam	2.9-3.0	1-3	cotton-stem	6.8
			cotton-seeds	traces
			cotton-wool	2.2
	3.0	>1000	beans	112.8
	3.0	>1000	poplar	725.6
	1.0-2.0	>1000	cotton (young)	38.1
	1.0-2.0	>1000	wheat (grain)	322.5
	1.0-2.0	2055	jugara (grain)	11.6
	1.0-2.0	>100	water melon	71.8
	1.0-2.0	>100	pumpkin	traces
Loam with sandy loam layers and sand	1.0-2.0	1-3	water melon	nil
			rice (stem)	nil
			rice (grain)	2.5
			maize (green mass)	19.7
			maize (grain)	1.3
		5-10	jugara (grain)	4.0
Sandy loam with sandy irrigated soils	1.0-2.0	< p.c.	poplar (young stems)	1.0
			poplar planted 1994-1995	19.0
			sunflower	103.6
			cotton (green mass - July)	1000.3
			cotton (stem)	11.4
			cotton (seeds)	0.8
			cotton (wool - October)	1.8
			wheat (grain)	6.0
			tomato	1.25
Sandy irrigated soils	1.0-2.0	1-3	technical sorgo: stem	1.5
			grain	1.0
			sunflower stem	-
			sunflower seeds	11.4
			jugara stem	0.6
			jugara grain	2.9
			technical sorgo:	
			stem	2.3
			grain	5.8
			cotton (green mass July)	57.1
			rice (grain)	2.4
			wheat (grain)	10.15
			cotton stem	0.3
			cotton seeds	2.0
			cotton wool	0.5
Loam stratum irrigation		20-30	pumpkin	-
			carrot stem	9.05
			carrot fruit	7.3
			tobacco foliage	3.35
		>250	pumpkin	traces

Note: Maximum permissible concentration: industrial crops - 0.1 mg/kg
other crops - 0.002 mg/kg

Table 3. Residual contents of Cl-pesticides in fodder crops in mg/kg

Crop	alpha HCH	gamma HCH	DDE	DDD	DDT
alfalfa 1 year	0.04	0.07	0.07	0.04	0.10
alfalfa 2 year	nil	nil	0.173	0.02	0.117
maize	0.023 0.002	0.003 0.002	0.008 0.054	0.02 0.011	nil 0.065
Natural vegetation					
salicornia	1.085 0.590 0.009	0.233 0.116 0.005	0.132 0.296 0.012	0.040 0.040 0.005	0.595 1.741 0.076

Note: Residuals of DDD and metabolites are *not permitted* in fodder crops

Figure 1. Collective farm Ahunbabaev: pesticide content in soil and groundwater

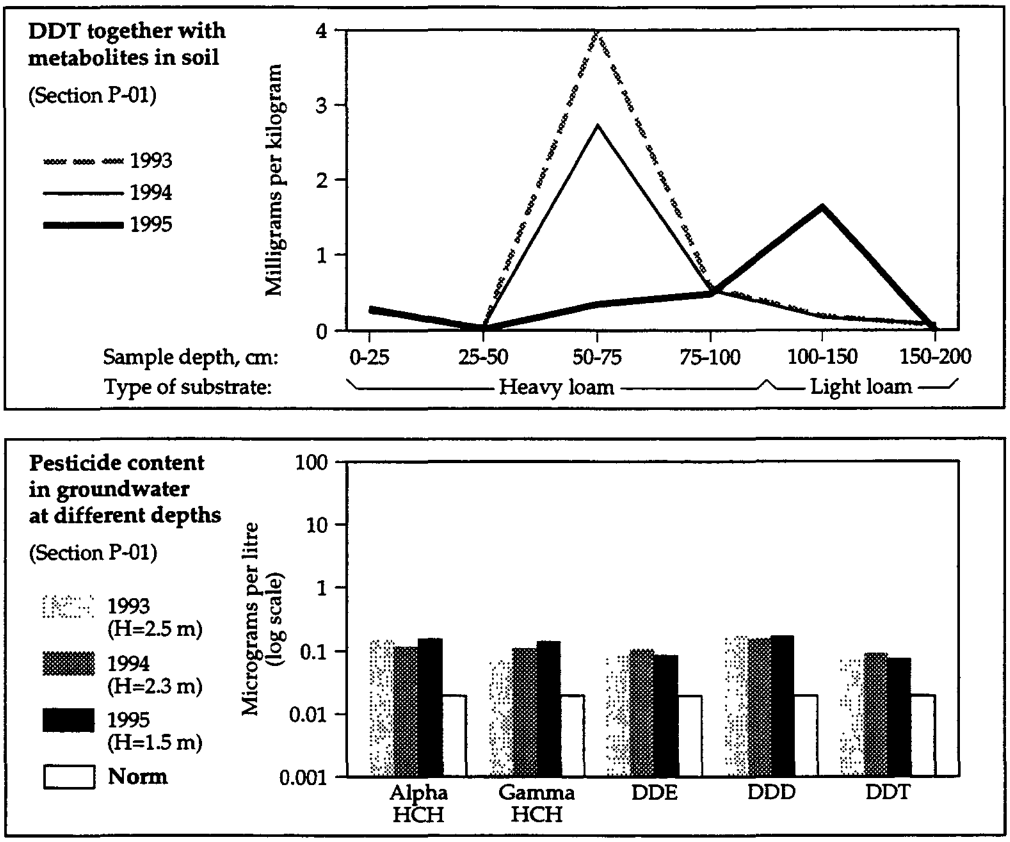


Figure 2. Collective farm Gungrad: pesticide content in soil and groundwater

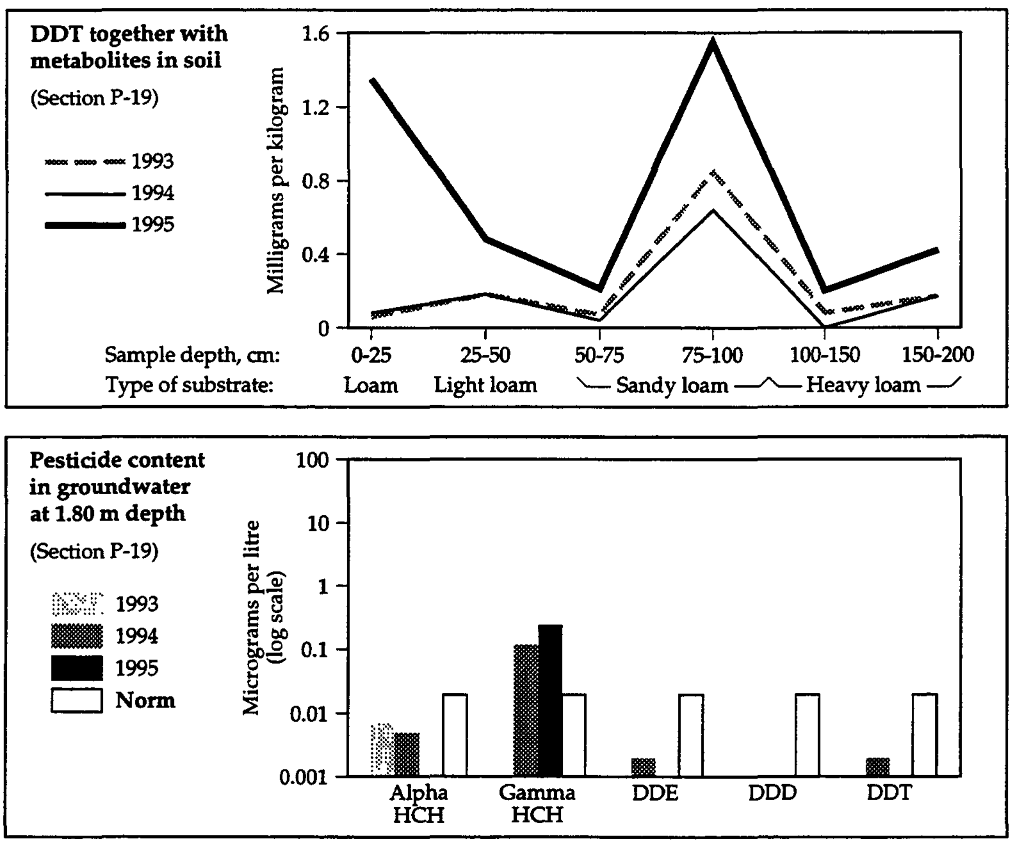
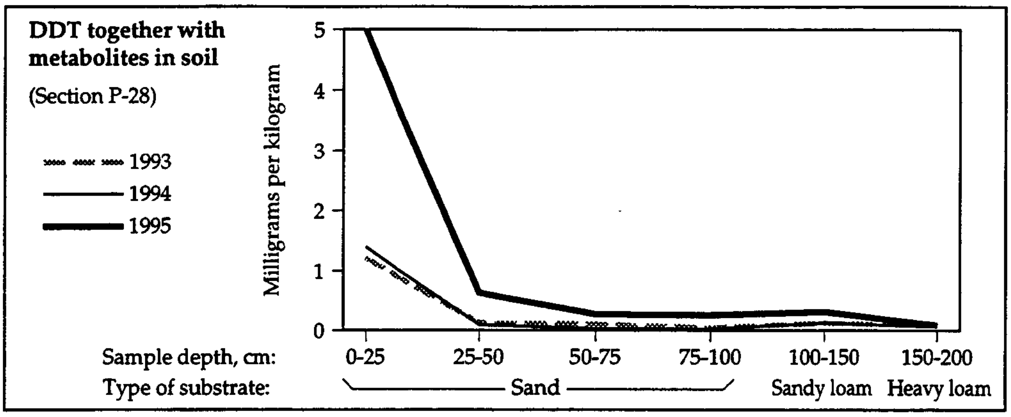


Figure 3. State farm Khalkabad: pesticide content in soil and groundwater



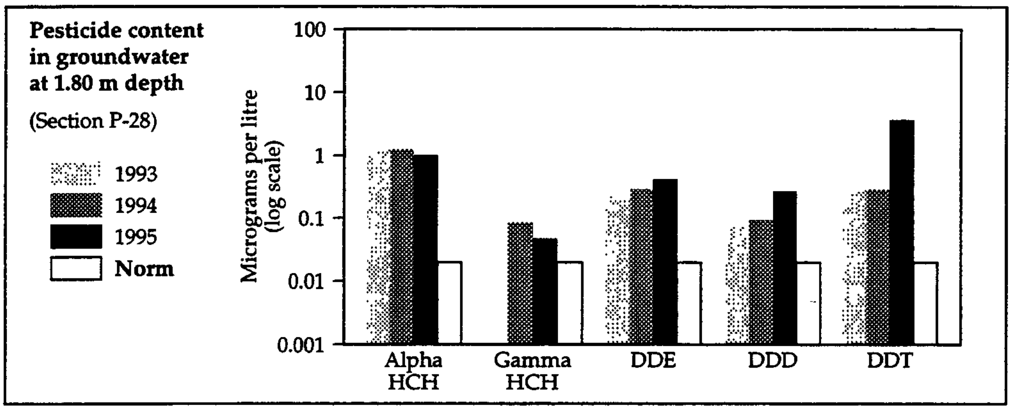
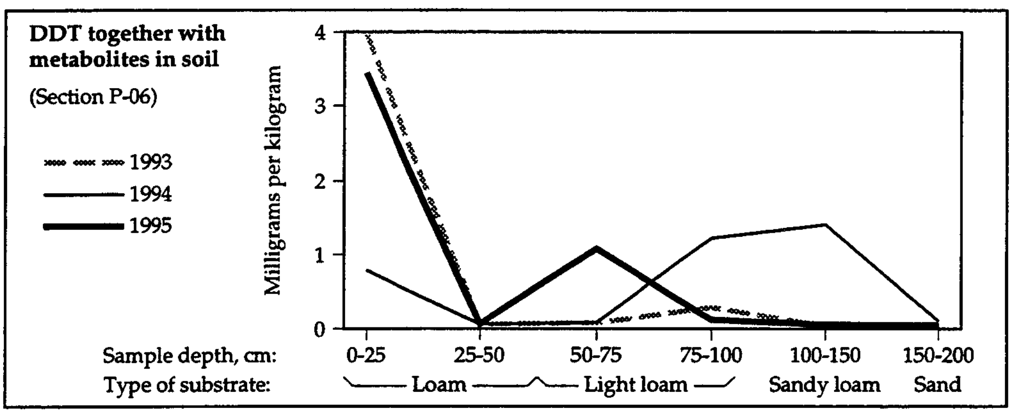


Figure 4. State farm Amu-Dar'ya: pesticide content in soil and groundwater



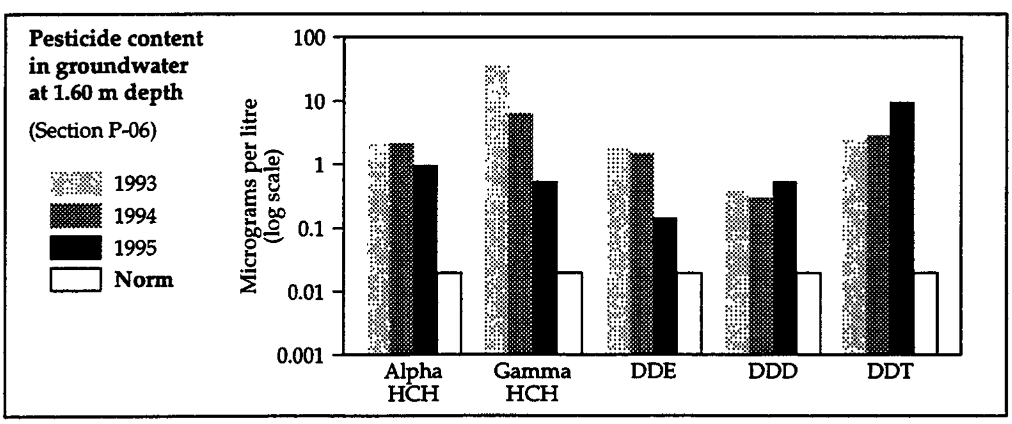
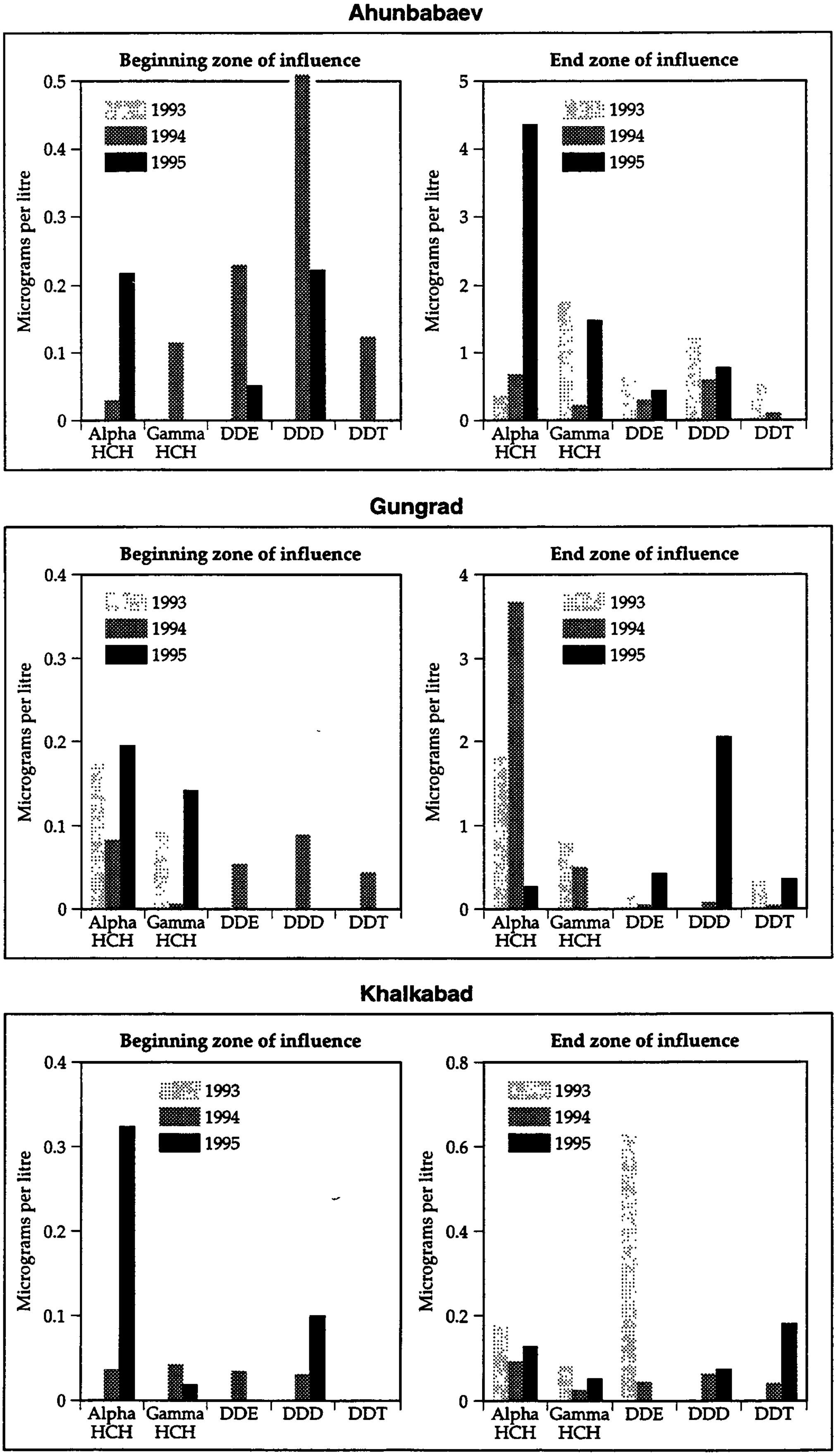


Figure 5. Pesticide contamination of the drainage water in different state farms



Waterbodies

LIVING ASSOCIATIONS OF THE NORTHERN PART OF THE ARAL SEA IN 1993-1995

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Introduction

The period from the end of the 1980s to the beginning of the 1990s is remarkable in the history of the Northern Aral due to two extremely important events. The first of these was the disappearance, by 1989, of the permanent connection between the Large and Small Aral (Fig. 1), as the Berg's strait became reduced to a small stream which could be considered as one of the Syr-Dar'ya delta branches (Aladin, 1989). Since then, the two water basins - Large and Small Aral - have separate development scenarios. Up to 1989, their common feature was progressive salinization, which was the same in both parts (Fig. 1). By this time, the forming of a main living association of aquatic organisms was fully completed, in typical conditions of polyhalinity, (Plotnikov, 1995, Filippov, 1994; Rusakova, 1995). By 1991, the flow of the Syr-Dar'ya started to increase owing to various natural and anthropogenic factors, and the dry Berg's Strait started to widen again. As suggested (Aladin, Plotnikov, 1995), the widening of the strait could lead to the diversion of almost the total flow of the Syr-Dar'ya into the Large Aral. If this happens, the Small Aral could dry up completely in the near future. Considering this, and taking into account the relatively high population density in the northern part of the Aral Sea region, plans were proposed to rehabilitate the Small Sea by building a dam, in order to prevent the flow of water from the Small Aral into the Large Sea (Bortnik, 1978, 1980; L'vovich, Zigel'naya, 1978; Chernenko, 1983; Micklin, 1991; Aladin, Plotnikov, 1995; etc.).

The dam across Berg's strait was built in 1993, with an effort to repair it in 1994. This dam now prevents the loss of the Syr-Dar'ya's water inflow from the Small Aral and has already allowed the level of the Small Sea to rise by 2-2.5 m, in spite of occasional damages. As a result, the hydrological conditions in the main part of the investigated aquatic areas in the Northern Aral changed considerably, which is the second important event of the present time. In 1992-1994, a visible tendency of flooding was noted in certain parts of the dried-off sea bed, with a certain reduction of water salinity (Fig. 2, Table 1). Already by Autumn 1993, - Spring 1994, the Bolshoi Sarychaganak Bay, desiccated in 1987, was restored, owing to the water level increase of 1.2-2 m. (Also referred to as B. Sarychaganak Bay and Sarychaganak Bay). In the past, this was the largest bay with numerous settlements on its coast, including Sea ports and the city of Aralsk.

While the latter event has had, so far, no visible effects on the main structural and functional characteristics of living associations, it has created the prerequisites for the restoration of some elements of fauna and flora, which inhabitated the basin before the regression of the lake, and now found refuge in pre-mouth areas and small freshwater terminal lakes. The increase of water levels has led to the appearance on the coast of a wide belt of embayments and temporary water basins, with a large salinity gradient (Table 1). In the future, in case of successful conservation and rehabilitation measures, they can become a source of biodiversity increase of the living associations in the Northern Aral.

During the last expedition in Autumn 1995, an abrupt drop of the Aral Sea water level of about 1m was recorded, with the rise of salinity in the Sarychaganak Bay up to 45 g/l, causing mass death of hydrobionts. The new crisis on the Small Aral was caused by excessive water discharge from the reservoirs on the upper flow of the Syr-Dar'ya river in Autumn-Winter 1994-1995. This water completely destroyed the dam in Berg's strait and a large water mass has flowed out from the Small into the Large Aral. Thus, the danger has risen again of the complete desiccation of the Sarychaganak Bay, the Small Aral Sea being subdivided into 3-4 isolated hyperhaline water bodies.

Direct investigations in any part of the Aral Sea in the present period have become difficult, for at least two reasons: (i) navigation is absent, and (ii) the coastline is inaccessible for land expeditions. Because of this, almost all hydrobiological investigations in 1985-1995 were concentrated on the 3-5 metres deep coastal waters, and only in some cases included the deeper aquatories. The data have been obtained during short-term expeditions, often without repetition during the vegetation season. A third reason has been caused by the increasing costs of expeditions and lack of available funds.

Nevertheless, even these fragmentary hydrobiological data can be used for some extrapolation on the whole territory of the Northern basin, as they were obtained for the most representative parts of the coastal aquatic zone (Fig. 3). Moreover, almost all Northern aquatic areas are now represented by shallows with depths of 3-6 m, excluding two areas in the central part and in the middle of Shevchenko Bay. These data also make it possible to evaluate the ongoing changes of living associations at the onset of conservation actions in the Northern Aral. This data can later be used as reference points for future long-term monitoring of the state of the Northern Aral.

Taking into account the limited length of this paper, the history and early stages of the modern regression of the Aral Sea will not be described here. Reference is made to several publications in English and German (Aladin., 1991a,b; Williams, Aladin, 1991; Keyser, Aladin, 1991; Aladin, Eliseev, Williams, 1991; Plotnikov et al., 1991; Aladin, Potts, 1992; Aladin, Williams, 1993; Diagnostic Study..., 1993; Aral Sea Project Seminar, 1994; Aladin et al, in print).

Materials and methods

Taking into account the specific conditions of hydrobiological studies on the Aral Sea nowadays, the most representative regions of the Northern Aral have been investigated, including the areas flooded in 1993-1994 (Fig. 3), and some temporary water basins on the flooded territories of the formerly dry sea bed. The brief environmental description of the investigated areas for 1990-1994 is condensed into Table 1. The main criteria of selection of localities for sampling and experiments were the gradients of different environmental factors and, among these, of salinity in the first place (Table 1). A brief review of methods used is given in Table 2.

Plants

Phytoplankton

By its floristic content and other characteristics, the phytoplankton is, to-day, very similar to that of the Caspian Sea. The diversity of fresh and brackishwater algae species is still high, but euryhaline species dominate in quantitative abundance. These are: *Actinocyclus ehrenbergii* Ralf. var. *ehrenbergii*, *Exuviella cordata* Ostf., *Chaetoceros wighamii* Bright., *Cyclotella caspia* Grun. var. *caspia*, *Diploneis smithii* (Breb.), *Navicula digitoradiata* Ralfs. var. *digitoradiata*, *Pleurosigma elongatum* W.Sm., *Oocystis solitaria* Wittr., *Campylodiscus echeneis* Ehr., *C.daemelianus* Grun., *Merismopedia punctata* Meyen, *M.tenuissima* Lemm., *Pseudoanaboena galeata* Bocher. f. *galeata*, etc., (Pichkily, 1981; Elmuratov, 1988; Rusakova, 1995; Orlova, Rusakova 1995).

By 1985, many species of Cyanophyta and Chlorophyta had disappeared, which were common in the period of quasi-stability, and from the ecological point of view, the phytoplankton has become more monotonous, consisting mainly of species of Bacillariophyta and Dinophyta (Fig. 4), which are typical for brackish and sea waters (Pichkily, 1981; Elmuratov, 1988; Dobrynin et al., 1990; Dobrynin, Koroleva, 1991; Rusakova, 1995).

By 1995, 243 species and subspecies of algae were found and identified in the main districts of the Northern Aral (Table 3). They belong to the following divisions: Bacillariophyta – 115 species, Chlorophyta – 62, Dinophyta – 28, Cyanophyta – 29, Cryptophyta – 3, Chrysophyta – 2, Euglenophyta – 2, Xantophyta – 1.

By comparing the taxonomy of algae collected in different parts of the Northern Aral (Fig. 4), a heterogenity in species distribution can be observed, caused by differences in the hydrological and chemical regimes (Table 1), and the season of year (taking Butakov Bay as an example). In both bays, the complex of dominant species consists, as a rule, of euryhaline diatoms of marine origin with predominating *Chaetoceras wighamii*, *Actinocyclus ehrenbergii*, and brackish water Dinophyta, which used to be typically the second in importance of the phytoplankton components in the previous period of quasi-stability. In all regions, the highest species diversity was noted in the Bacillariophyta group, suggesting not to be too sensitive to the nutrient regime (Guseva, 1961).

Concerning salinity conditions, Dinophyta are the most abundant in the highest saline districts. Intensive development of Chlorophyta and Cyanophyta is observed in the most refreshed zone, located near the Syr-Dar'ya mouth. Further away from the delta towards the main water body of the Small Sea, their populations become inhibited. The quantity of oligo- and mesohaline forms in highly saline regions varies significantly (Fig. 5).

Regarding the saprobity indices of phytoplankton species dominating in different periods in the Aral Sea, the tendency to gradual increase in number of a and b saprobionts in the investigated areas can be assumed.

Biomass evaluation has shown an increase in abundance of phytoplankton, from less than 1 g/m^3 in average, to 2-8 g/m^3 (Table 4). Only in the newly flooded Sarychaganak Bay was the biomass in June 1994 about 1 g/m^3, but even this is three times higher than in the same season of 1960 (Yablonskaya, 1964).

Phytobenthos

In June 1994, in the refilled region of Bolshoi Sarychaganak gulf, two higher aquatic plant species dominated among the benthic macrophytes: *Zostera noltei* Hornem *and Ruppia cirrhosa* (Petagna) Grande, and three species of green algae: *Chaetomorpha linum* (Mull.) Kutz., *Cladophora glomerata* (L.) Kutz. and *Cl. fracta* (Mull. ex. Vahl.) Kutz.

The following species of filamentous green algae were also found: *Rhizoclonium hierogliphicum* (Ag.) Kutz., and *Enteromorpha intestinalis* (L.) Link.

All these species form four associations of submarine plants:

1. Association *Zostera noltei* + *Ruppia cirrhosa* + *Chaetomorpha linum.*
2. Association *Ruppia cirrhosa.*
3. Association *Chaetomorpha linum* + *Cladophora glomerata* + *Cl.fracta.*
4. Association *Cyanophyta.*

The bottom of this basin is overgrown by the most resistant and widespread macrophyte species. All of them are cosmopolitan and polymorphic, and common for all Middle Asian brackish water basins. The green filament algae are oligo-mesohaline species, and the higher aquatic plants are mesohaline.

Primary production

Planktonic community

On the background of the actual nutrients balance (Table 5) and good light conditions (Table 1), using data obtained by direct measurements of the rate of photosynthesis and decomposition (mainly in Spring-Summer and early Autumn, Table 6), different authors noted that primary production in the investigated areas is now close to the level of slightly mesotrophic and mesotrophic lakes. For this statement we have used the classifications after Kitaev (1984), Bul'on (1985); data from: Dobrynin, et al. (1990), Dobrynin, Koroleva (1991), Orlova (1993, 1995), Orlova, Rusakova (1995), Aladin et al. (1996, in press), Filippov et al. (in press).

The vertical distribution of photosynthesis activity in plankton and some other plankton characteristics are presented on Fig. 6. The highest rate of photosynthesis, independently of districts, has been noted in samples collected from horizons 0.5-1 S (S – depth of water transparency, measured by Secchi disk). On stations with full lighting (dark areas on Figure 6) values from a middle horizon were the highest. It was not always directly related to the phytoplankton biomass and chlorophyll *a* content. In the majority of experiments, however, there was a tendency of decrease in photosynthetic activity with depth, on the background of decreasing algae biomass and chlorophyll. In the water column, daily decomposition was more homogeneous than photosynthesis in the plankton, except in the area near Bugun'.

The investigated areas are very different in relation to primary production and decomposition of phytoplankton (Table 6), particularly in connection with the season. In the area of the Syr-Dar'ya mouth and pre-mouth Bay, the values of total primary production under favourable light conditions (Aopt) have been rather constant for 2 years of observation. The total integral primary production (A) is usually lower than the daily decomposition (D), the A/D ratio being rather balanced, in the average (for 5 stations) about 1. The pre-mouth bay is still one of the most productive areas of the Northern Aral, (Novozhilova, 1973; Table 5). Data obtained for Syr-Dar'ya waters fluctuate from year to year and depend directly upon human activity, such as road construction across the Syr-Dar'ya during the construction of the dam.

For Shevchenko, Tshchebas and Butakov bays, the values of Aopt are also rather stable (in the average 300 mg C/l for 6 stations). Integral values A and D and A/D ratios are different and depend upon the hydrological conditions of each bay.

In the coastal waters of the Aral proper (bays near Bugun' and Tastubeck Cape), all characteristics of production and decomposition vary strongly in different zones, and from station to station. The most productive areas are situated in the narrow belt near the shorelines, where light penetrates the whole water column. The Aopt and A values in these districts exceed those in the other investigated areas. It is possible that this was connected with high photosynthetic activity of chlorophyll *a* (or daily assimilation numbers DAN) at the time of investigations, due to good light conditions (DANs in Table 5).

In 1994, a special investigation was carried out in the newly flooded Sarychaganak Bay (Fig. 3). Groups of stations were selected in accordance with the main aquatic and semiaquatic biotopes. All biotopes of the bay are characterized by high photosynthesis rate, including the majority of temporary water basins on the shoreline (Tables 1, 6); the contribution was highest of the areas where the bottom was covered by sea grass.

Evaluation of the contribution of planktonic and bottom communities to the primary production and aerobic decomposition of organic matter

Taking into account the significant changes in both benthic and planktonic aquatic plant communities, and the evident redistribution of their part in the total plant biomass in the Aral Sea, it was decided to evaluate, as a first approximation, their participation in the primary production. An outline for experiments was first drafted (Orlova, 1993), and later applied in several investigations (Orlova, 1995; Filippov et al., in press), for the determination of oxygen excretion and consumption by intact cores of bottom sediment, with bottom organisms on and in them (based on methods offered by Assman, 1953; Hayes, McAulay, 1959; Romanenko, Kuznetzov, 1973). They enabled an approximative evaluation of the contributions of water column and bottom periphytic associations to the primary production and decomposition.

For technical reasons, correct experiments could be conducted only in areas with full lighting of the water column. For other zones and stations, only data on daily aerobic decomposition could be obtained, measured by the decrease of dissolved oxygen in experimental boxes (as given in Table 7).

It was noted that even with full lighting, which means under conditions favourable for the development of bottom plants, the water column's contribution to primary production is considerably higher than that of the bottom. Excluding the Bays and Tastubeck Cape, it reaches nearly 100%. This contribution is two times lower in the pre-mouth area, where sea grass is rather developed (in the samples, the mean biomass was over 400 g/m^2, together with a high value of chlorophyll in a thin upper layer of bottom sediment: over 1,000 mg/m^2, against 77 mg/m^2 near Bugun', in May 1993) [Orlova, 1995].

Thus, in all aquatic territories of the Northern part of the Aral Sea (investigated in the last two years), the planktonic community plays the main role, both in photosynthesis and decomposition of organic matter (Table 8). Only in the vicinity of the mouth of the Syr-Dar'ya, the water column and bottom have approximately equal shares in primary production and decomposition.

The newly flooded Sarychaganak Bay has an outstanding position. Here, due to favourable hydrological conditions, macro-phytobenthos could greatly develop: sea grass covers about 30% of main area of the bay and, in temporary ponds, the coverage reaches (together with abundant filamentous green algae) up to 60-70%. At the same time, the phytoplankton biomass does not exceed 1 g/m^3, as it is represented by algae (mainly flagellate and diatoms) having small size cells. In accordance with such structure of the plant association, the main share in matter and energy exchange belongs to bottom communities, as it used to be in the previous periods of the Aral Sea history (Yablonskaya, 1964; Novozhilova, 1973; Kargevich, 1975).

It is thus possible to conclude that in connection with the structure of the first trophic level, a new distribution of roles took place between the water column and bottom in the waters of the Northern Aral, together with changes of trophic structure from oligotrophic or slightly mesotrophic, to a, b mesotrophic (following the classification of Kitaev, 1988, elaborated on the base of structure and functioning of phytoplankton in the lakes).

Animals

Zooplankton

Ciliates of the Aral Sea have rarely been studied, either in the past, or recently. Existing data are almost exclusively confined to the sub-order Tintinnina. The first species list of ciliates of this group appeared in 1903. A complete list of ciliates is given in Berg's monographs (1908): *Tintinnopsis cylindrata, Codonella relicta, Tokophrya* sp., *Acineta* sp., and *Vorticella* sp. Only tintinnid forms were determined as species, and hence only these forms will be discussed. Papers published in the 1930s mention three tintinnid species: *C.relicta, Tintinnidium fluviatile* and *T.pusillum*. A list of ciliata species, recognized in this study, is given in Table 8.

In recent times in the Small Aral Sea, three species of sub-order Tintinnina dominated: *Tintinnopsis cylindrica* Daday, 1867, *Metacylis mediterranea* var. *pontica* Jorgensen, 1924, *Tintinnidium fluviatile* Stein, 1833. The stomatid ciliates *Mesodinium* sp., *Tintinnopsis cylindrica* and *M. mediterranea* var. *pontica* were found in Butakov Bay and in the area near the mouth of the Syr-Dar'ya. The mouth itself was inhabited exclusively by *Tintinnidium fluviatile*. *M.mediterranea* and *Tintinnopsis cylindrica* probably first appeared in the Aral Sea by the end of the 1970s or early 1980s. At that time, salinity exceeded 13 g/l, that is the appropriate limit of the salinity barrier for the Aral Sea (Aladin 1990). *Tintinnidium fluviatile* is a typical freshwater form and therefore persists in the brackish estuarine water of moderate salinity, for example near the Syr-Dar'ya mouth (Smirnov, 1995).

In the embayments and temporary waters of Sarychaganak Bay, a total of 10 species of Ciliata was recorded in 7 stations. In temporary water bodies 9 species were found, and in the Gulf 6 species. In stations adjoining the zone of temporary waters, the composition of infusoria species was transitional.

The total list of species seems to be similar to those in the permanent remnants of former Sarychaganak Bay (salinity gradient from 18 g/l to over 200 g/l) situated near Aralsk city. Data on the gulf proper (stations 6, 7), result in a species list close to that of the Northern Aral open part, from which it differs only by the absence of Tintinnina suborder species, which usually dominate there. Only empty shells of *Tyntinnopsis cylindrica* Gaev. were found in temporary ponds. This circumstance may indicate that *T.cylindrica* were brought in from the Northern Aral, or developed in Sarychaganak Gulf in the Spring.

A maximum number of species and abundance was recorded in the temporary basins. Succession of the basins was accompanied by the decrease in species' diversity and increase of biomass of the persistent species (*Mesodinium* sp.) (Fig. 7).

Some of the recorded species were tested for salinity resistance (Table 9). The majority of ciliate species inhabiting the investigated area belongs to periphytonic and benthic groups. They are common for brackish waters of the arid zone in Asia (Agamaliev, 1983).

Planktonic Crustacea, Rotaria and free-living stages of bottom invertebrates

The Aral Sea zooplankton is now mainly formed of very few invertebrate species, responsible for over 90% of abundance and biomass. Despite the great changes in the composition of the Aral Sea fauna, copepods and larval bivalve molluscs still occur, as in the past. Originally the inhabitants of continental saline waters were: copepod *Arctodiaptomus salinus* (Doday) and larvae of bivalve molluscs from genera *Dreissena* and *Hypanis*, but now a significant part of the zooplankton consists of the mediterranean marine copepod *Calanipeda aquaedulci* Kritsch and the larval bivalve molluscs *Syndosmya segmentum* Recluz (=*Abra ovata* Phil.) and *Cerastoderma isthmicum* Issel. The main part of larval molluscs is formed by *S. segmentum*, as in the Aral zoobenthos (Andreev, Andreeva, Filippov, 1990; Andreev, Andreeva, 1991; Filippov, 1991, 1993a,b, 1994; Andreev, 1989; Plotnikov, 1995). In some cases, mollusc larvae in the zooplankton predominate over crustaceans. Besides these forms, a usual but not large element of zooplankton are rotifers of the genus *Synchaeta*, mainly *S.vorax* Rouss. Copepod *Halicyclops rotundipes aralensis* Bor. (from Cyclopoida) is found in all investigated parts of the Small Aral Sea and in Tshchebas Gulf of the Large Sea, but usually not in large numbers. Only in the Small Aral near the canal in Berg's strait and in the saline Butakov bay still exists *Podonevadne camptonyx* (G.O.Sars), the last representative of the cladocerans still remaining in the Aral Sea (Table 10, Fig. 8).

While mainly similar in both parts of the Aral Sea, in the Small Sea the species diversity of zooplankton is, to some extent, higher. In the Large Aral, Caspian cladocerans of the Podonidae family are no longer found, due to higher water salinity.

The May zooplankton in the Large and Small Aral is different in its quantitative composition. While, in the Small Sea (besides Butakov Bay) crustaceans and their larvae predominate, bivalve molluscs larvae predominate in the Large Aral near Barsakelmes Island, the only part studied this season. Having higher salinity, the Butakov Bay (Small Aral) is similar in this respect to the Large Sea (Table 11).

In the first half of the 1990s, the main features of seasonal changes in the Aral Sea zooplankton were these: in May, copepods *Calanipeda aquaedulcis* (in the Small Aral sometimes together with *H.r.aralensis*) and larval bivalve molluscs predominate, as in the 1970s. In September, copepods predominate as before, but the number of molluscs larvae decreases significantly, down to their disappearance by the end of the reproductive period (Table 11).

On different parts of the Small Aral Sea, one can observe differences in both the species' composition and quantity of zooplankton. This is caused by the characteristics of their hydrological and hydrochemical regimes.

The Small Sea near Tastubeck Cape. In Autumn 1993 copepods *Calanipeda aquaedulcis* and *H.r.aralensis* prevailed in the zooplankton of this part of the Small Sea, whereas the abundance of larval molluscs was low, as is usual for Autumn. The zooplankton abundance and biomass increased significantly in the eastern direction, towards the Trekhgorka mountain and Bolshoi Sarychaganak Bay (Table 11).

The Small Aral Sea near its Eastern coast at Bugun' settlement. In May 1993, the quantitative characteristics of zooplankton were diverse in different localities, depending on the water depth, in its turn related to the distance from the shore line. Zooplankton abundance and biomass were higher in shoals (203,300 ind./m^3 and 437 mg/m^3) than in places 4-6 m deep (13,700 ind./m^3 and 75 mg/m^3). The mean values were 70,000 ind./m^3 and 155 mg/m^3 (Table 11).

The Small Aral Sea near the Syr-Dar'ya river delta. The part of the Small Aral adjoining the Syr-Dar'ya river delta is of special interest because of its particular hydrological regime, marked by the refreshing influence of greatly variable freshwater inflow from the Syr-Dar'ya. In May 1992, the observed zooplankton abundance and biomass were relatively high, attaining on an average 244,000 ind./m^3 and 705 mg/m^3, respectively. In May 1993, in this part of the Small Aral, the observed zooplankton abundance and biomass were significantly lower: only 50,600 ind./m^3 and 109 mg/m^3 (Table 11). It is to be noted that zooplankton was not collected at the same points in 1992 and 1993, because it was difficult to identify their exact position. Hence, the differences are probably not only caused by changes of zooplankton development and structure, but they also reflect local features of these conditions. In the past, this part of the Aral Sea was the one with the highest zooplankton abundance and biomass (Lukonina, 1960; Kortunova, 1975; Andreev, 1989).

The Small Aral Sea, former Berg's strait. Together with the investigations in the channel in Berg's strait, zooplankton was investigated in the area from the vast shoal region of the Small Sea to south of the Syr-Dar'ya delta. Zooplankton abundance and biomass were high (Table 11). The zooplankton composition differed from that in the adjoining part of the Small Aral near the Syr-Dar'ya delta. Copepods strongly prevailed there, because in May 1992 and May 1993 the zooplankton consisted almost only of *Calanipeda aquaedulcis* and nauplii of copepods. This peculiarity probably can be explained by the character of bottom fauna in this region. On the vast bottom space here, no bivalve molluscs were detected (Filippov, Komendantov, Petukhov, 1993). Obviously, the larval bivalve molluscs in plankton are not of local origin, but are carried by currents from neighbouring parts of the Aral Sea.

Separating bays of the Small Aral Sea. Bolshoi Sarychaganak. Nowadays, rehabilitation of plankton and benthos biocenoses in the gulf occurs.

In 1993 and 1994, copepods *C.aquaedulcis* and *H.r.aralensis*, cladoceran *P.camptonyx*, larval bivalve molluscs *Syndosmya segmentum* and *Cerastoderma isthmicum*, rotifers *Synchaeta vorax*, were found in the gulf's zooplankton.

In May 1993, zooplankton abundance and biomass were very high, nearly 10 times higher than in the open Small Sea (Table 11). It is possible that this was caused by the supply of biogenic elements which accumulated in terrestrial plants while the gulf bottom was dry, and they were released when water covered the land (Kuznetsov et al., 1993; Filippov et al, in print; Orlova, personal communication). Hence, one could suppose the conditions were favourable for intensive zooplankton development, especially for phyto-detrivorous *Calanipeda aquaedulcis*. By September 1993, besides the usual decrease in the abundance of larval molluscs, an important change of zooplankton characteristics occurred. Its abundance and biomass sharply decreased.

In 1994, the zooplankton in the gulf was different from that of 1993. In June, zooplankton abundance and biomass were near to those of September 1993. Nearly 1/3 of abundance and biomass consisted of larval bivalve molluscs. By Autumn 1994, the gulf zooplankton became poorer, its abundance and biomass decreased nearly 10 times. This quantitative decrease of zooplankton, at least in Spring, could probably be explained by the low phytoplankton biomass. On the grounds of these four zooplankton observations and some other hydrobiological characteristics of Bolshoi Sarychaganak, it may be supposed that biota formation in the newly filled parts of the North Aral Sea will be analogous to that which occurs during the filling of water reservoirs.

By the end of September 1995, the zooplankton was extremely poor in the part of the Bay which remained after the water level had dropped. Only one copepod species *H.r.aralensis* was found in the samples. It is to be mentioned that there were only single individuals of this copepod and there were no other planktic invertebrates.

Now, from the 8 species of rotifers found in zooplankton in the open parts of the Aral Sea, (Andreev, 1989, 1991) only 6 remained (Table 8), of these only *Synchaeta vorax* and partly *S.cecilia* are widespread. Diversity of Cladocera has decreased, too. From 5 species found by the end of the 1970s (Andreev, 1989, 1991), 4 species disappeared in the 1980s (Aladin, 1989; Plotnikov, Aladin, Filippov, 1991; Andreev, Plotnikov, Aladin, 1992). *P.camptonyx* remains probably as the most resistant to increased salinity (only in the Small Sea). From 5 species of Copepoda (without Harpacticoida) recorded by the end of the 1970s, only 2 remain now, but of these, only the best adapted *Calanipeda aquaedulcis* remained in mass (Andreev, 1989, 1990; Plotnikov, 1995). During the 1980s, species diversity of the Aral Sea meroplankton did not change so much as that of the holoplankton, because the macrozoobenthos species composition did not change (Andreev, Andreeva, Filippov, 1990; Andreev, Andreeva, 1991; Filippov, 1991, 1993, 1994). During the crisis in the second part of the 1980s, nearly all Caspian species of hydrobionts were extinct, because salinity of 23-25 g/l is "critical" for them (Husainova, 1958; Aladin, 1990, 1991b; Plotnikov, Aladin, Filippov, 1991; Aladin, Filippov, Plotnikov, 1992). In the Small Sea, where the mean salinity did not exceed this limit owing to the stabilisation of the hydrological regime, remains of Caspian fauna persist, in contrast to the Large Aral, where this group of hydrobionts is now absent, because the still rising salinity has exceeded this limit.

From the end of the 1950s up to the early 1990s, the whole Aral Sea fauna changed fundamentally, because of progressing salinization and acclimatization of some aquatic species. The original fauna of freshwater and brackishwater species started to disappear with the increase in salinization and were replaced by aboriginal and introduced species of marine origin, and halophyles from saline continental waters of the arid zone. All Caspian species, except for *P.camptonyx,* are extinct (Table 8). Now only 20% remain of the species of the original fauna (except for meroplankton) which inhabited the Aral Sea when its salinity was still normal.

During 1991-1994, the species diversity of the Aral Sea fauna did not change. Whereas the fauna in the Large Aral is stable again, it is not stable in the Small Aral, where salinity is at a critical level – 23-25 g/l.

Zoobenthos

All the groups of benthic invertebrates, noted in the Sea by the end of the 1980s (Aladin, Kotov, 1989) were present in the benthic associations in 1993-1995. It should be emphasized that the benthos of the Large Aral (Barsakelmes Island) has not changed significantly since the end of the 1980s, in spite of the increase in salinity, from 27 g/l in 1989 to 41 g/l in 1993.

The main characteristic feature of macro-zoobenthos in the observation period was the extremely monotonous character of bottom communities. Species composition was the same in almost all investigated areas. In the Small Aral, benthos were represented by bivalves *S.segmentum* and *C.isthmicum,* gastropods *Caspiohydrobia* spp., polychaete *N.diversicolor* and shrimp *P.elegans.* In the Large Sea, *R.h.tridentatus* was found, in addition to the former species. *S.segmentum* was usually dominant in the biomass, while *Caspiohydrobia* spp. also formed dense populations at some stations (Fig. 9, Table 12).

Among all investigated areas, the pre-mouth bay (former Berg's strait) differed most from the others. While bivalves were almost absent, polychaetes dominated in terms of biomass and density. The total biomass was low. Such character of the zoobenthos was evidently caused by reduced salinity, higher content of inorganic suspended matter in water (Table 1) and unstable hydrological regime. In other investigated areas, the species composition and structure of macrozoobenthos did not differ significantly, in spite of strong differences in salinity (from 20 to 40 g/l). Thus, in 1992-1994 strong spatial salinity changes (20-40 g/l) did not affect the macro-zoobenthos.

The zoobenthos in Sarychaganak Bay was somewhat different from those found in other parts of the Northern Aral, similarly the plant associations and zooplankton. This was the consequence of the almost full separation of the Bay from the Aral proper, and the complete decomposition of benthic communities during the period of desiccation and salinization. In the last two years, after partial refilling of the bay by the water of the Small Aral Sea, the benthic associations started to develop again. Nowadays, all typical elements of the Small Aral fauna are also present here, but settlements of bivalves have still not been rehabilitated completely.

The total biomass of zoobenthos in the Small Aral in the 1990s is higher than in the Large Aral. Evidently, this is a consequence of a higher rate of primary production and allochthonous import of organic matter by the Syr-Dar'ya flow (Tables 1 and 6). The analysis of vertical distribution of zoobenthos has shown that abundance of all species and groups depends upon the water depth. The total biomass, as a rule, was lowest in both the most shallow and deepest parts, and highest at medium depths: in the Small Sea at 2-8 m, in Butakov Bay at 1 m, in the Large Aral at 2.5-15 m. The macrozoobenthos distribution in different parts of the investigated area was determined by morphometric characteristics of the aquatory where the samples were collected.

Based on the above, it can be concluded that in the future, not only salinity will have an effect on zoobenthic communities, but also changes of other hydrological and biotic factors.

The Aral Sea meiobenthos has been insufficiently studied. In the last years only ostracods were recorded. Whereas originally 11 species of these were present in the Aral Sea, only one euryhaline species - *Cyprideis torosa* - has survived, due to the increased water salinity. This species predominated in all benthos sampling areas in the period 1991-1995. It has to be specially noted that in Autumn 1995 when the Bolshoi Sarychaganak Bay was connected to the Small Sea, two ostracod species were found for the first time: *Cyprinotus salina* (Brady.) and *Eucypris inflata* (G.O.Sars). These organisms were never found before in the Aral.

Insect associations: aquatic and semi-aquatic insect associations in embayments and temporary water bodies

In the past, aquatic insects were an omnipresent element of the Aral benthos. Nowadays, this group occupies, in the Aral region, only selected embayments, temporary water ponds and rivers (Syr-Dar'ya, Amu-Dar'ya). Our investigations in several of the above-mentioned water bodies have shown that the largest number of aquatic insect species (over 17, Table 13) found refuge in the freshwater appendix of the Syr-Dar'ya, which has no connection with the lake. Next come the water bodies which are connected to the lake, such as embayments and temporary ponds along the coast: about 10 species were found in the embayment near Bugun' settlement (salinity 10-20 g/l); less in number (3-4) were species found in the flood pits near Aralsk city and under the cliffs of Tche-Bas Bay (salinity in the last site was about 1 g/l). In the hyperhaline temporary ponds along the coast only single species, or none, were recorded.

The recorded distribution of species abundance suggests that the main impact on the species diversity of aquatic insect associations is the biotope stability, along with salinity. The determinant factors are plant associations, used by the insects as substrate and refuge, which facilitate the invasion of the respective water bodies by the insects.

In relation to salinity, the identified aquatic insect species can be considered as euryhaline, as confirmed by our experiments (Table 14) and *in situ* observations (Piriulin, 1995). For instance, in the basin near Aralsk city, with a relatively constant salinity gradient from 20 g/l to over 200 g/l, nearly 10 species were present. The majority of these were recorded for salinity gradient 20-70 g/l; imago of *Cybister lateralimarginatus* and a few other species occur up to over 100 g/l.

A large number of species were detected only at the so-called "Ogorodny bugut" on Barsa-Kel'mes Island (seasonal variation of salinity 1-20 g/l). A. Konev (1993) reported about 10 species of the Dytiscidae family and 7 species of Hydrophylidae. Entomological research in the Barsa-Kel'mes reserve started in 1973 (Kabanova, 1995) and lasted till 1992; as this island became inaccessible, the investigations had to be stopped.

Terrestrial associations on the dried bottom

Based on our research results, some specific components of the entomofauna on the dry bottom of the Aral Sea are shown in Table 12. In spite of their narrowness, the post-aqual territories, having contact with coastal cliff and gypsophyle deserts, are settled by more species than other territories. This can be attributed to the higher variability of stations and plant associations. Migrants can settle on the dry bottom easier. Moreover, the biotic complexes of gypsophyle stations and their fauna are practically determined by waters of pluvial and nival origin, and do not depend on soil water horizons.

The dry bottom of the NE-NNE coast near the Syr-Dar'ya and Bugun' has no contact with zonal gypsophyle stations, but has contact with sandy, deflation affected territories; reduced associations of *Phragmites australis* existed there before regression. The dry bottom near Aralsk is strongly degraded due to urbanization and other factors, and thus is inhabited by a limited number of species.

General analysis of these materials must include retrospective data. Of particular importance are the results presented by Piriulin, Ozerski (1995). A new paper will be prepared in the near future.

Summarizing the data on aquatic insects, it is possible to consider the temporary water bodies near the Aral Sea as refuges for many halophyle insect species. In case the salinity of the Aral Sea should stabilize at a relatively high level (about 40 g/l), these species could become migrants into the coastal zone. After a period of naturalization and intensive quantitative development, they could become an important part of food stock for macro-consumers, as the freshwater and oligohaline aquatic insects species used to be in the period of quasi-stability.

Conclusions

Plants

From the 1960s up to the present day, significant changes were observed in the structure of producer's level, together with changes in hydrology and hydrochemistry.

In most investigated areas, except for the pre-mouth bay, freshwater forms of plankton and benthos were gradually replaced by brackish water, euryhaline and hyperhaline forms, resistant not only to salinity, but also to oscillations of the nutrient regime. After passing through a critical salinity barrier in the 1970s and mid-1980s, when the life of plant associations was inhibited, the total plant biomass and phytoplankton abundance tends to increase again since the end of the 1980s. The species diversity of planktonic micro-algae is now rather high, in spite of an increase of salinity towards the end of the 1980s and early 1990s. While, according to some opinions, salinity higher than the "critical" level should cause the decrease of species diversity and quantitative abundance of phytoplankton in inland waters (Kravtzova, 1989), in the present state of the Northern Aral, salinity does not seem to be a determining factor which impacts phytoplankton development.

Such rebuilding in the structure of the first trophic level has been initiated by salinity (Pichkily, 1981; Aladin, Kotov, 1989) in the first stages of regression, and is now maintained and accelerated by change of nutrient regime (Novozhilova, 1973; Alekin, Liakhin, 1984; Seas of the USSR, 1990) and light conditions (Aladin, Kotov 1989; Seas of the USSR, 1990; Orlova, 1995; Filippov et al., in print), formation of a new coastline, due to water level oscillation and change of bottom soils from sands to clays and muds (Aladin, Kotov, 1989).

In the majority of investigated areas, primary production goes on rather intensively both in the water column and on the bottom, in spite of the import of considerable amounts of alochtonous matter (from the Syr-Dar'ya and other sources). This was confirmed also by hydrochemical observations. In Spring, early Summer and

Autumn, the dissolved oxygen content in all water strata was not lower than 90% of saturation in the last three years, whereas in the 1980s it was often at the level of 55-76% (Aladin, Eliseev, Williams, 1993; Seas of the USSR, 1990). A noticeable contribution to primary production comes from coastal territories not deeper than 5m., and especially from the former dried-off sea bed. Phytoplankton has a leading role in primary production almost everywhere, with the exception of the newly flooded Sarychaganak Bay and some other flooded territories along the coast.

Animals

The examples with zooplankton and zoobenthos prove that living associations have now completed their adaptation to survive in conditions of high salinity. The main features of these associations are an extremely low, but stable species diversity and high resistance of each element to salinity oscillations. High abundance of contemporary zoobenthos was noted especially in the Small Sea, evidently connected with the income of sufficient allochtonous and autochtonous organic matter. The associations of planktonic crustacea and Rotaria are characterized by low species diversity and quantitative abundance. Salinity does not appear to be, at present, the main environmental factor which impacts the zooplankton and zoobenthos. Their distribution seems to be determined by depth, transparency, trophic conditions, wind and wave action, and by the morphology of each sub-area, especially in separated bays; and finally, by climate of the region.

The newly-flooded Sarychaganak Bay is in a particular situation. Living associations there are in the stage of renewal after the desiccation, which is reflected in oscillations of abundance and a species composition poorer than in the Sea proper.

Conservation programme

In view of the forthcoming conservation programmes, at least three scenarios could be envisaged for the biota of the Northern Aral Sea:

a) In the case of unsuccessful dam building, further desiccation of the Small Aral would continue, as the Syr-Dar'ya discharges would increasingly flow into the Large Sea (Fig. 2).

   As for plants, a restriction of species diversity could be assumed, caused by extinction of the remaining oligohaline and mesohaline species. Obviously, only halophylic algae could persist at salinity over 40 g/l, as is now the case in the hyperhaline temporary ponds along the coast. According to some suggestions, hyperhaline flora could exist at salinity over 42 g/l, till the appearance of precipitation (Aladin, 1991c).

   Taking into account experiments with animals (Filippov, 1995; Plotnikov, 1995; Aladin, 1995) and literature sources on the distribution of invertebrates in hyperhaline basins (Khlebovich, 1961; Kinne, 1971, etc.), and the state of aquatic insect associations in coastal ecosystems, it can be assumed that organisms of marine origin will keep their leading role until salinity reaches 60-70 g/l. At higher salinity, the marine fauna will be replaced by halophylic organisms of freshwater origin, including insects. At salinity above 70 g/l only very few species occur in the benthos - mainly larvae of Chironomidae and Ephydridae (Zeeb, 1961; Hammer, 1986; Timms et al., 1986), which are also present in the hyperhaline ponds in the coast of the Northern Aral. Obviously, only these groups will remain in the Sea when the salinity reaches 80-90 g/l. *Kaspiopodia* spp. may exist until salinity exceeds 100-110 g/l. Further changes of zoocenoses will be determined by the adaptive ability of the halophylic fauna. Halophylic organisms can tolerate, as a rule, salinity above 200 g/l, but they were very rarely found at a salinity of 200-300 g/l (Kinne, 1971; Hammer, 1986).

b) In the case of conservation of the water levels as they were from the beginning of the 1990s, the present living associations in the Small Sea could persist.

c) In the case of the rehabilitation of the Small Aral by building stable dams and preventing uncontrolled water losses from the basin into the Large Aral, a rise of water levels can be expected, accompanied by a considerable decrease in water salinity. A renewal of the structure of all living associations can then be envisaged, as it can be concluded from field observations and laboratory experiments of salinity resistance, and from the distribution in various water bodies of plants and invertebrates of freshwater, brackish water and marine origin: in the Aral Sea, Caspian Sea, low parts and estuaries of the Don and Volga, different types of reservoirs (Zenkievich, 1947; Zeeb, 1982; Husainova, 1959; Khlebovich et al., 1989; Filippov, 1994, etc.). Freshwater and oligohaline fauna and flora, which still inhabit refuges of different types in the deltaic zone and along the coastline, would begin to re-disseminate only after salinity decreases below 15-17 g/l. However, this process can be slowed down on account of the competition with euryhaline organisms which now inhabit the basin.

Brackish and freshwater fauna could replace the marine elements and begin to develop intensively only after salinity is reduced to 10 g/l.

References

Agamaliev F.G.: Ciliates of the Caspian Sea -Leningrad, 1983. 209 p.

Aladin N.V.: Zooplankton and Zoobenthos of coastal waters of Barsakelmes island (Aral Sea) // Proc. of Zool. inst. of Acad of Sci. of the USSR,V. 199, 1989, p.p. 110-114.(in Russian).

Aladin N.V., Kotov S.V.: Natural state of the ecosystem of the Aral Sea and its changes during anthropogenous impacts // Proc. of Zool. inst. of Acad of Sci. of the USSR,V. 199, 1989, pp 4-25. (in Russian).

Aladin N.V.: General characteristics of the Aral Sea hydrobionts from the viewpoint of osmoregulation physiology. Proc. of Zool. Inst. of Acad of Sci. of the USSR, 1990, v.199, pp.110-114. (in Russian).

Aladin N.: Lakes of the USSR with special reference to the Aral Sea // Abstracts of 5th Internat. Symposium on inland saline lakes. - Bolivia, 1991a. p.34.

Aladin N.V.: Salinity tolerance and morphology of the osmoregulation organs in Cladocera from the Aral Sea// Hydrobiologia 225:, 1991b, pp 291-299.

Aladin N.V., Plotnikov I.S.: Desiccating of the Aral Sea and possible ways of rehabilitation and conservation of the Northern Part //Proc. of Zoological inst. of RAS, V. 262, 1995, pp 3-17 (in Russian).

Aladin N.V.: Studying the influence of water salinity in separating bays on the Aral Sea hydrobionts //Proc. of Zoological inst. of Acad. of Sci. of the USSR. V.237. 1991c, pp 4-12(in Russian).

Aladin N.V., Plotnikov I.S., Filippov A.A.: The past and present of the Aral Sea fauna //Zool. J., 1991, v.70, No.4, pp.5-15. (in Russian).

Aladin N.V., Potts W.T.W.: Changes in the Aral Sea ecosystems during the period 1960-1990. // Hydrobiologia, V. 237, 1992, pp 67-79.

Aladin N.V., W.D.Williams.: Recent changes in the biota of the Aral Sea, Central Asia // Verh. Internat. Verein. Limnol. V. 25, 1993, 790-793.

Aladin N., Eliseev D., Williams B.: Case study on the Aral Sea // Proc. of Intern Symp on Wetland abd Waterfowl Conservation in South and West Asia. AWB Publication N 85.- Karachi, Pakistan, 1993,pp.33-37.

Aladin N.V.: Ecological State of the fauna of the Aral Sea during the last 30 Years // GeoJournal, V.35, N 1,1995, p.p. 29-32.

Aladin N.V., Orlova M.I., Plotnikov I.S. et al.: Changes in Aral Sea biota. 1996, Springer Verlag (in press)

Alekin, O.A. and Liakhin, Yu. I.: 1984. Chemistry of the Ocean. Leningrad. 200 pp. (in Russian).

Andreev N.I.: Zooplankton of the Aral Sea in the initial period of its salinization // Proceed. of Zool. Inst.of Acad. of Sci. of the USSR, 1989, v.199, pp 26-52. (in Russian).

Andreev N.I.: Zooplankton of Butakov Bay (the Aral Sea) in June 1990.// Proceed. of Zool. Inst. of RAS, 1991, v.237, pp 30-33. (in Russian).

Andreev N.I., Andreeva S.I.: To the question about productivity of the Aral Sea // Problems of Ecology in Baikal region (Problemy Ecologii Pribayikalia) Abstracts, N 1, - Irkutsk: 1979, pp. 141-142 (in Russian).

Andreev N.I., Andreeva S.I.: Zoobenthos of Butakov Bay of the Aral Sea in June 1990 and reasons of its poverty // Proc. of Zool. inst. of USSR. V. 237, 1991. pp. 40-44 (in Russian).

Andreev N.I., Plotnikov I.S., Aladin N.V.: The fauna of the Aral Sea in 1989. 2.The zooplankton. Int. J. Salt Lake Res., 1992. Vol. 1. p. 111-116.(in Russian).
Andreev N.I., Andreeva S.I., Filippov, A.A.: Zoobenthos of the Aral Sea in conditions of progressive salinization // Proc. of Zool. inst. Acad. of Sci.of the USSR. V. 223, 1990, pp. 24-31. (in Russian).
Aral Sea Project Seminar,founded by BMTF, Germany. -Tashkent: 1994, p.p. 7-14.
Assman A.V.: The role of algal overgrowths in forming of organic matter in Glubokoye Lake // Proc of All Union Hydrobiological Soc. (Trudy Vsesojusnogo gidrobiologicheskogo obshchestva), V.5, 1953, p.p. 138-157 (in Russian).
Berg L.S.: The Aral Sea. The experience of physical-chemical monography // Newsletters of Turkestanian Dept. of Russian Geographical Soc. (Isvestija Turkestanskogo otdelenija Russkogo Geograficheskogo obshchestva), V.5, 1908, N 9, 580 p. (in Russian).
Bortnic V.N.: Present and future of the Aral Sea. Obninsk:"Gidrometeoisdat", 1978, 11p. (in Russian).
Bortnic V.N.: Some hydrological aspects of the rehabilitation of the importance of the Aral Sea for fishing // Rybnoe, chosiaistvo, 1980, N 9, p.p. 56-58 (in Russian).
Bul'on V.V. Lows of primary production in limnitic ecosystems. Abstract of Doctoral thesis. -Leningrad., 1985, 32 p. (in Russian).
Chernenko I.M.: Water-ion balance and use of dessicating Aral Sea // Problems of mastering of deserts (Problemi osvoeniya pustin'), 1983, N 3, p.p. 18-25.(in Russian).
Diagnostic Study for the Development of an Action Plan for the Conservation of the Aral Sea. The Aral Sea// UNEP, 1993, p.p.62-68 (in Russian).
Dobrinin E.G., Koroliova N.G., Burkova T.M.: Estimation of the ecological state of the Aral Sea near the isle Barsakelmes // Proc. of Zool inst. Acad of Sci of the USSR, V. 223. 1990, p.p.31-35 (in Russian).
Dobrinin E.G., Koroliova N.G.: Production and microbiological processes in Butakov Bay (The Aral Sea) // Proc. of Zool inst. Acad of Sci of the USSR. V. 237, 1991, p.p.49-59 (in Russian).
El'muratov A.E.: Content and distribution of phytoplankton on the South of the Aral Sea in conditions of changed regime // in: Structure of aquatic living associations in downstream part of the Amudarya. - Tashkent, "Fan"1988, p.p. 25-34. (in Russian).
Filippov A.A.: Zoobenthos of Butakov Bay of the Aral Sea in September 1990 // Proc of Zool. Inst of Acad of Sci of the USSR, V. 237, 1991, p.p.44-49. (in Russian).
Filippov A.A.: Zoobenthos of coastal waters of the Barsakelmes island (The Aral Sea) in 1991 // Proc of Zool inst. of RAS, V. 250, 1993 a, p.p. 64-71. (in Russian).
Filippov A.A.: Some structural properties of macrozoobenthos of coastal zone of the Northern part of the Aral Sea // Proc. of Zool inst. of RAS, V. 250, 1993 b p.p. 56-63. (in Russian).
Filippov A.A.: Macrozoobenthos of coastal waters ot the Northern part of the Aral Sea in modern polyhaline conditions. Manuscript of Doctoral Thesis. - S-Petersburg: 1994.229 p. (in Russian).
Filippov A.A., Orlova M.I., et all.: State of the ecosystem of Sarychaganak Bay (The Northern Aral) in June 1994. Hydrobiological Journal, (in print).
Guseva K.A.: Factors, determining the development of plankton in water body // in: Primary production of Seas and inlet waters. - Minsk: 1961 (in Russian).
Hammer T.: Saline lake ecosystems of the world, 1986, Dr. W Junk Publishers. Dordrecht, 616 p.
Hayes F.R., McAulay M.A. Lake water and sediments. Oxygen, consumed in Water over Sediment cores. - Limnol., Oceanogr., V.4,1959, N3, p. 291-298.
Husainova N.Z. Cultures of the eastern shore of the Aral Sea and their life.// Newsletters Acad. Sci. KazSSR (Vestnik AN KasSSR), 1958, 6, pp.34-42 (in Russian).
Husainova N.Z.: Genesis of bottom fauna of the Aral Sea // Sbornik rabot po ichtiologii i gidrobiologii, N 2, 1959, p.p. 3-33 (in Russian).
Kabanova N.B.: Materials for fauna and ecology of Coleoptera of Barsakelmes island (Aral Sea).//Proc of Zoological inst. of RAS. V. 262, Part 2, 1995 pp.145-166. (in Russian).
Karpevich A.F.: Theory and practice of acclimatization of aquatic organisms. - Moscow "Pischevaya promishlennosct'", 1975. 432 p. (in Russian).
Kchlebovich V.V.,Ardab'eva A.G., et all: Correlation between the value of salinity, concentration of silica and development of phytoplankton in waters of the Northern part of the Caspian Sea // Proc of Zool. inst. of Acad of Sci of the USSR. V.196. 1989, p.p.51-63 (in Russian).
Keyser D., Aladin N.: Vom Meer zur Salzwueste: Der Aralsee //Oekozid 7, Der Kampf gegen Durst, Duerre und Desertification./Peter E. Stuben; Valentin Thurn (Hrsg). - Giessen: Focus-Verl., 1991, pp.213-228.
Kinne O.: Marine Ecology. - 1971, V. 1, Part 2, p.p. 683-1088.
Kitaev S.P.: Ecological base of bioproductivity of lakes from different climatic zones. - Moskow; "Nauka", 1984. 207 p. (in Russian).
Konev A.A.: Introduction to the fauna of Coleoptera of Barsakelmes reserve//Proc of Zoological inst. of RAS. V. 250, 1993. pp.174-187. (in Russian).
Kortunova T.A.: On the changes in Aral Sea zooplankton in 1959-1968. Zool. zhurn., 1975, vol.54. pp.567-669. (in Russuan).
Kravtzova G.V.: Phytoplankton in conditions of athalassic brackishwater bodies // Proc of the Zoological Inst. Acad. of Sci. of the USSR, 1989. V. 196 p.p. 65-81. (in Russian).
L'vovich M.I., Zigelnaya I.D.: Management of water balance of the Aral Sea // Newsletters of Acad of Sci of the USSR, ser. geogr., 1978, N 1, p.p. 42-54.
Lukonina N.K.: Population dynamics of *Diaptomus salinus* Daday in Aral Sea.// Zool. J., 1960, vol.39(2), pp.167-168. (in Russian).

Micklin P.: The Water Management Crisis in Soviet Central Asia // The Carl Beck Papers in Russian and East European Studies, 1991, N 905, 120 p.
Novozhilova M.N. 1973. Microbiology of the Aral Sea. Alma-Ata, 160 p (in Russian)
Orlova M.I.: Materials for the general evaluation of productional and destructional processes in coastal zone of the Northern part of the Aral Sea. 1 Results of field investigations in 1992 // Proc of Zoological inst. of RAS. V. 250, 1993, p.p. 22-31 (in Russian).
Orlova M.I.: Materials for the general evaluation of productional and destructional processes in coastal zone of the Northern part of the Aral Sea.2. About some properties of functioning of the ecosystem in Syr-Dar'ya delta and shallows of nearest bay //Proc of Zoological inst. of RAS. V. 262, 1995 pp 47-65 (in Russian).
Orlova M.I., Rusakova O.M.: Structural and functional characteristics of phytoplanktonic community in a district of Tastubeck cape in september 1993 year (the Northern Aral //Proc of Zoological inst. of RAS. V. 262, 1995 pp 208-231(in Russian).
Piriulin D.D.: On the characteristic of temporal reservoirs and aquatic insects fauna of Barsakelmes island and Near-Aral territory.// Proc of Zoological inst. of RAS. V. 262, Part 2, 1995 pp 3-75. (in Russian)
Piriulin D.D., Oserski P.V.: Orthopteroidea from Barsakelmes island and Near-Aral Sea territories.// Proc of Zoological inst. of RAS. V. 262, Part 2, 1995 pp 75-105 (in Russian).
Plotnikov I.S.: The Aral Sea (the Small Sea) zooplankton under conditions of the regime stabilization. Proceed. of Zool. Inst of RAS., 1995, v.262. pp 167-174 (in Russian).
Plotnikov I.S., Aladin N.V., Filippov A.A.: The past and present of the Aral Sea fauna // Zool. J., 1991, V. 70, N 4. p.p. 5-15. (in Russian).
Pichkily L.O.: Phytoplankton of the Aral Sea in conditions of anthropogenous impacts (1957-1980 years) - Kiev "Naukova dumka", 1981, p.p. 142-144 (in Russian).
Romanenko V.I., Kusnetzov S.I. Destruction of organic matter in muddy sediments // Microbiology, 1972, V. XLI, N.2, pp. 356-361. (in Russian).
Rusakova O.M.: Brief characteristics of the qualitative content of phytoplankton of the Aral Sea in Spring and in Autumn of 1992 year // Proc. of Zoological inst. of RAS, V. 262, 1995 pp 195-208(in Russian)
Seas of the USSR. Hydrometeorology and hydrochemistry of Seas ot the USSR. V.7, Aral Sea. - Leningrad: "Hydrometeoisdat", 1990, 195 p. (in Russian).
Smurov O.A.: Materials to *Tintinnina* (Ciliata, Polyhymenophora, Oligotrichidae) of the modern Aral (Small Sea)// Proc. of Zoological inst. of RAS, V. 262, 1995 pp 189-195 (in Russian).
Timms,B.V., Hammer U.T. et all.: A study of benthic communities in some saline lakes in Saskatchewan and Alberta, Canada // Internat. Rev. ges. Hydrobiol., 1986. V. 71, N 6 pp 759 -779.
Williams W.D., Aladin N.V. The Aral Sea: recent limnological changes and their conservation significance // Aquatic conservation: marine and freshwater ecosystems, V. 1,3 , 1991, p.p. 3-23.
Yablonskaya E. A.: To the question of importance of phytoplankton and phytobenthos in food chains of organisms of the Aral Sea // Stock of marine plants and animals and their use. - Moskow: 1964. p.p. 71-91. (in Russian).
Zeeb Y.Y.: To the typology of brackish and saline basins in Crimea and a characteristic of their fauna // Small waterbasins of far regions of the USSR and their use, Moskow-Leningrad, 1961, p.p. 293-305. (in Russian).
Zeeb Y.Y.: State of the investigation of biocoenoses of rivers, water reservoirs and estuaries of the North-Western part of the Black Sea.// XX Internat Conf. on study of Danube. Kiev:"Naukova Dumka", 1982. p.p. 6-20 (in Russian).
Zenkievich L.A.: Fauna and bioproductivity of the sea. Seas of the USSR. V.2. - Moskow-Leningrad:"Sovetskaya nauka". 1947. 588 p. (in Russian).

Table 1. Some environmental characteristics of investigated districts of Small Aral Sea in 1992-1994 (based on Orlova, 1993 and 1995; Orlova Rusakova, 1995; Filippov et. al., in press)

District	Date	T°C surf. horizon of water °C	Transparency M	Depth M	Salinity %	Seston Total weigh g/m²	Seston POM (in Carbon) g/m²	Chorophyll *a* µg/l
1	2	3	4	5	6	7	8	9
i. Barsa-Kel'mes	15-25.05.90	-	-	-	30	-	-	-
Syr-Dar'ya,	24.05.92	20	0.3	0.6-0.7	1.8*	22.4	0.74	-
St. 1 - 3	24.05.93	17	0.1	2(6-7)	1.8*	329	3.42	39.84
	22.05.92	19	0.3	0.6-0.7	1.8*	-	-	-
	24.05.93	17	0.1	2	1.8*	376	5.67	-
Syr-Dar'ya mouth	25.05.92	16	0.7	1.5	7	19.4	4.31	13.06
	22.05.93	17	0.65	1.4	18.5	27	21.86	-
Pre-mouth Bay								
St. 1	27.05.92	16	till bottom	1.2	22-23	9.1	0.67	-
St. 1	22.05.93	16	till bottom	1.4	22	-	-	-
St. 2	27.05.92	20	till bottom	2	25	10	0.93	-
Berg's Strait	27.05.92	-	-	0.8	-	10.2	1.02	-
Near s. Bugun'								
St. 1	30.05.93	17	till bottom	0.4	24	25	4.73	11.05
St. 2	31.05.93	18	till bottom	1.5	20	39	1.66	5.04
St. 3	1.06.93	18	1.3	3	21	60	1.51	41.72
St. 4	1.06.93	20	1.7	3	(surf) 11.5	(surf) 16.5	(surf) 2.04	11.02
					(1/2S) 15.5	(1/2S) 14	(1/2S) 3.59	
					(bott) 22	(bott) 72.5	(bott) 19.36	
Butakov Bay	1.06.92	21	till bottom	-	36	-	3.61	-
Shevchenko Bay	09.92	12	till bottom	2-2.5	29.5	-	-	-
Tshchebas Bay	09.92	15	till bottom	1.8-3	41	-	-	-

1	2	3	4	5	6	7	8	9
Near Tastubeck Cape								
St. 1	10.09.93	18	till bottom	0.5	-	177	2.20	14.33
St. 2	10.09.93	17	till bottom	1.3	17	63.75	2.13	11.64
St. 3	18.09.93	18	0.6	3	17	48	2.11	3.66
St. 4	12.09.93	19.5	1.8	5	25	48	2.19	9.02
St. 4	13.09.93	17.5	2.4	5	25	123	2.96	5.06
St. 5	16.09.93	17.5	1.8	6	25	50.75	2.19	2.90
Sarychaganak Bay								
St. 1**	22.06-26.06	18 - 35	till bottom	0.35-0.6	23-24	-	70.05	11.82
St. 2**	22.06-26.07	19 - 35	till bottom	0.35-0.5	24-31	-	101.89	184.61
St. 3**	22.06-26.08	20 - 35	till bottom	0.5-0.15	34-43	-	125.95	145.97
St. 4	23.06-26.06	19 - 30	till bottom	0.2-0.45	19-23	-	27.72	12.18
St. 5	23.06-26.06	25	till bottom	0.5-0.65	20-23	-	12.94	11.06
St. 6	25.06	23	till bottom	1.2	20	-	(surf) 9.94	(surf) 20.39
					-		(1/2S) 7.47	(1/2S) 11.47
					-		(bott) 8.84	(bott) 31.23
St. 7	25.06	24	till bottom	1.4	20	-	(surf) 8.22	(surf) 40.25
					-		(1/2S) 12.21	(1/2S) 32.08
					-		(bott) 10.84	(bott) 34.62

Remark * - after Bortnik, 1990

** - stations in temporal water bodies on the coast

Table 2. Brief description of main methods used

Type of work	Collection	Preliminary processing	Fixation	Storage	Analysis
1	2	3	4	5	6
Measurements					
Salinity	water sampler	-	-	-	Refractometer
Salinity	water sampler	no	no	cooled	Titration of Cl
Transparency	-	-	-	-	Secchi disc (m)
Sampling					
Seston (total weight)	water sampler	vacuum filtration through: scaled fibreglass or nitrocellulose filters	(no) drying to constant weigh at 80°C	-	Scaling
(POM)		the same filters, unscaled	(no), drying	cooled	Bichromat method
(photosynthetic pigments)		nitrocellulose or "Sartorius" filters	(no), drying on the air	frozen, in dark	UNESCO-SCOPE
Living associations (phytoplankton)	water sampler	vacuum concentration of 0.5 l of water on nitrocellulose filters with pore diameter 0.3 -1 μm to volume 10 ml	formalin, 1%	room temperature	Light microscope Identification Quantitative analysis
(ciliates)	water sampler	vacuum filtration through nitrocellulose filters, volume 300ml	fixation after Kuzmin	room temperature	Light microscope Quantitative analysis
(other zooplankton)	plankton net with gauze N 72	-	formalin, 4%	room temperature	Light binocular microscope Identification Quantitative analysis
(zoobenthos)	various bottom samplers	rewashing through gauze N 19-22	formalin, 4%, after sorting 70° alcohol	room temperature	Light binocular microscope Identification Quantitative analysis

1	2	3	4	5	6
Field experiments					
Primary production and destruction of plankton	water sampler	exposition in light and dark bottles, volume 100 ml, in different light conditions, in basins and in situ	-	-	Determination of dissolved oxygen by Winkler's method; results expressed in mgC with use of coefficient 0.44 (by Romanenko and Kuznetzov, 1972)
Primary production in bottom associations	vacuum bottom sampler	replacement and exposition of intact cores with strata of water in plastic tubes, light and dark, volume 0.3-1.5 l	-	-	Determination of dissolved oxygen by Winkler's method Results expressed as above

Table 3. Species content of phytoplankton in different areas of the Northern Aral

N	N	Algae Species and groups	L. sea L. Barsa-Kel'mes	Small sea Tshchebas Bay	Butakov Bay	Butakov Bay	Butakov Bay	Shevchenko Bay	pre-mouth Bay of Syr-Dar'ya	Tastubeck Cape	Sarychaganack Bay	Ecological properties Place of habitat	Relation to salinity	Geography
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			[1]	[4]	[3]	[2.5]	[4]	[4]	[4]	[5]	[6]			
		Cyanophyta												
		Chroococcales												
1	1	*Merismopedia tenuissima* Lemm.							+	+	+	p	hl	c
2	2	*M. punctata* Meyen		+				+		+	+	p	hl	c
3	3	*M. minima* G. Beck	+											c
4	4	*M. glauca* (Ehr.) Nag. *f. glauca*		+			+	+				p	i	c
5	5	*Microcystis aeruginosa* Kutz. emend. Elenk. *f. aeruginosa*	+		+			+	+			p	hl	c
6	6	*M. pulverea* (Wood) Forti emend. Elenk	+									p		c
7	7	*Gloecapsa minuta* (Kutz.) Hollerb. *f. minuta*	+						+				hl	c
8	8	*G. vacuolata* (Skuja) Hollerb.	+											
9	9	*Gomphosphaeria lacustris* Chod. *f. lacustris*							+			p	i	c
10	10	*G. aponina f. aponina* Kutz.					+	+	+			p	hl	c
11	11	*Coelosphaerium pusillum* Van Goor							+			p	hl	c
12	12	*Johannesbaptistia pellucida* (Dickie) Taylor et Drouet *f. anabaenifomis* I. Kissel.					+					bt	mz	b
13	13	*Anabaena* Bergii Ostenf. var. *bergii*						+		+		p	mz	b
14	14	*A. flos-aquae* (Lyngb.) Breb.	+									p		c
15	15	*Oscillatoria ornata* (Kutz.) Gom. *f. planctonica* Elenk.	+				+	+			p	i	b	
16	16	*O. setigera* Aptek.							+			bt	i	b
17	17	*O. limnetica* Lemm.	+											
18	18	*O. woronichinii* Anissim.								+	+	bt	i	b
19	19	*O. irrigua* (Kutz.) Gom.								+	+	bt	i	b
20	20	*O. amphibia* Ag.									+	bt	hl	b
21	21	*Oscillatoria geminata* Menegh.								+				
22	22	*Spirullina major* Kutz.		+			+	+				p	i	b
23	23	*S. labyrithriformis* (Menegh.) Gom.		+			+	+				p	hl	b
24	24	*Lyngbia limnetica* Lemm. *f. limnetica*		+		+		+	+	+		p	hl	b
25	25	*L. aestuarii* (Mert.) Liebm.									+	e-p	hl	b
26	26	*Aphanizomenon flos-aquae* (L.) Ralfs. *f. flos-aquae*	+			+				+				
27	27	*Phormidium mucicola* Hub-Pestalozzi et Naum	+											c
28	28	*Ph. fragile* (Menegh.)									+	p	hl	b
29	29	*Eucapsis minor* (Skuja) Hollerb.								+				
		Chrysophyta												
30		*Dinobryon divergens* Imh. var. *divergens*							+			л	и	к
31		*D. divergens* Imh. v. *angulatum* (Scl)				+						p	ol	c
32	3	*D. sociale* Ehr.				+						p	ol	c
		Xantophyta												
33	1	*Goniochloris mutica*					+							
		Bacillariophyta												
		Descoidales												
34	1	*Melosira granulata* (Ehr.) Ralfs var. *granulata*	+					+	+	+		p	i	c

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			[1]	[4]	[3]	[2.5]	[4]	[4]	[4]	[5]	[6]			
35	2	*M. islandica* O.Mull.	+						+			p	i	c
36	3	*Sceletonema costatum* (Grev.) Cl.		+				+	+			p	mz	c
37	4	*S. sabsalsum* (A. Cl.) Bethge	+		+									
38	5	*Cyclotella caspia* Grun	+			+		+	+		+	p	mz	b
39	6	*C. comta* (Ehr.) Kutz. var. *comta*	+					+	+			p	i	c
40	7	*C. glomerata* Bachmann	+			+						p	fr	sa
41	8	*C. meneghiniana* Kutz.	+	+	+	+	+	+	+	+	+	p	hl	c
42	9	*C. kuetzingiana* Thw.	+								+	p	hl	c
43	10	*C. quadrijuncta* (Shroter) Hust	+									p	fr	
44	11	*Stephanodiscus astrea* (Ehr.) Grun var. *astrea*							+			p	i	c
45	12	*S. hantzschii* Grun. var. *hantzschii*							+			p	i	c
46	13	*S. tenuis* Hust	+									p	fr	b
47	14	*Coscinodiscus lacustris* Grun.							+		+	p	mz	c
48	15	*C.jonesianus* (Grev.) Ostf.			+					+		p	i	b
49	16	*Actinocyclus ehrenbergii* Ralfs var. *ehrenbergii*		+			+	+	+	+	+	p	mz	b
50	17	*A. caspicus*	+								+			
51	18	*Actinicyclus* sp.			+									
		Biddulphioidales												
52	19	*Chaetoceros wighamii* Bright.		+			+	+			+	p	mz	c
53	20	*Ch. simplex* Ostf.				+								
54	21	*Ch. subtilis* Cl. var. *subtilis*					+	+				p	mz	c
55	22	*Ch. socialis* Laud. *f. socialis*												
56	23	*Ch. muelleri* Lemm			+	+	+					p	mz	c
		Araphinales												
57	24	*Tabellaria fenestrata* (Lyngb.) Kutz. var *fenestrata*		+					+			e-p	i	b
58	25	*T. flocculosa* (Roth.) Kutz.		+					+			e-p	i	b
59	26	*Diatoma elongatum* (Lyngb.) Ag. var. *elongatum*	+	+	+			+	+			p	hl	b
60	27	*Fragellaria capusina* Desm. var. *capusina*		+					+			p	i	c
61	28	*F. virescens* Ralfs.							+			e	i	b
62	29	*F. vausheriae* (Kutz.) Cleve-Euler		+				+	+			p	-	c
63	30	*Synedra rumpens* Kutz. var. *rumpens*	+	+				+	+	+		p	i	c
64	31	*S. ulna* (Nitzsch.) Ehr. var. *ulna*		+				+	+	+		e-p	i	c
65	32	*S. acus* Kutz. var. *radians* Kutz.		+				+	+	+		e-p	i	c
66	33	*S. scutellum* Ehr.								+				
67	34	*Talassionema nitzshioides* Grun.						+	+		+	p	mz	b
		Raphinales												
68	35	*Cocconeis pediculus* Ehr.		+			+	+	+		+	e-p	hl	c
69	36	*C. placentula* Ehr. var. *placentula*		+			+	+	+			e-p	i	b
70	37	*C. scutellum* Ehr.		+			+	+			+	e-p	mz	c
71	38	*Achnantes brevipes* Ag.		+		+	+	+				p	mz	c
72	39	*Rhoicosphenia curvata* (Kutz.) Grun.		+				+	+			e	mz	c
73	40	*Mastogloia* Brauni Grun.		+				+				e-p	mz	b
74	41	*M. baltica* Grun.					+	+				p	mz	c
75	42	*Diploneis smithii* Breb. var. smithii	+	+				+	+			e	mz	b
76	43	*D. smithii* var. *pumula* (Grun.) Hust.	+									e	mz	b
77	44	*D. oculata* (Breb.) Cl.							+	+	+	p	i	c
78	45	*D. bombus* Ehr.		+					+	+		e-p	mz	b
79	46	*Navicula cryptocephalina* Kutz. var. *cryptocephalina*		+				+	+	+	+	p	hl	c
80	47	*N. c.* var. *intermedia* Grun.		+			+	+	+	+		p	hl	b
81	48	*N. radiosa* Kutz. var. *radiosa*		+			+	+		+		bt	i	b
82	49	*N.brasiliensis* Grun.								+		bt	mz	b
83	50	*N. peregrina* (Ehr.) Kutz.		+				+	+			p	mz	b

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			[1]	[4]	[3]	[2.5]	[4]	[4]	[4]	[5]	[6]			
84	51	*N. menisculus* (Schum.) Hust. var. *menisculus*		+			+	+	+			p	mz	b
85	52	*N. digitoradiata* (Greg.) A.S.		+			+	+	+			p	mz	b
86	53	*N. lanceolata* (Ag.) Kutz. var. *lanceolata*							+			bt	i	c
87	54	*N. cuspidata* Kutz. *f. cuspidata*							+			p	hl	b
88	55	*Pinnularia microstauron* (Ehr.) Cl. *f. biundulata* O. Mull.							+	+		p	-	c
89	56	*P. m.* var. Brevissoni (Kutz.) Hust.							+			p	i	c
90	57	*P. interrupta* W. Sm.							+			bt	i	c
91	58	*Gyrosigma acuminatum* (Kutz.) Rab. var. *gallicum* Grun.		+				+	+	+		bt	hl	b
92	59	*Fleurosigma angulatum* (Queck.) W.Sm. var *ongulatum*		+				+		+		bt	mz	b
93	60	*A. paludosa* W. Sm. var. *paludosa*		+		+		+	+	+		p	mz	b
94	61	*A. paludosa* W. Sm. var. *duplex* Crun	+									p	hl	b
95	62	*A. ornata* (? Bail)				+						bt	fr	c
96	63	*Amphora robusa* Greg.		+			+	+				bt	mz	b
97	64	*A. delicatissima* Kresske				+				+			hl	c
98	65	*A. coffaeformis* (Ag.) Ktz. var. *coffaeformis*									+	bt	hl	c
99	66	*A. coffaeformis* (Ag.) Ktz. var. *acutiuuscula* (Ktz.) Hust.									+	bt	hl	c
100	67	*A. ovalis* Ktz.								+			fr	c
101	68	*Cymbella prostata* (Berk.) Cl.		+					+			bt	nl	b
102	69	*C. lanceolata* (Ehr.) V.H.		+				+	+			e-p	i	b
103	70	*C. cistula* (Hemp.) Grun.		+					+			e-n	k	c
104	71	*C. aspera* (Ehr.) Cl.		+					+			p	i	c
105	72	*C. ventricosa* Kutz. var. *ventricosa*		+	+	+		+	+	+		bt	i	b
106	73	*Gomphonema acuminatum* Ehr. var. *conronatum* (Ehr.) W. Sm.		+				+	+			e-p	i	c
107	74	*C. ventricosum* Greg.		+				+	+			bt	i	c
108	75	*C. clivaceum* (Lyngb.) Kutz. var. *clivaceum*		+		+		+	+			e-p	i	c
109	76	*C. parvulum* (Kutz.) Grun. var. *subelliptica* Cl.							+			p	i	c
110	77	*C. constricutum* (Ehr.) var. *capitatum* (Ehr.) Cl.		+				+	+			e	i	c
111	78	*Didymosphaenia geminata* (Lyngb.) M.Schmidt.		+					+			bt	i	c
112	79	*Rhopalodia gibba* (Ehr.) O. Mull.		+				+				e	hl	c
113	80	*Rh. gibberula* (Ehr.) O. Mull.									+	e	hl	b
114	81	*Rh.musculus* (Kutz.) O. Mull.		+				+				e	mz	b
115	82	*Nitzschia tryblionella* Hantzsch. var. *levidens* (W. Sm.) Grun/		+				+	+	+		bt	hl	b
116	83	*N. triblionella* v. *victoria* Crun.			+	+								
117	84	*N. hungarica* Grun.		+			+	+	+			e	hl	b
118	85	*N. acuminata* (W. Sm.) Grun.		+			+	+	+	+		bt	mz	b
119	86	*N. apiculata* (Greg.) Grun.	+	+			+	+	+			bt	mz	c
120	87	*N. angustata* (W. Sm.) Grun.		+		+	+	+	+			bt	i	c
121	88	*N. a.* var. *acuta* Grun.		+				+	+			bt	i	c
122	89	*N. frustulum* (Ktz.) (Grun.)				+						p	fr	c
123	90	*N. frustulum* (Ktz.) Grun.) var. *subsalina* Hust.	+			+						p	hl	c
124	91	*N. termalis* Kutz.							+			p	i	c
125	92	*N. linearis* W. Sm.		+				+				bt	i	c
126	93	*N. subtilis* (Kutz.) Grun. var. *gracilis* Grun.							+			p	i	c
127	94	*N. palea* (Kutz.) W. Sm.		+		+		+	+			p	i	b
128	95	*N. p.* var. *debilis* (Kutz.) Grun.	+	+				+	+			p	i	b
129	96	*N. paleaca* Grun	+									p	fr	c
130	97	*N. communis* Rabh.				+			+			p	i	c
131	98	*N. communis* Rabh var. *abreviota* Grun	+									p	i	c
132	99	*N. vermicularis* (Kutz.) Grun		+	+	+	+	+	+	+	+	bt	i	b

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			[1]	[4]	[3]	[2.5]	[4]	[4]	[4]	[5]	[6]			
133	100	*N. sigma* (Kutz.) W.Sm.		+				+				p	mz	b
134	101	*N. Lorensiana* Grun. var. *subtilis* Grun.		+			+	+				p	mz	b
135	102	*N. acicularis* W. Sm. var. *acicularis*							+			p	i	c
136	103	*N. closterium* (Ehr.) W. Sm.	+	+	+	+	+	+	+	+		p	mz	b
137	104	*N. longissima* (Breb.) Ralfs.		+			+	+		+		p	mz	b
138	105	*N. stagnorum* Rabh.	+									e	i	b
139	106	*N. kuetzingiana* Hilse	+									bt	i	b
140	107	*N. acuta* Hantzsch.									+	bt	i	b
141	108	*N. termalis* Ktz.	+									p	i	b
oooo	109	*N. tenuirostris* Mer.								+	+	p	hl	b
oooo	110	*Surirella ovalis* Breb.		+				+	+	+		bt	mz	b
oooo	111	*S. ovata* Kutz. var. *ovata*				+		+	+			bt	i	c
oooo	112	*S. ovata* var. *salina* (W. sm.) Beth.								+		bt	hl	b
149	116	*Cymatopleyra solea* (Breb.) W. Sm.				+						p	fr	c
150	117	*Coscinidiscus jonesianus* (Grev.) Ostf.								+				
151	118	*Gomphonema olivaceum* (Lyngb.) Kutz. var. *minutissima* Hust.	+									p	i	c
		Dinophyta												
		Prorocentrales												
152	1	*Exuviella cordata* Ost.		+		+	+	+		+		p	mz	b
153	2	*Prorocentrum obtusum* Ost.		+			+	+		+	+	p	mz	b
154	3	*P. proximum* Makar.				+								
		Peridiniales												
155	5	*Glenodonium lenticula* (Bergh) Schiller *f. lenticula*		+		+	+	+	+	+	+	p	mz	b
156	6	*G. pilula* (Ost.) Schiller		+		+	+	+	+	+		p	mz	b
157	7	*G. penardii* Lemm.	+			+				+		p	fr	c
158	8	*G. penardiiforme* (Lind.) Schiller	+	+		+			+			p	i	b
159	9	*G. caspicum* (Ost.) Schiller							+			p	mz	b
160	10	*G. lacustre* (Bergh) Shiller				+								
161	11	*G. pauluium* Lindemann	+									p	i	b
162	12	*Peridinium trochoideum* (Stein.) Lemm.		+				+	+	+		p	mz	b
163	13	*P. inconspicuum* Lemm.								+		p	fr	c
164	14	*P. achromaticus* Lev.			+	+						p	mz	b
165	15	*P. latum* Pauls			+							p	i	c
166	16	*P. pusillum* (Penard) Lamnermann				+						p	i	c
167	17	*P. allorgii* Lef.				+								
168	18	*P. subsalsum* Ostf.				+						p	mz	b
169	19	*P. pellicidum* (Bergh) Shutt				+								
171	20	*Goniaulax spinifera* (Clap. & Lachm.) Dies.		+			+	+		+		p	mz	b
172	21	*G. polyedra* Stein								+		p	mz	b
173	22	*G. apiculata* (Penard) Entz		+			+	+				p	mz	
174	23	*Ceratium hirundinella* (O.F.M.) Bergh							+			e-p	i	c
178	27	*Dynophysis* sp.				+								
179	28	*Gymnodinium fungiforme* Aniss.				+				+		e-p	hl	
		Cryptophyta												
		Cryptomonadales												
180	1	*Cryptomonas salina* Wisl.	+									p	hl	c
181	2	*Cr. marsonii*	+											
182	3	*Cr. erosa* Ehr.	+									p		
		Chlorophyta												
		Protococcales												
183	1	*Tetraedron triangulare* Korschik							+			p	i	c
184	2	*T. minimum* (A.Br.) Hansg. var. *minimum*							+			p	i	c
185	3	*T. caudatum* (Corda) Hansg. var. *caudatum*							+			p	i	c

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			[1]	[4]	[3]	[2.5]	[4]	[4]	[4]	[5]	[6]			
186	4	*Pediastrum simplex* Meyen var. *simplex*							+			p	i	c
187	5	*P. boryanum* (Turp.) Menegh. var. *boryanum*							+			p	hl	c
188	6	*P. duplex* Meyen var. *duplex*							+			p	hl	c
189	7	*Treubaria planctonica* (Smith.) Korschik.							+			p	i	b
190	8	*Dictyosphaerium pulchellum* Wood. var. *pulchellum*							+			e-p	i	b
191	9	*D. ehrenbergianum* Naegeli							+			p	i	c
192	10	*Lagerhimia wratislavensis* Schroed. var. *wratislavensis*							+			p	i	b
193	11	*Chodatella citriformis* Show							+			p	i	c
194	12	*Ch. longiseta* Lemm. var. *longiseta*							+			p	i	c
195	13	*Ch. subsalsa* Lemm.							+			p	i	c
196	14	*Ch. quadriseta* Lemm.							+			p	i	c
197	15	*Francea tenuispina* Korsch.							+			p	i	b
198	16	*Oocystis solitaria* Wittrock		+				+	+	+		p	i	c
199	17	*O. submarina* Lagerb.				+			+			p	hl	c
200	18	*O. Borgei* Show.	+	+			+	+	+	+		p	i	c
201	19	*O. parva* W. & West.	+											
202	20	*O. crassa* Wittrock	+											
203	21	*O. coronata* Lemm.							+			p	i	c
204	22	*Oocystidum ovale* Korsch. var. *ovale*							+			p	i	c
205	23	*Didimocystis planktonica* Korshik				+						p	mz	c
206	24	*Coelastrum cambricum* Archer. var. *cambricum*							+			p	i	b
207	25	*C. sphaericum* Naegeli							+	+		p	i	b
208	26	*Crucigenia tetrapedia* (Korsch.) W. & G.S. West							+			p	i	c
209	27	*Tetrastrum glabrum* (Roll.) Alstr. & Tiffany							+			p	i	c
210	28	*T. staurogeniaeforme* (Schroed.) Lemm.							+			p	i	c
211	29	*Aktinastrum Hantzchii* Lagerh. var. *hantzchii*							+			p	i	c
212	30	*Scenedesmus obliquus* (Turp.) Kutz. var. *obliquus*							+			p	i	c
213	31	*S.o.* var. *alternans* Christjuk							+			p	i	b
214	32	*S. acuminatus* (Lagerh.) Chodat. var. *acuminatus*							+			p	i	c
215	33	*S. a.* var. *olongatus* Smith.							+			p	i	c
216	34	*S. bijugatus* (Turp.) Kutz. *bijugatus*							+	+		p	i	c
217	35	*S. arcuatus* Lemm. var. *arcuatus*							+	+		p	i	b
218	36	*S. quadicauda* (Turp.) Breb. var. *quadricauda*		+				+	+	+		p	hl	c
219	37	*S. bicaudatus* (Hansg.) Chod. var. *bicaudatus*							+	+		p	i	c
220	38	*S. opoliensis*	+											
221	39	*A. angustus* (Bernard.) Korsch.								+				
222	40	*Ankistrodesmus longissimus* (Lemm.) Wille var. *longissimus*							+			p	i	c
223	41	*A. acicularis* (A.Br.) Korsch. var. *acicularis*			+				+			p	i	c
224	42	*A. subcapitatus* Korsch.							+			p	i	c
225	43	*A. pseudomirabilis* Korsch. var. *pseudomirabilis*							+			p	i	c
226	44	*A. angustus* (Bernard.) Korsch.							+	+		p	i	c
227	45	*A. densus* Korsch.							+			p	i	c
228	46	*A. fusiformis* Corda							+			p	i	c
229	47	*A. bibraianus* (Reinsch.) Korsch.							+			p	i	c
230	48	*A. gracilis* (Reinsch.) Korsch							+			p	i	c
231	49	*A. minutissimus*				+								
232	50	*Hyaloraphidium contortum* Pasch. & Korsch.							+			p	i	c
233	51	*Kirhneriella linaris* (Kirchn.) Mod. var. *linaris*				+			+			p	i	c
234	52	*K. contorta* (Schmidle) Rohlin							+			p	i	c
235	53	*Elakatothrix lacustris* Korsch.							+			p	oh	c

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
			[1]	[4]	[3]	[2.5]	[4]	[4]	[4]	[5]	[6]			
236	54	*Chlamidomonas simplex*	+											
237	55	*Ch. conferta*	+											
		Conjugatophyceae												
239	57	*Cosmarium phaseolus* Breb. var. *phaseolus*							+			л	и	δ
240	58	*C. pyramidatum* Ereb.							+			л	и	к
241	59	*C. laeve* Rabenh.							+			л	и	к
242	60	*Koliella longiseta* Vicher.								+		p	mz	
243	61	*Stigeoclonium* sp.				+						p		
244	62	*Lagerhemia subsola*	+											
245	63	*Pdimonas epiphytica*	+											
		Euglenophyta												
246	1	*Trachelomonas volvocina* Ehr.				+						p	mz	
247	2	*Euglena variabilis* Klebs.				+						p	ch	

Remarks: [1] Dobrinin et. al., 1990
[2] Dobrinin, Koroliova, 1991
[3] Orlova, Rusakova, 1995
[4] Rusakova, 1995
[5] Rotar',`Koroliova, 1992
[6] Filippov et. al., (in press)
p - planktonic species
bt - benthic species
e - epiphytes
e-p - epiphytic-planktonic
fr - freshwater species
oh - oligohaline species
mz - mezphaline species
hl - halophylic species
b - boreal occurence
c - cosmopolitic occurence
sa - subalpian occurence

Table 4. Quantitative characteristics of phytoplankton in 1989-1994

District and season	Depth (m)	Number (mln.cells/m³), biomass (g/m³)						Authors
			Cyanophyta	Dinophyta	Bacillariphyta	Chlorophyta	Total	
Near Barsa-Kel'mes i.	1 - 1.5v	N*	480 - 4872	60 -132	52 - 486	0 - 68	536 - 5490	Dobrynin et al.,
(July 1989)		B	no data	no data	no data	no data	no data	1990
Butakov Bay	1.5 - 3	N*	16-2360	16 - 160	4 - 144	4 - 68	44 - 2676	Dobrynin, Koroliova,
(Sept. 1990)		B*	near 0 - 0.071	0.087 - 1.763	near 0 - 2.695	near 0 - 0.12	0.14 - 3.75	1991
The same	no data	N	0 - 64	8 - 16	28 - 486	0 - 4	36 - 570	Koroliova, 1993
(autumn, 1991)		B	0 - 0.004	0.08 - 0.38	0.006 - 0.239	0 - 0.0002	0.086 - 0.653	
Tastubeck Cape	5	N	168 -1100	412 - 1053	252 - 332	5 - 10	837 - 2495	Orlova, Rusakova,
(Sept. 1993)		B	0.0045 - 0.033	3.89 - 4.34	2.09 - 2.91	0.0003 - 0.002	5.985 - 7.285	1995
Sarychaganack Bay	1.2 - 1.4	N*	30 - 786	2 - 8	153 - 504	0	445 - 1149	Filippov et al.,
(June 1994)		B*	0.0003 - 0.112	0.011 - 0.079	0.188 - 0.902	0	0.201 - 0.991	(in press)

Remarks: * - data for different horizons

Table 5. Dynamic of ionic compound of waters in Syr-Dar'ya and Amu-Dar'ya rivers and Aral Sea in 1960-1985 (after: Seas of the USSR ..., 1990: Chapters 12-16)

District	Period	Content of main inorganic ion								pH*
		HCO_3	SO_4	Cl	Ca	Mg	Na + K	Summa	PO_4* µg/l	
Syr-Dar'ya (in g/l)	1911-1960	0.186	0.164	0.04	0.088	0.021	0.044	0.543	6-11	
	1961-1970	0.179	0.456	0.106	0.093	0.054	0.158	1.055	48-93	
	1971-1980	0.19	0.579	0.168	0.112	0.076	0.187	1.312	12-42	
	1981-1985	0.184	0.923	0.187	0.131	0.09	0.329	1.844		
Amu-Dar'ya (in g/l)	1911-1960	0.153	0.105	0.074	0.083	0.011	0.044	0.471	10-13	
	1961-1970	0.125	0.131	0.085	0.062	0.019	0.061	0.483	14-20	
	1971-1980	0.111	0.244	0.137	0.081	0.026	0.109	0.708	11-22	
	1981-1985	0.145	0.619	0.357	0.128	0.074	0.0315	1.64		
Small Sea (in %)	1961-1965								3-5	8.1-8.15
	1971-1975								5	8.25
	1977	0.18	5.54	5.9	0.69	1.27	3.42	17		
	1981	0.16	6.28	7.01	0.77	1.15	4.82	20.19		
	1983	0.17	5.93	8.56	0.76	1.52	5.58	24.43		
	1981-1985								15-20	8.1-8.3
Big Sea (in %)	1961-1965								3	8.1-8.15
	1971-1975								5	8.25-8.3
	1977	0.18	4.92	5.35	0.63	1.19	2.99	15.26		
	1981-1985								20-55	8.05-8.1
	1981	0.17	5.45	6.13	0.7	0.99	4.31	17.75		
	1983	0.17	5.86	7.3	0.69	1.23	4.9	20.15		
	1985	0.17	6.97	7.85	0.87	1.22	5.65	22.72		

Remark * -average for several years (in Spring) in surface horizon of water

Table 6. Some characteristics of primary production and decomposition in plankton of investigated areas in Northern Aral in 1989-1994

District	Stations (total)	Season	Daily values: Primary production			Daily values: Destruction	A/D ratio	DAN	Author
			A opt μgC/l	A μgC/m²	P μgC/m²	D μgC/m²		μgC/μgCla	
Near i. Barsa-Kel'mes*	28 *	0.7-0.8 1980	2.7 - 324.6	34.3 - 649.2	-	-	-	30	Aladin, Kotov, 1989
---- ' ' ----	1	07.1989	177	166.5**		151.5	1.1	-	Dobrinin et.al., 1990***
Butakov Bay	2	09.1990	300	310 - 650**	-	-	-	-	Dobrinin, Koroliova, 1991***
	1	09.1992	332	830	abs	1117	0.7	-	Orlova, 1993
Syr-Dar'ya	3	05.1992	1440	-	-	-	-	-	Orlova, 1993
	2	05.1993	0 - 476	0 - 47.6	abs	900 - 8400	near 0	0 - 15	Orlova, 1995
Syr-Dar'ya mouth	1	05.1992	134	93.8	abs	128	0.7	-	---- ' ' ----
	1	05.1993	208	135.2	abs	176.9	0.8	14	---- ' ' ----
Pre-mouth Bay	2	05.1992	401	521	68	434	1.2	-	---- ' ' ----
	1	05.1993	336	470.4	abs	603.4	0.8	-	---- ' ' ----
Shevchenko Bay	1	09.1992	323	646	545	101	6.4	-	Orlova, 1993
Tshchebas Bay	2	09.1992	84 - 581	252 - 872	48 - 746	204 - 126	1.2 - 6.9	-	---- ' ' ----
The Bay near	2 ****	05.1993	4289 - 883	2534 - 222	2313 - 95	221 - 127	11.5 - 1.7	372 - 175	---- ' ' ----
s. Bugun'	2	05.1993	3215 - 324	114**	abs	287	0.4	25 - 29	---- ' ' ----
Tastubeck Cape	2 ****	09.1993	3054 - 3696	1525 - 4850	131 - 814	1462 - 3747	1. - 1.3	20 - 370	Orlova, Rusakova, 1995
	3	09.1993	1416 - 2000	3501 - 6419**	abs - 2202	4110 - 5110	0.5 - 1.5	-	---- ' ' ----
Sarychaganack Bay	3 (****)	06.1994	62 - 1496	15 - 1025	abs - 169	367 - 1095	0.01 - 1.46	0.36 - 8	Orlova, unpubl data
	2 ****	06.1994	440 - 880	132 - 528**	abs - 176	220 - 352	0.6 - 1.5	20 - 51	Filippov et al., (in press)
	2	06.1994	545 - 1496	352 - 1232**	abs - 660	528 - 572	0.7 - 2.15	12 - 31	

from Table 6

Remarks: A - total value of daily primary production
Aopt - total value in optimal light conditions
P - net value of daily primary production (P=A-D)
D - daily value of destruction
DAN -Daily Assimilation number (DAN=Aopt/Cchl a)
* - Values were obtained by measurements based on depth and transparency by method of Bul'on (1985)
** -Integral values were measured by curves of vertical distribution of primary production values without ** by formula A=Aopt*S (S - transparency, Bul'on, 1985),
*** - Radiocarbon method was used for determination of primary production, obtained value is between total and net
**** - stations near shoreline
(****) - stations in temporal water bodies, connected with shoreline

Table 7. Comparative evaluation of the contribution of planktonic and benthic communities into primary production in lightened areas (h=transparency) of investigated aquatic territories of Northern Aral in 1992-1994

District	St. (no.)	Season	Plankton		Benthos		Total values		Contribution of plankton to:	
			Ap mgC/m²	Dp mgC/m²	Ab mgC/m²	Db mgC/m²	Aw mgC/m²	Dw mgC/m²	Aw % of whole value	Dw
Butakov Bay	1	05.1992	830	1117	22	280	852	1397	97	80
Syr-Dar'ya	1*	05.1993		900		59		959		94
	3*	05.1993		8400		79		8479		99
Syr-Dar'ya mouth	1*	05.1992		128		337		465		28
	1*	05.1993		176.9		177		353.9		50
Pre-mouth Bay	R1	05.1992	521	434	363	264	884	698	59	62
	R2	05.1992	250	714	230	145	489	859	51	83
	R1	05.1993	470.4	603.4	753	597	1223.4	1200.4	38	50
Shevchenko Bay	1	09.1992	646	101	53	349	699	450	92	22
Tshchebas Bay	1	09.1992	872	126	13	158	885	284	99	44
The Bay near	1**	05.1993	<u>4289</u>	<u>793</u>	2534	221	6823	1014	63	78
s. Bugun'	2**	05.1993	883	563	222	127	1105	690	80	82
	4*	05.1993		261		287		548		48
Tastubeck Cape	1**	09.1993	1525	1462	34	129	1559	1591	98	92
	2**	09.1993	4805	3747	164	637	4969	4384	97	85
	4*	09.1993		4217		850.52		5067.5		83
	4*	09.1993		4110		620		4730		87
	5*	09.1993		5101		775.28		5876.3		87
Sarychaganack	1(**)	06.1994	537	37	3471	2741	4008	2778	13	1
Bay	2(**)	06.1994	1023	889	1321	3275	2344	4164	44	21
	4**	06.1994	132	220	992	827	1124	1047	12	21
	6	06.1994	352	528	691	405	1043	933	34	57
	7	06.1994	1232	572	5452	6019	6657	6591	19	9

Remarks:- A,D as in previous table
Whole values - are a sum of data for planktonic and benthic communities (Aw=Ap+Ab); (Dw=Dp+Dw)
* - stations, where transparency was less than depth.
Here it was possible to determine only whole value of destruction
** - stations on shallows near shoreline
(**) - stations in temporal water bodies

Table 8. Species composition of ciliates of the Northern Aral

Species	Water bodies near Aralsk city	Embayments of B. Sarychaganak Bay	Bolshoi Sarychaganak Bay	Small Sea	Berg's Strait	Mouth of Syr-Dar'ya
Cyclotrichium sp.	-	-	-	+	+	+
Acineta sp.	-	-	-	-	-	+
Frontonia marina	+	+	-	-	+	-
Urozona bueschli	+	+	+	+	+	+
Mesodinium sp.	+	+	+	+	-	-
Vorticella sp.	-	-	-	-	-	+
Zoothamnion sp.	+	-	-	-	-	-
Condylostoma patens	+	+	+	-	-	-
Litonotus sp.	+	+	-	-	+	-
Fabrea salina	+	-	-	-	-	-
Strombidium sulcatum	+	+	-	+	+	+
Strombidium viride	+	+	+	+	+	+
Strobilidium sp.	-	-	-	+	-	-
Tintinnopsis cylindrica	-	-	-	+	+	-
T. fluviatile	-	-	-	-	-	+
T. fluviatile f. *cylindrica*	-	-	-	-	-	+
Metacylis mediterranea	-	-	-	+	+	-
Oxytrichidae g. sp.	+	+	-	+	+	-
Euplotes crassus	+	+	-	+	+	-
Euplotes sp.	+	+	-	+	-	-
Uronychia sp.	+	+	+	+	-	-

Table 9. Salinity resistance in ciliata from the constant remnant of Sarychaganack Bay near Aralsk city

Species	Type of impact	Active state	
		upper** limit (%)	lower limit (%)
*Frontonia marina**	stepwise acclimation	180	10
F. salina	— " "—	220	25-30
*Condylostoma patens**	— " "—	160-170	10
*Euplotes crassus**	— " "—	160	10

Remarks: *-species common for Sarychaganack Bay proper and its temporary embayments
** - reaching the upper limit
Ciliata in our experiments usually derive from cysts

Table 10. The Aral Sea zooplankton species composition (from Andreev, 1989, with changes)

	Zernov, 1900	Meissner, 1901-1902	Virketis, 1925	Behning, 1932-1933	Lukonina	Atlas ...	Andreev, 1976-1981	Aladin, 1981-1988	Plotnikov, 1990-1994
1	2	3	4	5	6	8	9	10	11
Rotaria:									
Eosphora ehrenbergi Weber						+	+		
Trichocerca marina (Daday)				+					
Synchaeta vorax Rouss.				+		+	+	+	+
S. cecilia Rouss.							+		+
S. gyrina Hood							+		
S. tremula (Müller)						+			
S. neapolitana Rouss.				+					
Synchaeta sp.	+	+						+	
Brachionus plicatilis Müller	+	+	+			+	+	+	+
B. quadridentatus Herm.		+	+			+			
B. calyciflorus Pallas	+				+	+	+		
Keratella cochlearis (Gosse)					+	+			
K. tropica (Apstein)						+		+	
K. quadrata (Müller)		+		+	+	+			
K. valga (Ehrenb.)		+				+			
Notholca squamula (Müller)						+	+		+
N. acuminata (Ehrenb.)	+	+	+	+		+	+		+
Lecane (Monostyla) *lamellata* (Daday)	+					+			
Colurella adriatica Ehrenb.				+		+			
C. colurus (Ehrenb.)		+				+			
Hexarthra oxyuris (Zernov)	+	+			+	+			
Collotheca mutabilis (Hudson)				+		+			
Cladocera:									
Diaphanosoma brachyurum Lievin			+	+		+			
Alona rectangula G.Sars		+	+	+		+			

Table 10 continued

	Zernov, 1900	Meissner, 1901-1902	Virketis, 1925	Behning, 1932-1933	Lukonina	Atlas ...	Andreev, 1976-1981	Aladin, 1981-1988	Plotnikov, 1990-1994
1	**2**	**3**	**4**	**5**	**6**	**8**	**9**	**10**	**11**
Ceriodaphnia reticulata (Jurine)	+	+	+	+	+	+			
Moina mongolica Daday	+	+	+	+	+	+			
Cercopagis pengoi aralensis M. - Bolt.	+	+		+	+	+	+		
Evadne anaoyx G. Sars	+	+	+	+	+	+	+	+	
Podonevadne camptonyx (G. Sars)	+	+	+	+	+	+	+	+	+
P. angusta (G. Sars)						+	+	+	
P. trigona (G. Sars)						+	+	+	
Copepoda:									
Arctodiaptomus salinus (Daday)	+	+	+	+	+	+			
Calanipeda aquaedulcis Kritch.						+	+	+	+
Cyclops vicinus Uljanin		+				+			
Cyclops oithonoides G. Sars									
Thermocyclops crassus (Fisher)		+	+	+		+	+		
Acanthocyclops viridis (Jurine)				+		+	+	+	
A. bisetosus (Rehb.)							+		
Mesocyclops leuckarti (Claus)	+	+	+	+	+	+			
Halicyclops rotundipes aralensis Bor.		+		+	+	+	+	+	+
Schizopera aralensis Bor.						+	+		+
S. jugurta (Blanch. et Rich.)				+		+	+		
Cletocamptus confluens (Schmail)				+		+			
C. retrogressus Schmank.		+		+		+			
Halectinosoma abrau (Kritch.)		+				+	+		+
Nannopus palustris Brady		+				+			
Mesochra aestuarii Gurney		+		+		+	+		
Nitocra lacustris (Schmank.)						+	+		
N. hibernica (Brady)						+	+		+
Onychcampus mohammed (Blanch. et Rich.)		+				+	+		
Canthocapmtus sp.	+								
Limnocletodes behningi Bor.						+	+		
Enhdrosoma birsteini Bor.						+			
Leptocaris brevicornis (Van Douwe)						+	+		
Paraleptastacus spinicauda trisetosus Noodt						+	+		
Copepoda parasitica:									
Ergasilus sieboldi Nordmann		+		+		+			
Paraergasilus sieboldi (Mark.)						+			
Caligus lacustris St. et Lut.				+		+			
Lamproglena pulchella Nordm.						+			
Lernea esocina (Burm.)						+			
Branchiura:									
Argulus foliaceus (Linne)						+			
Mollusc larvae:									
Dreissena sp.	+	+	+	+	+				
Hypanis sp.						+			
Syndosmya segmentum Recluz						+		+	+
Cerastoderma sp.						+		+	+

Table 11. Abundance (N, thousands ind/m³) and biomass (B, mg/m³) of the Aral Sea zooplankton in 1992-1994

	Place	Season	Rotifers		Crustaceans		Larval molluscs		Total	
			N	B	N	B	N	B	N	B
Large Sea	Tshchebas Gulf	IX-92	1.4	2.4	8.5	36.6	0.2	0.4	10.0	39.4
Small Sea	at northern coast	IX-93	0.1	0.2	4.4	18.6	0.1	0.3	4.6	19.3
	at eastern coast	V-93	0.8	1.4	45.6	100.7	23.8	52.9	70.0	155.0
	Shevchenko Gulf	IX-92	2.8	5.0	2.6	7.7	0.0	0.0	5.0	12.7
	at Syr-Dar'ya	V-92	0.6	1.1	172.2	547.9	70.9	156.1	243.7	705.0
	at Syr-Dar'ya	V-93	0.4	0.8	31.7	68.2	18.2	40.0	50.6	109.0
	Berg's Strait	V-92	0.0	0.1	60.0	158.7	3.3	7.2	63.3	166.0
	Butakov Bay	V-92	4.6	8.3	9.3	29.6	43.2	95.1	57.2	132.9
	Bolshoi Sarychaganak	V-93	1.5	2.7	304.4	649.5	33.3	73.2	304.8	725.4
	Bolshoi Sarychaganak	IX-93	0.4	0.8	27.0	94.1	0.5	0.0	27.9	95.6
	Bolshoi Sarychaganak	VI-94	0.7	1.3	29.9	62.5	14.6	32.0	45.2	95.8
	Bolshoi Sarychaganak	IX-94	0.8	1.5	1.7	5.3	0.2	0.4	2.7	7.1

Table 12. Abundance (N, ind/m²) and biomass (B, g/m²) of zoobenthos at the explored sites of the Aral Sea in 1992-1993

Site (year)	*S. segmentum*		*C. isthmicum*		*Caspiohydrobia*		*N. diversicolor*		*R. harrisii*		Total	
	N	B	N	B	N	B	N	B	N	B	N	B
Small Sea												
Butakov Bay	14310	338.75	304	105.69	8507	30.89	1328	26.11	-	-	24449	501.45
Tastubeck Cape	7145	268.30	602	270.42	18302	40.12	779	3.56	-	-	26828	582.41
Shevchenko Bay	9353	284.27	952	149.59	27803	43.40	1065	6.05	-	-	39173	483.30
Near Bugun'	5604	192.15	273	66.72	10774	15.53	785	4.01	-	-	17435	278.41
Sarychaganak Bay	3264	51.48	994	14.17	2704	11.24	3195	28.52	-	-	10157	105.41
Pre-mouth area (92)	1383	27.03	19	6.35	1896	6.16	2489	21.46	-	-	5787	61.01
Pre-mouth area (93)	800	55.20	0	0.00	1916	8.24	770	23.40	-	-	3486	86.84
Large Sea												
Tshchebas Bay (92)	4237	99.28	87	102.12	874	1.73	1870	11.93	42	6.86	7111	221.92
Tshchebas Bay (92)	4420	156.09	79	146.76	729	2.22	1379	19.20	63	1.55	6670	325.82

Table 13. Aquatic insects of any temporary waterbody on dried bottom zone of Aral Sea

Species and groups	Biotopes and regions					
	Bug.	Syr.	Äralsk	BS	N.lag.	etc.
Insecta						
Ephemeroptera	I	+	I	a	I	a
Odonata						
Calopterygidae	a	I	I	a	a	a
Lestidae	a	a	I	a	a	a
Coenagrionidae	+	+	I	a	I	a
Libellulidae	I	+	I	I	I	a
Aeshnidae	I	I	I	I	I	a
Heteroptera						
Ilyocoris cimicoides	a	+	a	a	a	a
Ranatra linearis	a	+	+	a	a	a
Nepa cinerea	a	+	+	a	a	a
Notonecta viridis	+?	+	+	a	a	a
Plea leachi	+	++	a	a	a	+
Corixa sp.	+	+	+	a	I	+?
Sigara sp.	+	+	++	+	I	+
Gerridae	I	I	I	a	I?	a
Coleoptera						
Haliplidae						
Haliplus sp.	a	+	a	a	a	a
Noteridae						
Noterus clavicornis	?	+	a	a	a	a
Dytiscidae						
C. enneagrammus Ahr.	a	a	++	a	a	a
Coelambus flaviventris	+	+	d?	a	+?	a
Colymbetus fuscus	+?	a	a	a	I	I
Dytiscus circumflexus	(I)	I	(I)	(I)	(I)	I
Cybister lateralimarginatus	(I)	+	I	(I)	(I)	I
Gyrinidae						
Aulonogyrus ?concinnus Klug.	a	I	I	a	(I)	a
Gyrinus caspius Men.	a	a	I	a	a	a
Hydraenidae						
Ochthebius spp.	I	I	I	II	I	a
Hydrophilidae						
Berosus sp.	I	I	I	I	(I)	a
Berosus spinosus	+	+	a	a	(I)	a
Hydrophilus piceus	(I)	I	I	(I)	(I)	a
Paracymus aeneus	I	a	I	II	I?	a
Hydrobius fuscipes L.	a	a	a	a	(I)	a
Hydrophilus flavipes Stev.	a	a	a	a	(I)	a
Trichoptera						
Oecetis intima	I	I	a	a	a	a
Diptera						
Chironomidae	+	+	+	a	a	a
Culicidae	I	I	a	I	I	a
Ephydra sp.	+	I	+	+	I	I
Tabanidae	I	+	a	I	I	a?
Syrphidae						
Eristalis ?tenax	a	I	+	a	I	a
Total no. of insect species (except migrants)	10	17	10	2/5?	2	3

from Table 13

Legend

Bug. - near Bugun' village
Syr. - appendix Syr-Darja on dried bottom zone of Aral Sea
Äralsk - reservoir near cliff, harbour of Äralsk
BS - pools near coast of B. Sarychaganak Bay
N.lag. - coastal pools on northern coast of Aral Sea (Butakov Bay, Schevschenko Bay, Tshchebus Bay)
etc. - pits with water near Äralsk city and on coast Tshchebus Bay

\+ - larvae are present
++ - mass species
I - only imago are present
II - mass species
(I) - imago are present only on coastal line (migrants)

Table 14. Arthropoda of dried bottom zone of the Aral Sea in 1993-1996

Species and groups month year	Syr-Dar'ya 05. 1993	Bugun' 05. 1993	Tshchebas 06. 1993	Tastubeck 09. 1996	Äralsk 09. 1994
Chelicerata					
Mesobuthus eupeus	-	-	?	++	-
Orthochirus sp.	-	-	?	+	-
Galeodes caspius	-	-	+	+	-
Licosa sp.	-	-	+	+	+
Hexapoda					
Collembola, gen. sp.	-	-	-	+	-
Odonata					
Coenagrionidae	+	+	+	+	+
Aeschnidae	+	+	+	+	+
Libellulidae	?	?	?	+	+
Mantoptera					
Ameles sp.	-	-	+	-	-
Iris polistictica	-	-	?	+	-
Empusa pennicornis	-	-	+	+	-
Dermatoptera					
Anechura asiatica	-	-	+	+	-
Labidura riparia	+	+	+	+	+
Orthoptera					
Platycleis intermedia	-	-	+	-	-
Oecanthus turanica	-	-	+	+	-
Gryllidae	?	?	?	++	+
Gryllotalpa unispina	+	+	+	?	++
Acrida oxycephala	-	-	-	+	-
Pyrgomorpha bispinosa	+	+	-	+	-
Ochrilidia hebetata	+	-	+	+	-
Leptopternis gracile	-	-	?	+	-
Heteracris adspersa	-	-	+	+	?
Calliptamus cephalotes	-	-	?	+	-
Sphyngonotus sp.	-	-	+	+	+
Hemiptera					
Saldula sp.	-	+	-	-	-
Lygaeus sp.	+	-	+	-	-
Vashiria sp.	-	-	?	+	-
Chorosoma gracile	-	-	+	?	-
Aelia furcuta	-	-	-	+	-
Brachinema germarii	-	+	?	?	+
Neuroptera					
Chrysopidae	-	-	+	-	-
l Myrmeleontidae	+	-	?	+	+
I Myrmeleontidae	-	-	+	+	+
Coleoptera					
Cicindela littoralis	-	+	+	+	+
Calosoma auropunctatum	-	+	+	+	-
Brachinus sp.	-	-	-	+	-
Cymindis picta	-	-	?	+	-
Harpalodema turkmenica	-	-	?	++	-
Dicheirotrichus ustulatus	-	-	?	++	-
Scarites lucida	-	-	++	-	-
Sylpha sp.	-	-	+	-	-
Saprinus sp. /Histeridae/	-	-	+	?	-
Hister unicolor	-	-	-	+	-

Table 14 continued

Species and groups month year	Syr-Dar'ya 05. 1993	Bugun' 05. 1993	Tshchebas 06. 1993	Tastubeck 09. 1996	Äralsk 09. 1994
Chyoneosoma sp.	++	+	+	+	-
Melolonthini, gen. sp.	-	-	++	-	-
?*Haplosoma* sp.	++	+	-	+	-
Onytis humerosus	-	-	+	+	-
Scarabaeus typhon	-	-	+	-	-
Coccinella septempunctata	-	+	+	+	?
C. quatuodecimguttata	?	+	?	+	+
Julodis variolaris	-	-	[+]	+	-
Anatolica sp.	+	+	-	+	-
Blaps pruinosa	+	+?	+	+	++
Cyphogenia sp.	-	-	?	+	+
Trigonoscelis echinata	-	-	+	?	+
Sternoplax affinis	-	-	+	+	+
Pimelia cephalotes	-	-	+	-	-
Adavius fimbriatus	+	+	-	-	-
Diaphanidus vulpinum	-	-	+	-	-
Adesmia gebleri	+	?	+	+	?
Colposcelis longicollis	-	-	[+]	[+]	?
Microdera gracile	-	-	+	+	+
Chrysomelidae, gen.sp. 1	-	-	+	+	-
Chrysomelidae, gen.sp. 2	+	+	-	-	-
Leptinotarsa decemlineata	-	-	(+)	-	-
Theone sylphoides	-	-	-	(+)	-
Gastrophysa polygoni	-	-	+	+	-
Cassida sp.	-	-	-	+	-
Ischironota sp.	-	-	(+)	(+)	-
Apionidae /on Tamarix/	-	+	?	?	-
Gen. sp. (Curculionidae)/	-	++	?	+	-
Stephanophorus verrucosus	-	-	?	++	?
Chromonotus pictus	-	-	-	+	-
Megamecus variegatus	+	+	+	+	+
Bothynoderes spp.	+	+	?	(+)	-
Lixus spp.	-	+	+	+	+
Lepidoptera					
Coleophora sp. /on Suaeda/	-	-	+	+	++
Coleophora sp/on Salicornia/	-	-	+	+	+
Coleophora eremosparti	+	-	-	-	-
Agdistis tamaricella	+	+	?	+	+
Pterophoridae, gen. sp.	-	-	-	+	+
Nomophila noctuella	+	+	?	+	?
Psarosa nucleolella	+	?	-	+	-
Cossidae /on Phragmites/	-	+	+	?	-
Holcocerus sp.	-	-	?	+	-
Hesperiidae, gen. sp.	-	-	+	-	-
Lycaenidae	-	-	++	+	-
Pontia daplidice	-	+	+	+	+
Pieris rapae	-	+	-	-	-
Colias erathe	-	-	?	+	+
Papilio machaon	-	-	+	+	-
Vanessa cardui	++	+	(+)	(+)	+
V. atalanta	-	-	-	(+)	-
V. io	-	-	-	-	(+)

Species and groups month year	Syr-dar'ya 05. 1993	Bugun' 05. 1993	Tshchebas 06. 1993	Tastubeck 09. 1996	Äralsk 09. 1994
Mellitea sp.	-	-	+	-	-
Satyrus anthe	-	-	-	+	-
Epinephele sp.	-	-	[+]	-	-
Aglossochloris fulminaria	-	-	+	+	-
Lythria purpuraria	-	-	+	-	-
Lasiocampidae, gen. sp.	+	-	-	-	-
Eriogaster ?henkei	-	-	+	-	+
Malacosoma castrensis	-	-	+	+	+
Hyles livornica	+	-	+	-	-
Orgia dubia	-	-	-	+	-
Cucullia argentina	-	-	+	-	-
Clitie illunarius	-	+	+	+	-
Athetis sp.	-	-	+	+	-
Metopoplus	-	-	?	+	-
Chloridea	-	-	?	+	-
Phytometra gamma	-	-	?	[+]	+
Hymenoptera					
Camponotus sp.	+	-	?	-	?
Mutillidae, gen. sp.	-	-	-	+	-
Ammophyla sp.	-	-	-	+	-
Diptera					
Eristalis tenax	-	-	?	+	+
Number of species	25	29	56	75	31

Legend

Syr-Dar'ya.	- near Syr-Dar'ya on dried bottom zone of Aral Sea
Bugun'	- dried bottom zone near Bugun'
Tshchebas	- dried bottom zone of Tshchebas Bay
Äralsk	- dried bottom zone near meteorological observatoria of Aralsk city
+	- species is present
++	- species is present very often
?	- species is not found, but must be present here according to its ecological and zoogeographic characteristics
-	- species is absent
(+)	- species is present only on coastal line (migrant)
[+]	- species is present on zonal biotop behind dried bottom zone

Figure 1. Aral Sea water levels and salinity 1961-1994

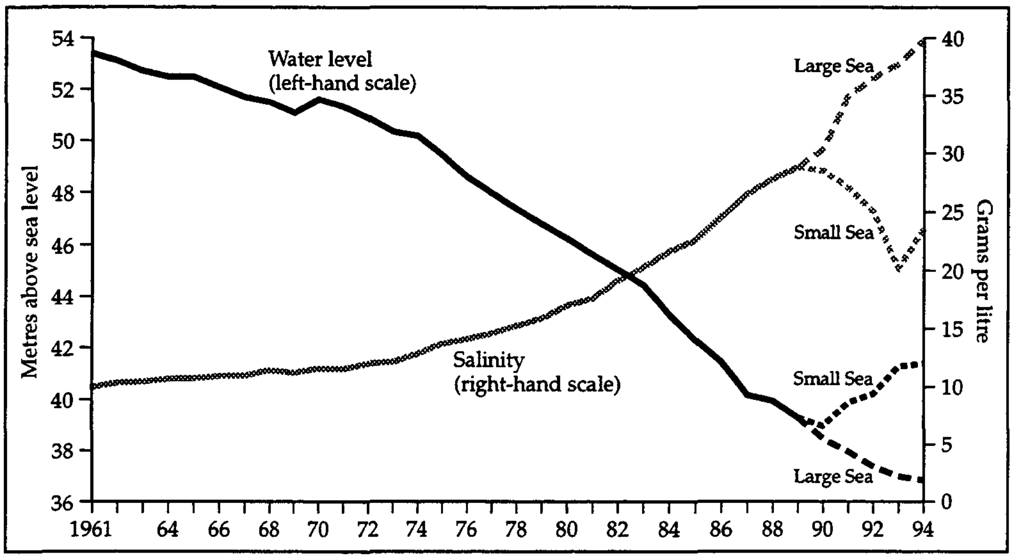


Figure 2. Investigated areas

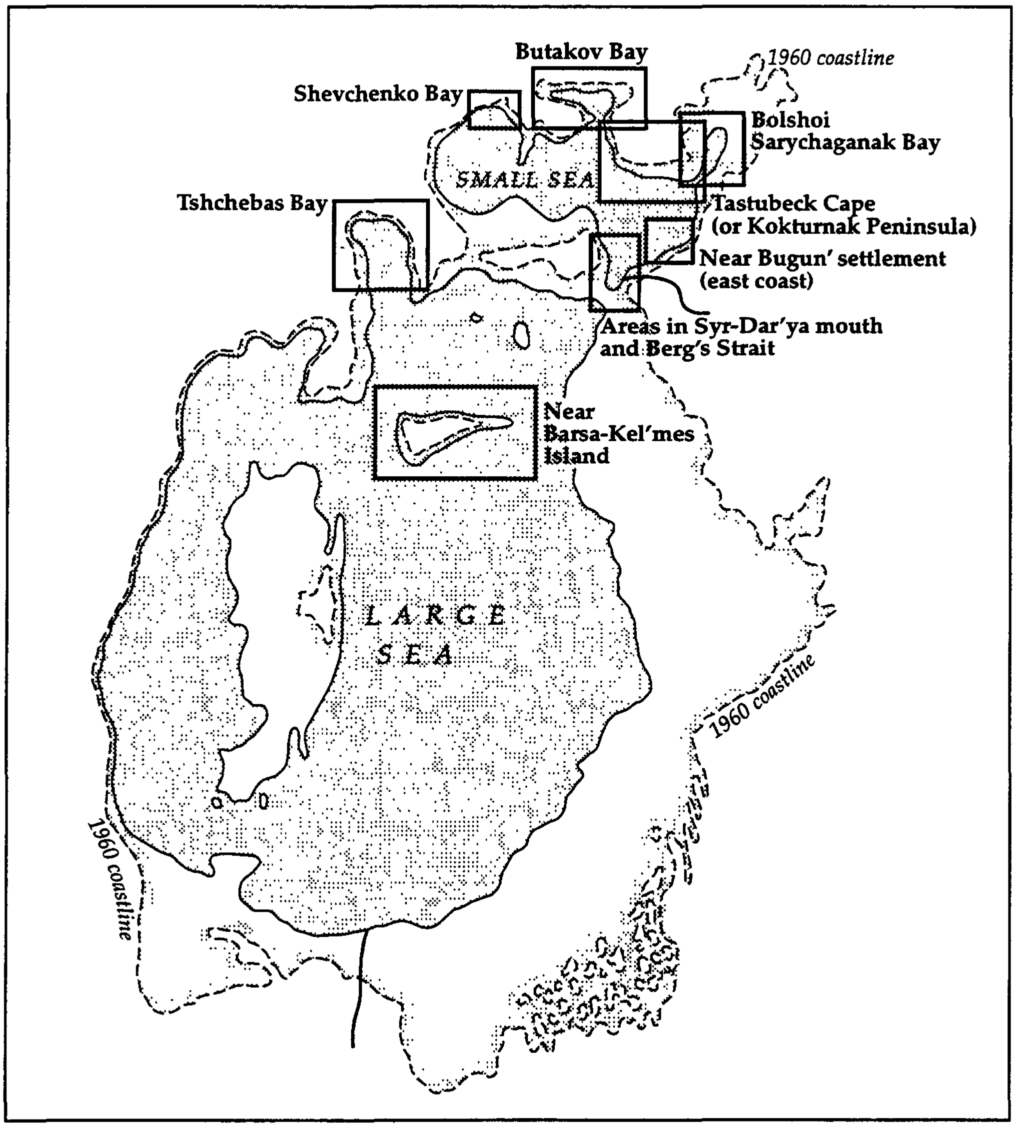


Figure 3. Taxonomical composition of phytoplankton in different areas of the Northern Aral in 1982-1994

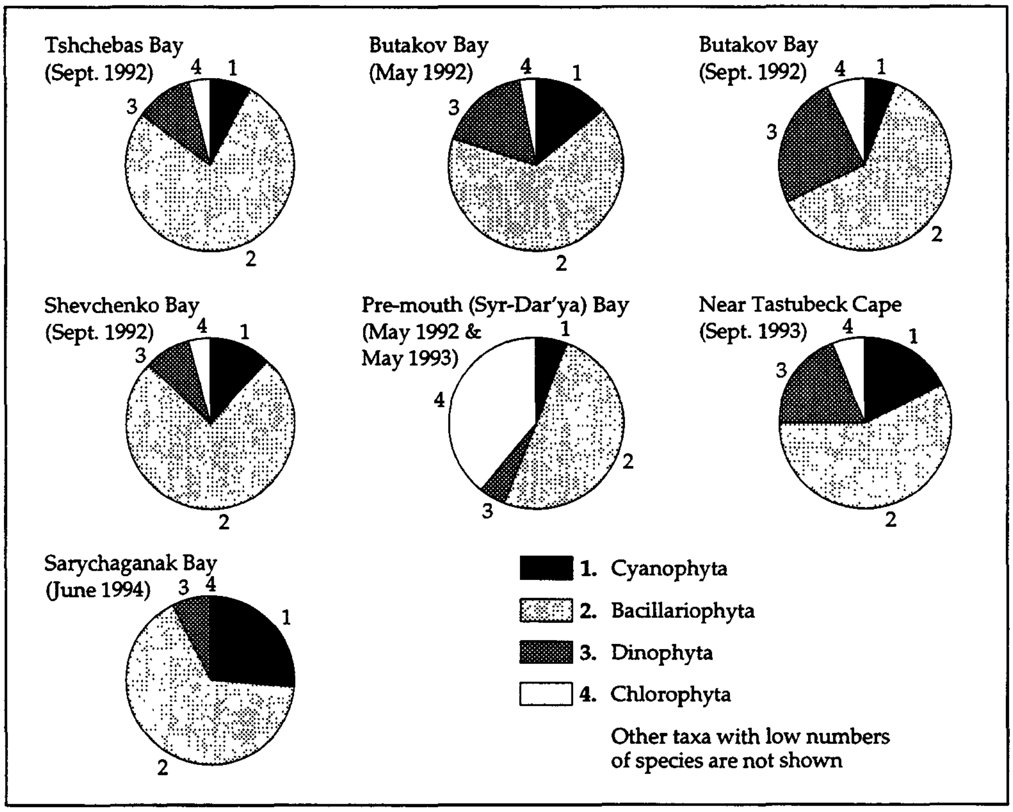


Figure 4. Composition of phytoplankton in relation to salinity conditions for different areas of the Northern Aral in 1989-1994

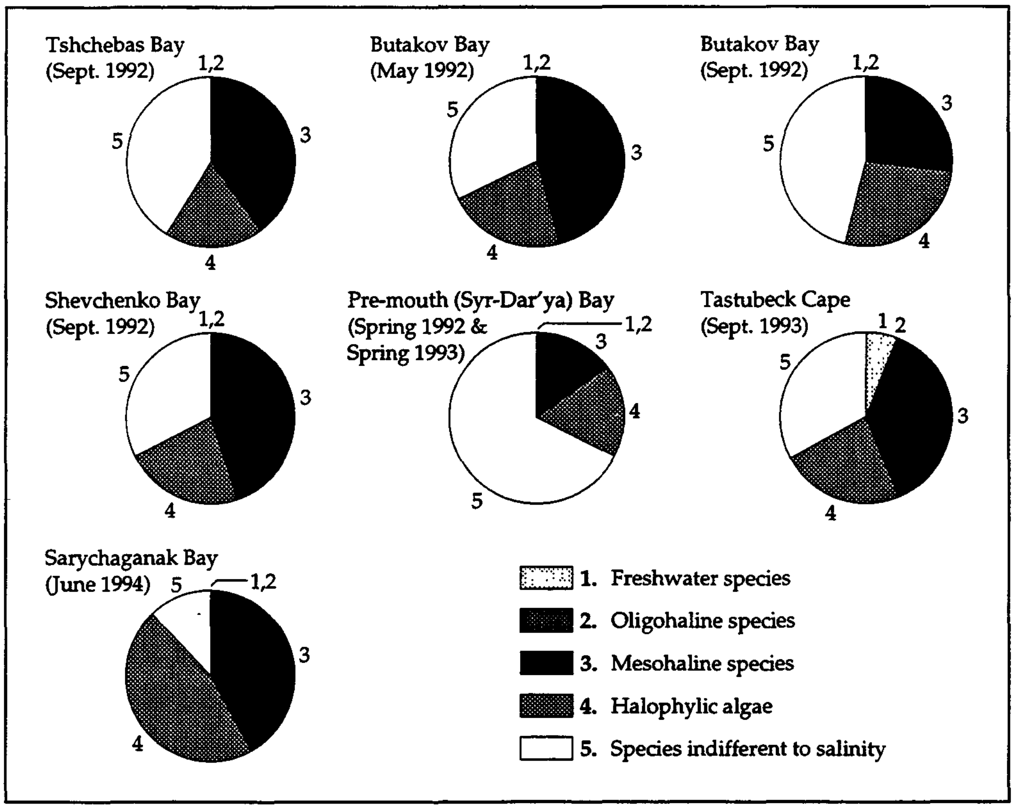


Figure 5. Vertical distribution of some characteristics of the planktonic community

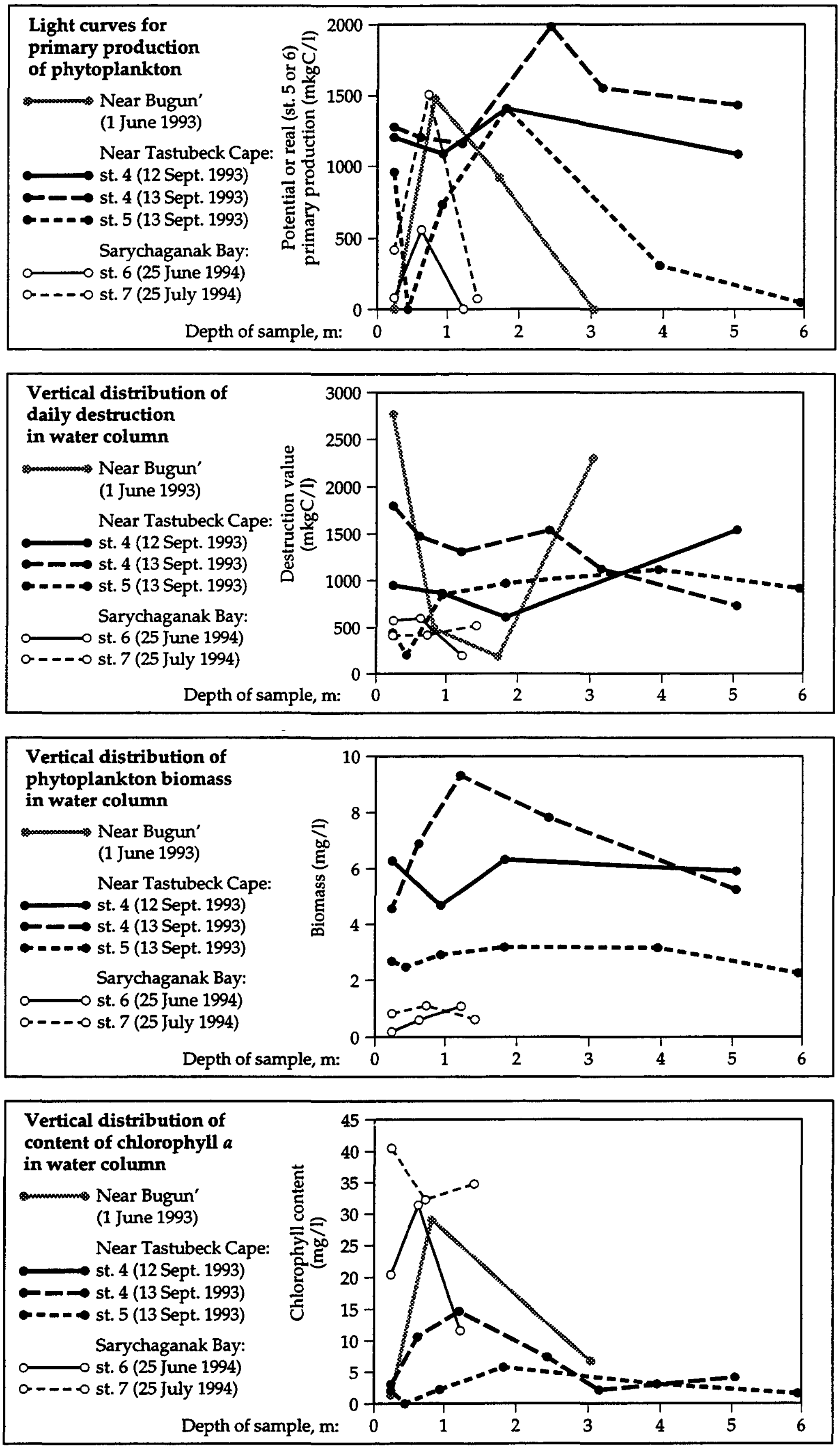


Figure 6. Number of species and biomass of ciliates in Sarychaganak Gulf and its embayments (data for 22 June 1994)

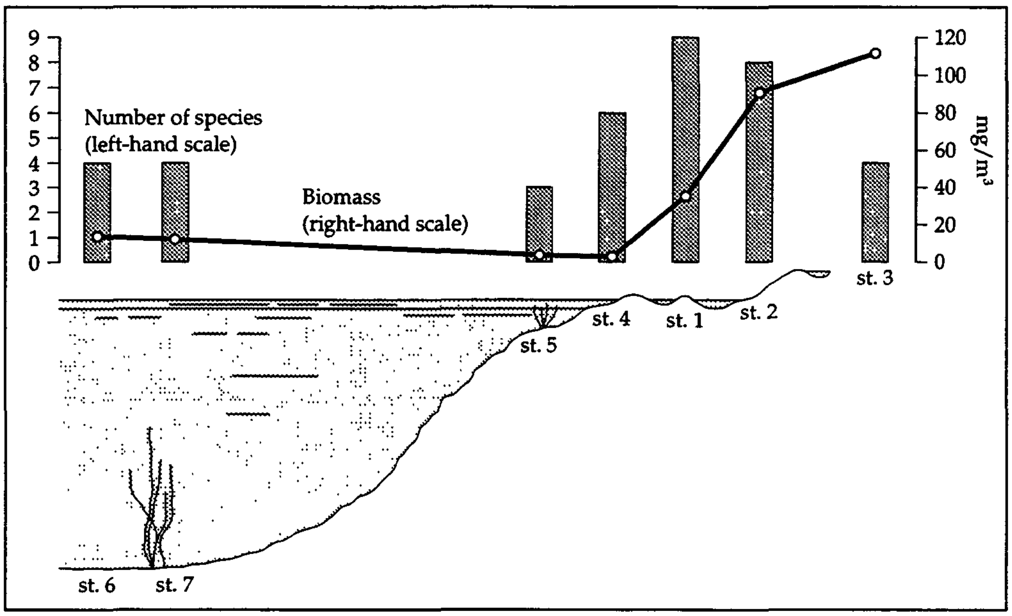


Figure 7. Zooplankton composition and mean biomass in the open Aral Sea

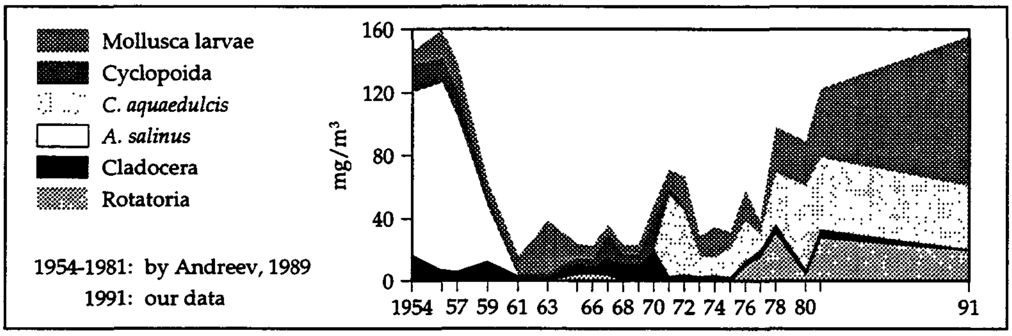
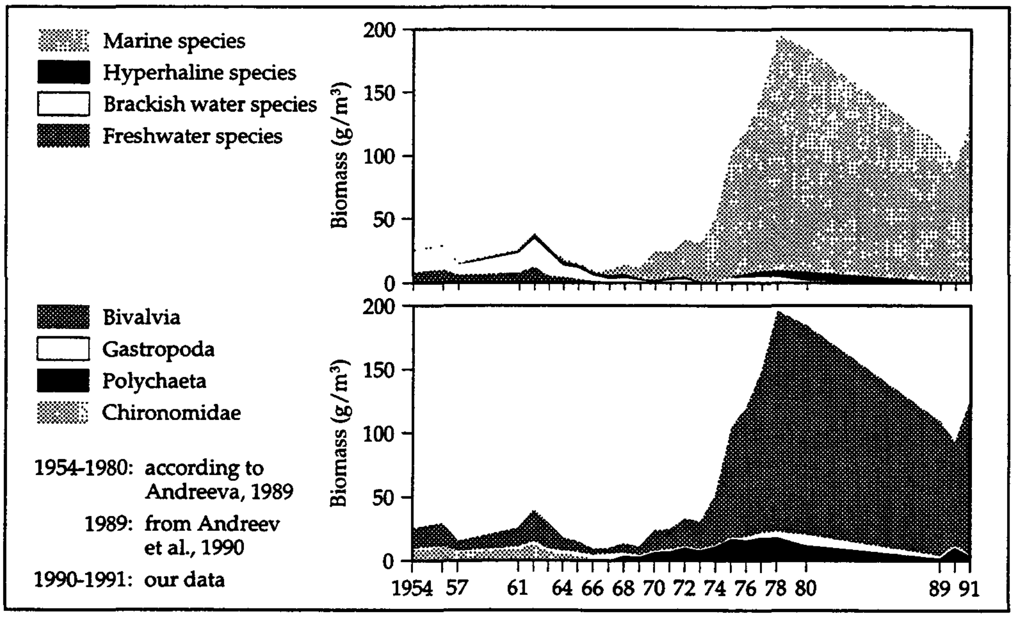


Figure 8. Macrozoobenthos composition and biomass variation



MONITORING AND SIMULATION OF WATER-SALT REGIME OF THE LACUSTRINE SYSTEMS IN THE SYR-DAR'YA DELTA

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Since 1989 the Syr-Dar'ya delta region has officially been declared an ecological disaster zone. Consequent to the lowering of the Aral Sea level and disturbance of the Syr-Dar'ya river hydrological regime, radical changes of the ecosystems occurred, and the ecosystem's resource potential decreased considerably.

At present, Kazakstan and foreign organizations are working on a number of projects for the ecological rehabilitation of this region. Within the framework of the World Bank Aral Sea Programme (Stage 1), a project has been prepared for the regulation of the Syr-Dar'ya river bed and development of the delta. However, it became obvious that the hydrological information base was insufficient for working out effective solutions for the delta reconstruction. For the same reason, the local administration lacks the means to control the complex problems in this region.

The delta lakes system is one of the main elements of hydrography in the mouth area of the Syr-Dar'ya river. In conditions of natural water regime, in the downstream reach of the Syr-Dar'ya, the total open surface area of the numerous lakes (more than 500) was about 1500 km^2 [1]. The lacustrine area of the delta was more than 7%. In the delta zone, 28 lakes had over 10 km^2 surface, among which the Kamyshlybash lakes had a total of 178 km^2. The most important for fish production were the greatest lake systems: Aksai Kuvandar'ya, Kamyshlybash, Akchetau, Domalak, Aigirin, Karauzek and Primorie.

In that period, the water consumption of the lacustrine systems and natural delta complexes was estimated at 12% of water discharge in the entry section of the delta (by analogy with the Amu-Dar'ya and the Ili rivers). This was 1.87 km^3/year, on average. Already in the 1930s, the water regime of the delta channels and surface area of the lakes was influenced by water abstraction from the Syr-Dar'ya for irrigation. In a few decades of intensive development of irrigation in the Syr-Dar'ya basin, the total area of the delta lakes was reduced by half, and in 1950 it was about 830 km^2 [1]. Due to the breaking up of the large lakes, the number of lakes increased considerably.

In the 1960s, anthropogenic reduction of the Syr-Dar'ya discharge further reduced the lake area to 789 km^2. The largest lakes remained in the Kamyshlybash system, and also on the left bank of the river, such as Akchetau and Karakol [2].

The discharge at the entry section of the delta (at Kazalinsk), which was 40-46% of the Syr-Dar'ya run-off in the early 1960s, in the second half of the 1970s was reduced to less than 4%. According to aerial photographs [3], by 1976 the total lake area decreased to 400 km^2, and the water volume was about 1.5 km^3. Only the Kamyshlybash, Akchetau and Primorie lacustrine systems remained important for fishery, owing to water supply through canals such as the Soviet, Taukzhemir and others, after the construction of the Amanatkol and Aklak dams in 1974 [4].

According to approximate calculations, in 1974-75 the average flow in the entry section of the Syr-Dar'ya delta was 2.5 km^3, out of which 1.0 km^3 was used for economical purposes, 0.6 km^3 were unproductive losses and 0.9 km^3 flowed into the Aral Sea (varying between 0.4 and 4.0 km^3 in different years). About 0.43 km^3 was used for the fish-productive lakes and water bodies (from a total area of 267 km^2).

The great ecological and economical importance makes it necessary to assess the water and salt balance of the delta lacustrine system, and to evaluate quantitatively the natural and man-made changes of their components. This task becomes increasingly complex because of the manifold water exchange processes between the lakes, the river, the Aral Sea and the atmosphere, due to the increasing influence of economical activity in the Syr-Dar'ya basin. The difficulties are amplified by the lack of hydrometeorological stations in the Syr-Dar'ya mouth area and the short period of available field observations.

In order to create a reliable information base, an outline of local hydrological monitoring network in the delta area was elaborated, making use of the equipment provided for the Sub-project. The investigated zone has been subdivided into four sections: upper, middle, lower and mouth sectors. Accordingly, five basic sections were fixed at the entry and exit of each sector, located at Bascara, Raimkol, Amanatkol, Karateren and the Syr-Dar'ya mouth (Fig. 1).

The flow in the upper sector (98 km) is very strongly modified by the inflow of drainage waters, collected from the irrigated fields. In the middle sector of the delta (98 km), the river flow is strongly influenced by the Kamyshlybash lake systems at the right bank and Akchetau at the left bank. The lower sector (50 km) is located in the zone of the Aklak dam. The mouth sector (25 km) is most affected by the deformation of the Syr-Dar'ya river bed, due to the lowering of the Aral Sea water level.

Water balance simulation model for the Kamyshlybash lacustrine system

The Kamyshlybash lacustrine system is the largest of its kind in the Syr-Dar'ya delta. The system comprises five interacting lakes, namely Kamyshlybash, Laikol, Kayazdy, Kuly and Zhalanshkol (Fig. 2). The last four lakes are situated in the Syr-Dar'ya flood plain, and represent an "antechamber" (compensation basin), through which the system exchanges water with the river. This compensation basin comprises 24% of the total area and 12% of the water volume of the whole system, and interacts with the main water body - the Kamyshlybash lake - through an inter-lake channel. The edges of the open water surface of the lakes are overgrown by half-immersed vegetation, which cover 29% of the compensation basin area and 13% of the main water body.

Apart from the geographical zonality, which determines the relationship between evaporation and precipitation, the water balance is strongly influenced by azonal and anthropogenic factors, such as morphometry of the lakes and interlake channels, presence of water vegetation, inflow of river and drainage water, water diversion from the lakes.

In natural river regime, the water level variations of the lake system reflected the variations of the Syr-Dar'ya stages. Owing to the considerable storage capacity of the lake system, the hydrographical variations were less articulated than in the river. The filling phase of the lake system was observed in April-July, and the draining phase in August-March [5,6].

After the construction in 1974 of the temporary Amanatkol Dam on the Syr-Dar'ya, the stages of the lake system were controlled by the operation of the dam. However, the floods of 1993-94 destroyed part of the dam and since then, the new regime of the

Syr-Dar'ya has been determined by the flow at Kazalinsk. This affected the flow regime of the Kamyshlybash lake system correspondingly.

At present, within the World Bank Aral Sea Program, the construction of a permanent dam at Amanotkol is being considered[1], located at the same place as the former temporary dam. By raising the water level in the river to elevation 56.7 m.abs., the dam would secure stable water supply to the Kamyshlybash lake system, and release water from the Syr-Dar'ya to the Aral Sea. Furthermore, an alternative is being considered of pumping water from the northern part of Kamyshlybash lake into a canal, designed to provide 10 m^3/s water for the planned recreational reservoir at Aralsk, during the warm season of the year (6 months).

In the view of past and planned modifications of the Syr-Dar'ya delta water regime, it is of great scientific and practical interest to evaluate the previous and future water balance of the Kamyshlybash lake system.

In the first stage of investigations, the water balance of the lacustrine system was modelled by the the following equation:

$$Z_K^{T+1} = Z_K^T \pm \frac{Q^T}{F_K^T} + X^T - E_B^T \frac{F_B^T}{F_K^T} - E_T^T \frac{F_T^T}{F_K^T} - \frac{G^T}{F_K^T} \qquad (1)$$

where: T – number of the model time step (1 month);

Z_K^T – stage in the lacustrine system at the beginning of the T-month;

Q^T – volume of external water exchange with the system in the month, including surface and underground components;

X^T – precipitation per month on the total surface of the lacustrine system;

E_B^T – evaporation per month from open water surface of the lacustrine system;

E_T^T – total evaporation from reed overgrowth;

G_T^T – volume of water diversion from the lacustrine system;

F_B^T, F_T^T, F_K^T – areas of open water surface, surface overgrown by vegetation, and total surface, respectively, of the lacustrine system at the beginning of the T month.

The above water balance equation was applied to the results of investigations carried out in 1993-95, within the first phase of the hydrological monitoring programme.

Water levels of the Syr-Dar'ya and the Kamyshlybash were recorded by automatic stage recorders, installed at Koszhar (lake) Baskara and Karateren (river).

For the calculation of evaporation from the open water surface and surface covered by half-immersed vegetation, the observation of meteorological data was organized in Novokazalinsk (Priaral Ecological Center) and Koszhar (coast of Kamyshlybash lake).

[1] By the Italian firms "Italconsult" and "Electroconsult"

Data on the morphometry of the lake system was improved by inspection and bathymetric surveying. In particular, relationships could be defined for the determination of the lake open surface area and overgrown surface area in function of the water level (within the range of observed variations):

$$F_B^T = 76.4 + 30.1\left(Z_K^T - 50.7\right);\ 50.7 \le Z_K^T \le 57.0 \qquad (2)$$

$$F_T^T = 20.5\left(Z_K^T - 52.7\right);\ 52.7 \le Z_K^T \le 57.0 \qquad (3)$$

The interaction between the 'antechamber' (compensation basin) and the 'main water body' was investigated by measuring occasionally the flow velocity and direction in the connecting inter-lake channel.

Evaporation from open surface and surface covered by half-immersed vegetation

Evaporation is the main negative component of the water balance of the Kamyshlybash lake system and its correct determination is of great practical importance.

In most contemporary formulae for the calculation of evaporation from water surfaces, Dalton's Law is used:

$$E = K_C \cdot \Delta e \qquad (4)$$

where K_C – total evaporation coefficient, mm/(24 hours·GPa);

Δe – difference between vapour pressure under temperature of water surface (e_n, GPa) and vapour pressure in air on the some height (about 2 metres) above water table (e_2, Gpa).

For the determination of the coefficient K_C, a great number of formulas have been proposed, based on different descriptions of the evaporation process. However, in the former USSR, following the prescriptions of the "Instructions for evaporation calculation from the surface of water bodies", evaporation had to be calculated by the formula of the State Hydrological Institute (St.Petersburg), based on the observation of water surface temperature:

$$E = 0.14 \cdot (1+0.72U_2)\cdot(e_1 - e_2)\cdot\tau \qquad (5)$$

where U_2 – wind velocity at a height of 2 m above water surface;

t – number of days and nights.

In the absence of data on the average surface temperature of the water body, the calculation of evaporation was recommended by the simplified formula of A.P. Braslavsky [9]:

$$E = 0.13 \cdot \left[1+0.8U_2 + f(\Delta t)\right] \cdot (e_n - e_2) \cdot \tau \qquad (6)$$

where Δt $= t_1 - t_2$; $f(\Delta t) = \exp(0.18\Delta t) - 1$ with $\Delta t<0$ and

$f(\Delta t) = 1.9[1-\exp(-0.085\Delta t)]$ with $t \ge 0$;

t_1 – temperature of water body surface, °C;

t_2 – air temperature at 2m height above the water table.

The structure of these relationships is not accurate enough. Based on the concept of a two-layer process of evaporation into turbulent air, with the presence of a viscous buffer layer, A.P. Braslavsky proposed in 1985 a formula which appears to have the most accurate structure [8]:

$$K_C = \frac{1}{\frac{1}{K_0} + \frac{1}{K}} \tag{7}$$

where K_0 = 350 mm/24 hours (GPa);

$$K = 0.22 \cdot \left(\frac{U_{2,U}}{\alpha_t}\right)^{0.7} + 1.3 \cdot \left\{\exp\left[-1.4 \left(\frac{U_{2,U}}{\alpha_t}\right)^{0.7}\right]\right\} \cdot \frac{|\delta t|^{0.33}}{\delta t \cdot \alpha_t^{0.67} (273+t_2)^{0.33}}$$

$$a_t = 0.916 + 0.00634 t_2;$$

$$\delta t = t_n\left(1 + \frac{0.378 e_n}{P_a}\right) - t_2\left(1 + \frac{0.378 e_2}{P_a}\right);$$

where $U_{2,U}$ – true wind velocity [4];

$U_{2,U} = U_a + 0.4/(1+1.6U_a^2)$ wind velocity measured by anemometre (U_a);

$U_{2,U} = U_F + 1.4(1+0.4U_F^2)$ wind velocity measured by wind vane (anemoscope) (U_F);

e_n – maximum vapor pressure (GPa) at the –0.3 °C temperature (t_n) (average mean of gradient of water in thin cold layer forming on the water table);

P_a – atmospheric pressure, Pa.

Thus, the monthly evaporation from the water surface was calculated by the formula:

$$E = \frac{1}{\frac{1}{K_0} + \frac{1}{K}} \cdot (e_n - e_2) \cdot \tau \tag{8}$$

The calculation steps were as follows.

1. Over the whole water surface, the mean values of wind velocity, temperature, humidity and total low cloudiness were calculated.

2. Water surface temperature was calculated by means of the thermic balance equation for the water body.

3. The thickness of the evaporated layer was calculated.

The calculation method of mean values of the meteorological parameters over the water body is described in [7]. The improved variant of this method which was actually used in the calculations, is described in [8,9].

The mean values of air temperature and humidity over the water surface were calculated by means of the averaged transformation coefficient $M_{av.aq}$, which was determined from the previously calculated average values M_{av} for a number of cross sections, cutting the water surface in the directions of the eight compass points. The values of M_{av} were calculated on the basis of the equation by which the water temperature $t_{2,B}$ and humidity $e_{2,B}$ can be determined in a point, at distance X from the leeward shore:

$$t_{2.B} = t_2' + (t_n - t_2')\cdot M \quad (9)$$

$$e_{2.B} = e_2' + (0.8e_n - e_2')\cdot M \quad (10)$$

where t_2', e_2' – temperature and humidity of air touching the water body;

$$M = 1\text{–}\exp\{(0{,}08th(0{,}12\Delta t)\exp[-0{,}1(X-0{,}04)]-0{,}19\}(X-0{,}04)^{0{,}4}\}. \quad (11)$$

The mean value of M_{cp} along the profile, of length X_0, is determined as

$$M_{cp} = \frac{1}{X_0}\cdot\int_0^{X_0} M dX \quad (12)$$

or

$$M_{cp} = \frac{M_{X_0} + \alpha M_{X_0/2}}{2+\alpha}\cdot\left(1-\frac{0.04}{X_0}\right) \quad (13)$$

$$\alpha = 15\cdot(1 - exp[-0.4(X - 0.04)^2]$$

Here, M_{X_0} and $M_{X_0/2}$ are transformation coefficients calculated by the formula (11) for distances $X=X_0$ and $X=X_0/2$.

The values of M_{av} were calculated by formula (13) for the air arriving from dry land onto the leeward shore. In the case of complicated shape of the water body and the close presence of other water surfaces or very humid areas (e.g. overgrown by reed), the air will reach the water body with changed temperature and humidity. This fact was considered for calculation of $t_{2,B}$ and $e_{2,B}$.

$$M_{cp} = (1/X_0)\int_{X_d}^{X_0-X_d} M dX \quad (14)$$

X_d – length of hypothetical water body is equal:

$$X_d = \{\ln[1-(1-M_{\bar{n}})M_1/B_d\}^{2,5} \quad (15)$$

where

$$M_c = \frac{1}{1+\dfrac{0.2X_3^{0.425}}{X_3^{1.42}\cdot X_4^{-0.12}}};$$

$M_1 = 1\text{–}\exp(B_4X_4^{0.4});$

$B_d = -0.19+0.08\text{th}(0.12\Delta t)\exp(-0.1X_d);$

$B_4 = -0.19+0.08\text{th}(0.12\Delta t)\exp(-0.1X_4);$

X_4 – length of additional (another) water body;

X_3 – length of dry area separating the additional water body from the one being considered.

The average value of the transformation coefficient was determined taking into account the frequency of direction changes of the wind. As wind velocities over dry land and water surface U_2 are different, transition coefficients K_F were applied to the wind velocity measured at the meteorological station, in order to obtain the wind velocity over the water. Aerological data on multi-annual average wind velocity (for ice-free season) at 1 km height U_{1000} was used for this purpose:

$$U_2 = K_F U_F \tag{16}$$

where U_F – average monthly wind velocity measured by wind vane;

$K_F = 0.6 \frac{U_{1000}}{U_F}$;

$\hat{E}_{F,L} = 0.7\hat{E}_F$ and $U_{2,L} = 0.7\hat{E}_F U_F$ in case of ice cover.

Further calculations were made for 24-hour intervals. The daily values of air temperature, humidity, solar radiation absorbed by water and reflected back to the atmosphere, were interpolated between the mean monthly data. Monthly evaporation was then determined as the sum of daily (24-hour) values.

Water surface temperature by the end of considered 24 hours are calculated as below:

$$t_{\hat{e}} = t_i + (S_p + S_a + S_r + S_{\grave{e}\tilde{n}} + S_{\grave{e}z} - S_{\hat{e}} + Q_a)/c \cdot r \cdot m \cdot H_{c\delta} \tag{17}$$

where t_H – water surface temperature at the beginning of the 24 hours, °C;

S_p and S_a – total solar radiation and back radiation of atmosphere absorbed by water;

S_r – heat exchange between water mass and bottom;

S_{uc} – heat emission as a result of evaporation;

S_{uz} – heat radiation of water surface;

$S_{\hat{e}}$ – heat emission as a result of turbulent convection;

c – heat capacity of water, calorie/g;

r – specific weight of water, g/cm³;

m – relation between average temperature of water mass of the water body and temperature at water surface;

H_{cp} – average depth of the water body, cm;

Q_a – advection of heat.

Components of heat balance are expressed by cal/(cm²/per 24 hours).

Calculations for ice-free period were made according to formula (17). For the ice period, the thickness of ice and evaporation from surface of snow-ice cover are calculated. The temperature of the snow-ice cover is determined by the heat balance equation:

$$S_\delta = S_0 \cdot \hat{E}_N \cdot \hat{E}_d \cdot \hat{E}_z \cdot \hat{E}_r \cdot (1 - \grave{A}_B) \tag{18}$$

where S_0 – intensity of total solar radiation on unit of water area for cloudless sky and albedo of underlying dry surface equal to zero;

K_N – coefficient taking into account the retention by clouds of part of the total solar radiation;

K_e – coefficient taking into account the influence of air humidity on the value of total solar radiation reaching the water surface;

K_z – coefficient depending on the altitude of the water surface;

K_r – coefficient taking into account the influence of the intensity of solar radiation on the water body, of the albedo of the underlying surface and of the size of water body;

A_B – albedo of water surface for total solar radiation, in fractions of unity;

$$\hat{E}_{\mathring{a}} = \tilde{N}_n(\mathring{a}_{\ddot{i}\delta} - \mathring{a}_2)$$

where $\tilde{N}_n = 0.01\{0.32+0.146g+(0.126g-1.58)\cos[2+3.1416(30.4I-0.25g-7.7)/365\};$

$\mathring{a}_{\ddot{i}\delta} = 12-0.000567\, g^{2.2}+[6.6-0.00267(g-50)^2]\cdot\cos\{a3.1416[30.4I-221.2+0.0173(g\ 69)^2]/365\};$

$a = 0.5236(I-6.2);$

I – number of months.

The calculation technique of all coefficients is described in detail in [10,11].

$$S_a = 0.92\{[1-\exp(-1.12e_2{}^{0.15})](1-N_o)+\{0.97-0.106[0.01\cdot(t^2+50)]^{3.4}\}N_i+0.85(N_o-N_i)\}\cdot s(273.2+t_2)^4 \quad (19)$$

where s – the Stephan-Boltsman constant, equal $11.7\cdot10^{-8}$ cal/cm$^2\cdot$24 hours$+K^4$);

N_0 and N_H – total and lower cloudiness, as fraction of unity.

Own radiation of water surface of the water body is calculated by ordinary formula

$$S_{uz} = 0.92s(273.2 + t_n)^4 \quad (20)$$

Coefficient of radiating capacity was assumed as 0.92.

$$Sr= (1-0.02)\acute{I}_{\tilde{n}\delta}\{[35-0.044(g-30)_{1.58}]\sin\{0.0172.[30.4(I-1)+D-250]\}\} \quad (21)$$

$$S_{\grave{e}\tilde{n}} = (59.7-0.065\cdot t_{\ddot{i}})\cdot \mathring{A} \quad (22)$$

$$S_{\hat{e}} = 0.00065\cdot D_{\grave{a}}\cdot \hat{E}(t_i-t_2) \quad (23)$$

Here H_{cp} – average depth of the water body;

D – date of month;

P_a – atmosphere pressure.

A computer programme was prepared in Turbo-BASIC for the described method of evaporation calculation, which gives good results in arid climates. The monthly evaporation can be calculated in two ways:

1. using measured surface water temperature data;
2. using calculated surface water temperature values, obtained by applying heat exchange equations to meteorological data from the land and water surfaces.

The input data for the programme consists of:

- mean monthly water surface temperatures for the year in consideration;
- length of trajectory of the wind over the water body (or, combination of distance over land and water, for the eight compass points;
- data on wind trajectories over land and water body observed at the coastal meteorological stations;
- multi-annual average values of the mean monthly albedo for land and water surfaces, with correction for turbidity;
- length, average width and depth of the water body;
- latitude of the locality;
- coefficient of the wind vane and multi-annual average wind velocity in the meteorological station;
- multi-annual average atmospheric pressure at the meteorological station and its altitude;
- data for the considered year for the selected meteorological station: highest, mean and lowest air temperature; air humidity; mean wind velocity at the altitude of the measuring device; general and lowest cloudiness; wind frequency in the directions of the eight compass points (data for each of the 12 months in the year).

The output data of the computer programme were the following:

- the thickness (in mm) of the evaporated layer, calculated for ice-free months;
- humidity and temperature of the air blowing over the water body, obtained at the coastal meteorological station;
- computed values of evaporation, temperature of the water, air and the snow-ice cover, humidity, wind velocity, general and lowest cloudiness, ice thickness - all these averaged over the surface of the water body, and computed for each of the 12 months;
- month and date of beginning of formation, melting and disapearance of ice; maximum thickness of the ice cover;
- annual value of evaporation;
- components of the heat balance from I to XII months and their total value.

The evaporation from Kamyshlybash lake was calculated for 1994-1995, using data from the Kazalinsk meteorological station. The calculations will be corrected in the future, by data from the new meteorological station at Koszhar, established for the Project close to the lake (Tables 1 and 2).

It is more difficult to evaluate the water losses from surfaces overgrown by aquatic vegetation. In spite of many investigations, this problem has not yet been solved [12].

The suggested empirical methods for the calculation of transpiration from half-immersed vegetation are based on the parameters such as radiation balance, deficit of air saturation and exchange coefficient, which depends on wind velocity. The formulation of this problem is, however, very complex, as the transpiration depends also upon the kind, dimensions and density of the vegetation, development phases of the plants, nutrient supply, etc [1].

Bearing this in mind, it was decided at this stage of the research, to apply a coefficient for the conversion of open water surface evaporation into total evaporation of reed overgrown surfaces. For the Syr-Dar'ya delta, the mean monthly values of this coefficient are shown in Table 3, with an average value of 1.5.

Retrospective and prognostic water balance assessments of the Kamyshlybash lacustrine system

Observations have proved that the annual variations of the water levels in the Kamyshlybash lake system changed radically as compared to the hypothetical natural state. At present, water accumulates in the lake system usually in Autumn-Winter (August-February). Intensive lowering of stages was recorded in the warm season, April-July. The lowest stages were recorded in August-September (54.80 m.abs.), and the highest in March (56.67 m.abs.).

Analogous phases were recorded of the Syr-Dar'ya water level variations. In Summer-Autumn, water levels in the river are higher than in the lake system, and in Spring, the lake levels predominate (Table 4). The determinant factors of this process are:

1. higher evaporation from the lake surface in the Summer months; and

2. modifications of the Syr-Dar'ya stages in the vegetation.

In the retrospective assessment of water balance components, the greatest problem has been to determine the water exchange between the lake system and the river. The difficulties are caused by the lack of data on discharges in the channels which feed the lake system, and the complicated interaction between the river and the 'antechamber', which communicate in direct contact over a length of 19 kilometers. Therefore, at the present phase of investigations, the volumes of water exchange between the lake system and the Syr-Dar'ya were determined as the remaining term in the water balance equation (1). The calculations confirm that the water exchange between the lake system and the Syr-Dar'ya depends on the water regime of the river, the flow direction being determined by the difference in water levels.

The total outflow from the lake system (surface and sub-surface) accounts for 52% of the discharge part in the water balance equation, whereas 35% is attributed to evaporation from open water surfaces and 13% to evapo-transpiration from surfaces overgrown by aquatic vegetation. The regulatory effect of the lake system is thus confirmed, expressed in the moderation of the amplitudes of short-term water level variations in the river (Fig. 3).

The analysis of experimental data made it possible to define an approximate relationship between the volume of water exchange and the water levels in the lake and river (Fig. 4).

$$Q_L^T = -61\Delta Z + 956(\Delta Z_T)_2\Delta Z > 0 \tag{24}$$

$$Q_C^T = -10\Delta Z - 517(\Delta Z_T)_2\Delta Z < 0 \tag{25}$$

where Q_L^T and Q_C^T – inflow into the Kamyshlybash lake system and outflow from the system, in time interval T (10^6 m^3);

ΔZ^T – difference between water levels in the lacustrine system and river at the beginning T^{th} time interval (m).

Having calibrated the model parameters (1) by field data, it was possible to predict the water balance of the lake system for the planned water management solutions (Tables 5 and 6). Water withdrawal from the lake influences only the discharge part of the water balance: if 158,000,000 m^3 are withdrawn (between April and September), the outflow from the lake will be reduced from 52% to 38% of the discharge part in the water balance, while the volume lost for evaporation will remain practically unchanged. In the case of water intake by pumping, certain problems can be expected because of the significant amplitude of water level variations in the course of the year (around 2 m).

The construction of a dam at Amanotkel would assure the stability of water levels in the river and would create favourable conditions for steady water supply into the Kamyshlybash lake system. The projected headwater level of 56.7 m. abs. would change the water exchange between the lake and the river (Fig. 5). The return flow from the lake into the river would practically end and evaporation losses would dominate the discharge part of the water balance: 49% from the open water surfaces and 23% from the areas overgrown by aquatic vegetation. The stable water level in the lake would be favourable for the water intake from the lake.

Water salinity of the Kamyshlybash lacustrine system

Water salinity of the Kamyshlybash lacustrine system is mainly determined by components of water and salt balance, such as water exchange with the river system, precipitation and evaporation. The relationships between these components are responsible for the seasonal and perennial fluctuations of water volume and soluble salt resources.

Economic activity connected with the use of Syr-Dar'ya water for irrigation has a great deal to do with the formation of water salinity in the lacustrine system. According to the data of the Institute of Geography of the NAS RK for the last 15 years (1979-1994), the average water salinity of the lacustrine system increased 1.8 times (from 3.44 to 6.20 g/l). Observations from 1993 to 1995 have recorded seasonal variability of the average water salinity. So, within the phases of inflow into the system (Autumn-Spring period) salinity tends to reduce, while the total salt resource in the lake system slightly increases (Table 7).

Probably owing to the comparatively short periods of observation, no general patterns of horizontal and vertical distribution of water salinity in the Kamyshlybash lacustrine system could be established. The lake water belongs to the sulphate class of the sodium group, by chemical composition.

The specific feature of the lacustrine system is contamination by pesticides, in consequence of the large amount of water coming from the irrigation fields. River waters are purified to a large degree (Table 9) by passing through hygrophilous vegetation, algae and sedimenting into the deep reaches.

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References

1. Nikitin A. M.: About the dynamics of the middle and lower course of Syr-Dar'ya river. – *Transactions of SARNIGMI*, 1977, issue 56 (131), 22-30 pp.
2. Philonets P. P., Omarov T. R.: *Lakes of Central and Southern Kazakstan*. – Alma-Ata, Nauka, 1973, 198 pp.
3. Nikitin A. M., Lesnik Yu. N. Assessment of the dynamics of flatland lakes by use of space photoimages. – *Transactions of SANII*, 1982, issue 87 (168), 49-55 pp.
4. Elibaev I. O. About chemical composition of water of lowplain lakes of the Syr-Dar'ya river. – In: *Biological foundation of fish production in Central Asia and Kazakstan*. – Dushanbe, Donish, 1976, 77-79 pp.
5. Chebanov M. S.: *Systems approach to water and thermic regime of delta lakes*. – Leningrad, Hydrometeoizdat, 1989, 160 pp.
6. Nikitin A. M. Water resource and water balance of the Central Asian lakes and water storages. –*Transactions SANII*, 1986, Vol. 108 (189), p. 96.
7. *Instruction for evaporation calculation from surface of water reservoirs*. – Leningrad, Hydrometeoizdat, 1969, 83 pp.
8. Braslavsky A. P., Ostroumova L. P. Assessment of accuracy of modern formulas suggested for evaporation calculation from surface of water bodies. – *Transactions of KazNIGMI*, 1991, issue 107, 16-45 pp.
9. Braslavsky A. P., Ostroumova L. P. New formula for calculation of coefficient of air temperature and humidity transformation during air moving above water surface. – In *Transactions of KazNII Goscomhydromet*, 1975, issue 91, 75-87 pp.
10. Braslavsky A. P., Chistyaeva C. P. Calculation of evaporation from the Balkhash lake by improved technique. – In *Transactions of KazNIGMI*, 1978, issue 68, 3-44 pp.
11. Kirillova T. V. *Radiation regime of lakes and water storages*. – Leningrad, Hydrometeoizdat, 1970, 254 pp.
12. Braslavsky A. P., Shergina K. B.: *Evaporation losses from water storages in arid zone of Kasakstan*. – Alma-Ata, Nauka, 1965, 225 pp.
13. Korganov A. S. Influence of unproductive transpiration on run-off and hydrological effectivity of its change into productive one. – *Transactions of GGI*, 1973, issue 208, 127-134 pp.

Table 1. Components of heat balance MJ/m²

Radiation absorbed by water		Heat exchange		Radiation of water surface	Heat input for evaporation	Total		Change of heat content of water mass
Total solar radiation	Back radiation	With ground	With turbulent convection			Input	Output	
109.1	663.4	27.1	-99.5	-808.6	-73.3	834.5	-1024.2	-189.7
147.8	610.6	12.0	-89.9	-730.3	-66.2	804.1	-925.1	-121.0
326.8	660.5	-5.6	-65.1	-809.7	-64.2	1030.4	-985.8	44.6
607.7	747.1	-21.2	40.0	-885.9	-104.1	1455.8	-1055.5	400.3
738.9	862.6	-32.7	2.4	-1044.3	-286.4	1674.0	-1422.9	251.1
820.1	892.9	-33.5	-4.4	-1096.3	-430.5	1787.8	-1633.1	154.6
841.1	941.6	-27.2	-19.4	-1174.7	-536.8	1860.6	-1835.0	25.6
670.3	910.5	-12.5	-52.2	-1150.6	-464.7	1649.9	-1753.4	-103.6
553.1	797.7	5.1	-71.3	-1059.0	-388.6	1415.1	-1585.3	-170.2
367.5	722.8	22.1	-108.5	-992.4	-285.2	1161.0	-1446.6	-285.6
205.3	654.8	31.6	-80.7	-869.7	-140.1	930.6	-1138.1	-207.4
120.3	654.2	34.6	-104.2	-824.7	-86.6	844.4	-1059.9	-215.5

Table 2. Calculated average hydrometeorological characteristics for water area

Month	Evaporation, mm	Temperature, °C			Humidity GPa	Wind velocity, m/s	Cloudiness		Thickness of ice, cm
		Water	Snow-ice cover	Air			Total marks	Lower marks	
4	40	8.5	0.0	10.1	7.9	2.6	4.3	0.5	0
5	115	18.0	0.0	17.8	11.2	2.5	3.7	0.8	0
6	169	24.0	0.0	23.5	15.2	2.4	2.6	0.6	0
7	212	26.7	0.0	25.4	17.1	2.3	2.2	0.1	0
8	193	25.4	0.0	22.3	16.4	2.2	3.4	1.0	0
9	162	21.4	0.0	16.5	11.4	2.2	2.2	0.1	0
10	111	14.3	0.0	9.1	7.7	2.3	3.3	0.1	0
11	54	7.3	0.0	3.3	5.9	2.4	4.8	0.4	0
12	23	2.1	-6.5	-3.7	4.2	2.2	6.9	1.9	4
1	0	0.0	-6.2	-5.5	3.7	1.8	6.8	1.1	16
2	5	0.0	-4.7	-5.2	3.7	1.8	6.6	1.7	23
3	16	0.0	-2.2	-3.3	3.9	1.8	4.0	0.9	0

Table 3. Values of conversion coefficient K in different months of the vegetative season

Month	V	VI	VII	VIII	IX	X
K	1.32	1.29	1.66	1.67	1.98	1.31

Table 4. Assessment of water balance components for the Kamyshlybash lacustrine system according to experimental data

No	Com-ponents	Unit	1994									1995			Annual values
			IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	
1	Z^T_b	m	56.26	56.03	55.45	55.17	55.07	55.19	55.56	55.90	56.22	56.39	56.58	56.65	
2	Z^T_k	m	56.67	56.38	56.09	55.22	54.96	54.80	55.13	55.62	55.80	56.32	56.35	56.48	
3	ΔZ	m	–0.41	–0.35	–0.64	–0.05	0.11	0.39	0.43	0.28	0.42	0.07	0.23	0.17	
4	Z^T	m	0.021	0.026	0.001	0	0.021	0.001	0.001	0.006	0.041	0.014	0.006	0.007	0.145
5	E^T_B	m	0.040	0.115	0.169	0.212	0.193	0.162	0.111	0.054	0.023	0	0.005	0.016	1.100
6	τ^T	–	1.00	1.32	1.29	1.66	1.67	1.98	1.31	1.00	1.00	1.00	1.00	1.00	1.49
7	E^T_f	m	0.040	0.152	0.218	0.352	0.322	0.321	0.145	0.054	0.023	0	0.005	0.016	1.638
8	F^T_B	m^2	256.1	247.4	238.6	212.4	204.6	199.8	209.7	224.5	229.9	245.6	246.5	250.4	
9	F^T_f	m^2	81.4	75.4	69.5	51.7	46.3	43.0	49.8	59.9	63.6	71.2	74.8	77.5	
10	F^T_k	m^2	337.5	322.8	308.1	264.1	250.9	242.8	259.5	284.4	293.4	319.8	321.3	327.9	
11	ΔW^T	10^6 m^3	–97.9	–93.6	-268.1	–68.7	–32.7	80.1	127.2	51.2	152.6	9.6	41.8	19.4	–79.1
12	W^T_0	10^6 m^3	7.1	8.4	0.3	0	5.3	0.2	0.3	1.7	12.0	4.5	1.9	2.3	44.0
13	W^T_B	10^6 m^3	10.2	28.4	40.3	45.0	39.5	32.4	23.3	12.1	5.3	0	1.2	4.0	241.7
14	W^T_f	10^6 m^3	3.3	11.5	15.2	18.2	14.9	13.8	7.2	3.2	1.5	0	0.4	1.2	90.4
15	Q^T	10^6 m^3	–88	–65	–212	–6	11	127	158	63	148	6	42	25	209

Table 5. Predicted water balance for the Kamyshlybash lacustrine system in case of withdrawal of 10 m³/s

No	Com-ponents	Unit	1994									1995			Annual values
			IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	
1	Z_b^T	m	56.26	56.03	55.45	55.17	55.07	55.13	55.56	55.90	56.22	56.39	56.58	56.65	
2	Z_k^T	m	56.67	56.31	56.01	55.22	54.86	54.64	55.26	55.42	56.10	56.16	56.31	56.52	
3	ΔZ	m	–0.41	–0.28	–0.56	–0.05	0.21	0.49	0.30	0.48	0.12	0.23	0.27	0.13	
4	Q^T	10^6 m³	–88	–42	–162	–6	36	205	74	197	14	42	63	14	347.0
5	G^T	10^6 m³	25.9	26.8	25.9	26.8	26.8	25.9	0	0	0	0	0	0	158.1
6	F_B^T	km²	256.1	245.3	236.2	212.4	201.6	196.8	213.7	218.5	238.9	240.7	245.3	251.6	
7	F_T^T	km²	81.4	74.0	67.9	51.7	44.3	41.0	52.5	55.8	69.7	70.9	74.0	78.3	
8	F_k^T	km²	337.5	319.3	304.1	264.1	245.9	237.8	266.2	274.3	308.6	311.6	319.3	329.9	
9	ΔW^T	10^6 m³	-121.5	–95.8	-240.2	–95.1	–39.3	133.2	42.6	186.5	18.5	46.7	67.0	1.4	–96.0
10	W_0^T	10^6 m³	7.1	8.3	0.3	0	5.2	0.2	0.3	1.6	12.6	4.4	1.9	2.3	44.2
11	W_B^T	10^6 m³	10.2	28.2	39.9	45.0	38.9	31.9	23.7	11.8	5.5	0	1.2	4.0	240.3
12	W_T^T	10^6 m³	3.3	11.2	14.8	18.2	14.3	13.2	7.6	3.0	1.6	0	0.4	1.2	88.8

Hydrometeorological data of 1994 and 1995 years have been used for prognostic assessments.

Table 6. Predicted water balance for the Kamyshlybash lacustrine system with regard for withdrawal of 10 m³/s, and river water levels sustained by dam

No	Com-ponents	Unit	1994									1995			Annual values
			IV	V	VI	VII	VIII	IX	X	XI	XII	I	II	III	
1	Z^T_p	m	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	56.7	
2	Z^T_k	m	56.67	56.59	56.45	56.36	56.34	56.40	56.35	56.55	56.57	56.70	56.70	56.69	
3	ΔZ	m	0.03	0.11	0.25	0.34	0.36	0.30	0.35	0.15	0.13	0	0	0.01	
4	Q^T	10^6 m³	5.0	11.0	50.5	96.0	108.0	74.0	102.0	18.4	42.6	0	0	5	512.5
5	G^T	10^6 m³	25.9	26.8	25.9	26.8	26.8	25.9	0	0	0	0	0	0	158.1
6	F^T_b	km²	256.1	253.7	249.5	246.8	246.2	248.0	246.5	252.5	253.1	257.6	257.3	256.7	
7	F^T_f	km²	81.4	79.7	76.9	75.0	74.6	75.8	74.8	78.9	79.3	84.2	82.2	81.8	
8	F^T_k	km²	337.5	333.4	326.4	321.8	320.8	323.8	321.3	331.4	332.4	340.0	339.8	338.5	
9	ΔW^T	10^6 m³	−27.0	−46.7	−29.4	−6.4	19.2	−16.2	64.3	6.6	49.9	−3.4	−6.8	−16.7	−12.6
10	W^T_0	10^6 m³	7.1	8.7	3.3	0	6.4	0.3	0.3	2.0	13.6	4.8	2.0	2.4	57.5
11	W^T_b	10^6 m³	10.2	29.2	42.2	52.3	47.5	40.2	27.4	13.6	5.8	0	1.3	4.1	273.8
12	W^T_f	10^6 m³	3.3	12.1	16.8	26.4	24.0	24.3	10.8	4.3	1.8	0	0.4	1.3	125.5

Hydrometeorological data of 1994 and 1995 years have been used for prognostic assessments.

Table 7. Water-soluble salt resources of the Kamyshlybash lacustrine system

No.	Parameters of the system	Unit	October 1993	September 1994	April 1995
1	Average salinity, *M*	g/l	6.09	6.20	5.40
2	Water volume, *W*	mln. m³	810	771	1092
3	Salt resources, S	kt	4930	4782	5897

Table 8. Water salinity composition of the Kamyshlybash lacustrine system, gram/litre

No points	Sampling sites (lakes & rivers)	Salt-forming ions							
		Cl^-	SO_4^{2-}	HCO_3^-	Na^+	K^+	Ca^{2+}	Mg^{2+}	S
	1979 July								
2	Zhalanashkol lake	0.18	0.30	0.20	0.22	0.01	0.16	0.09	1.68
10	Kamyshlybash lake	0.35	1.32	0.18	0.41	0.01	0.15	0.17	2.62
12	Kamyshlybash lake	0.57	2.02	0.21	0.67	0.02	0.20	0.27	3.98
14	Kamyshlybash lake	0.67	2.24	0.21	0.75	0.03	0.20	0.31	4.43
	1993 October								
2	Zhalanashkol lake	0.84	3.00	0.26	0.91	0.03	0.33	0.41	5.78
4	Laykol lake	0.76	2.73	0.14	0.97	0.03	0.07	0.42	5.14
5	The channel	0.31	3.10	0.16	0.93	0.03	0.29	0.42	5.75
10	Kamyshlybash lake	0.83	3.21	0.19	0.92	0.03	0.34	0.44	5.97
12	Kamyshlybash lake	0.85	3.27	0.18	1.00	0.03	0.32	0.43	6.10
14	Kamyshlybash lake	0.88	3.37	0.19	0.98	0.03	0.32	0.49	6.29
16	Syr-Dar'ya river (Amanatkel)	0.13	0.67	0.39	0.24	0.01	0.12	0.09	1.68
	1994 September								
1	Zhalanashkol lake	0.71	2.79	0.23	0.73		0.22	0.44	5.18
2	Zhalanashkol lake	0.74	3.89	0.22	1.90		0.18	0.17	7.10
3	Laykol lake	0.89	3.89	0.19	1.87		0.12	0.27	7.23
4	Laykol lake	1.06	3.93	0.21	1.92		0.12	0.32	7.56
5	The channel	10.6	3.65	0.21	1.73		0.14	0.33	7.12
6	Kamyshlybash lake	0.89	3.22	0.20	0.72		0.14	0.69	5.85
7	Kamyshlybash lake	0.89	3.41	0.20	1.04		0.14	0.57	6.24
8	Kamyshlybash lake	0.89	3.99	0.18	1.13		0.36	0.53	7.08
9	Kamyshlybash lake	1.06	3.55	0.20	1.38		0.14	0.49	6.82
10	Kamyshlybash lake	0.89	3.31	0.21	0.61		0.24	0.72	5.98
11	Kamyshlybash lake	0.89	3.31	0.21	0.77		0.28	0.61	6.07
12	Kamyshlybash lake	0.89	3.02	0.20	0.68		0.20	0.63	5.05
13	Kamyshlybash lake	0.60	2.35	0.16	0.59		0.22	0.39	4.31
14	Kamyshlybash lake	0.89	3.22	0.22	1.06		0.22	0.47	6.08
	1995 April								
4	Laykol lake	0.55	1.70	0.18	0.49		0.21	0.27	3.41
12	Kamyshlybash lake	0.92	2.83	0.21	0.86		0.31	0.43	5.57
15	Syr-Dar'ya river(Baskara)	0.09	0.38	0.17	0.08		0.10	0.06	0.88
16	Syr-Dar'ya river (Karateren)	0.13	0.49	0.18	0.12		0.10	0.08	1.11

Table 9. Content of pesticides in the water of the Kamyshlybash lacustrine system (milligram/litre)

No	Site of sampling	Hexachloran			
		α -isomer	γ - isomer	DDT	DDE
1	Syr-Dar'ya river	0.051	0.003	0.021	0.260
2	Laykol lake	0.022	0.003	0.020	0.260
3	Kamyshlybash lake	0.015	0.002	0.012	0.130

The above figures should be considered as preliminary. Further investigations of the evolution and functioning pattern of the Kamyshlybash lacustrine system should continue by improved instrumental observations and data processing techniques.

Figure 1. Scheme of hydrological monitoring of the delta of the Syr-Dar'ya

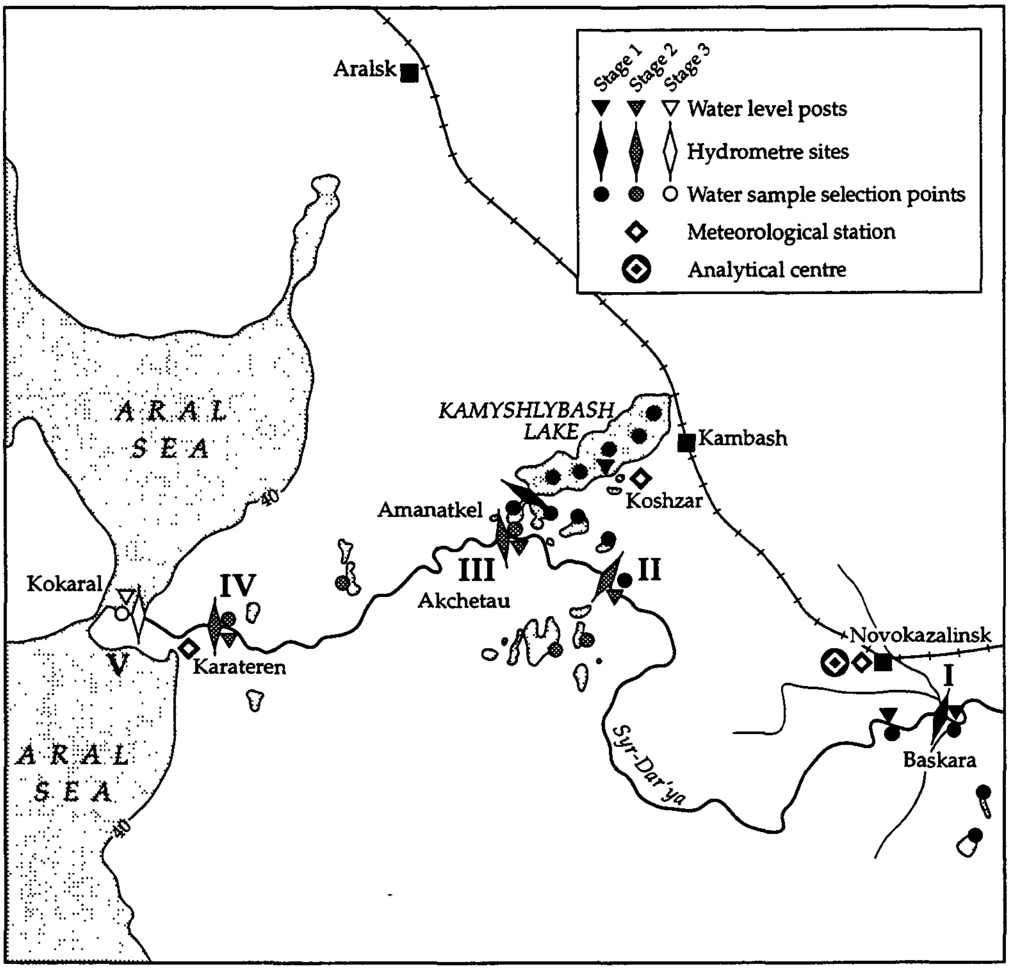


Figure 2. Scheme of the Kamyshlybash lacustrine system

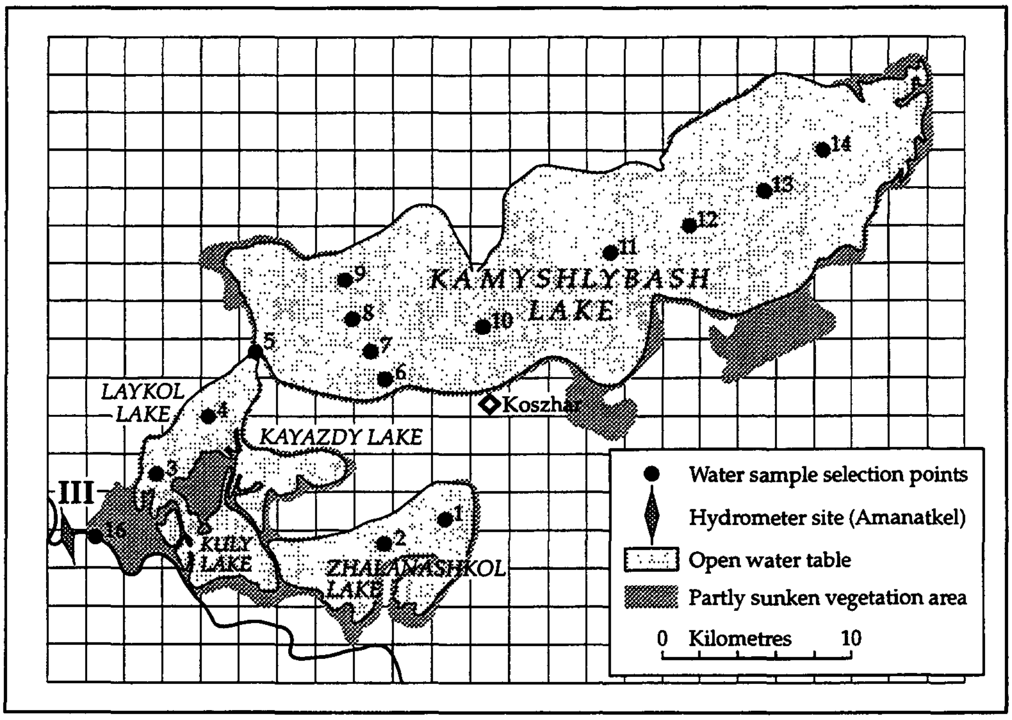


Figure 3. Water balance of the Kamyshlybash lake system, April 1994-March 1995

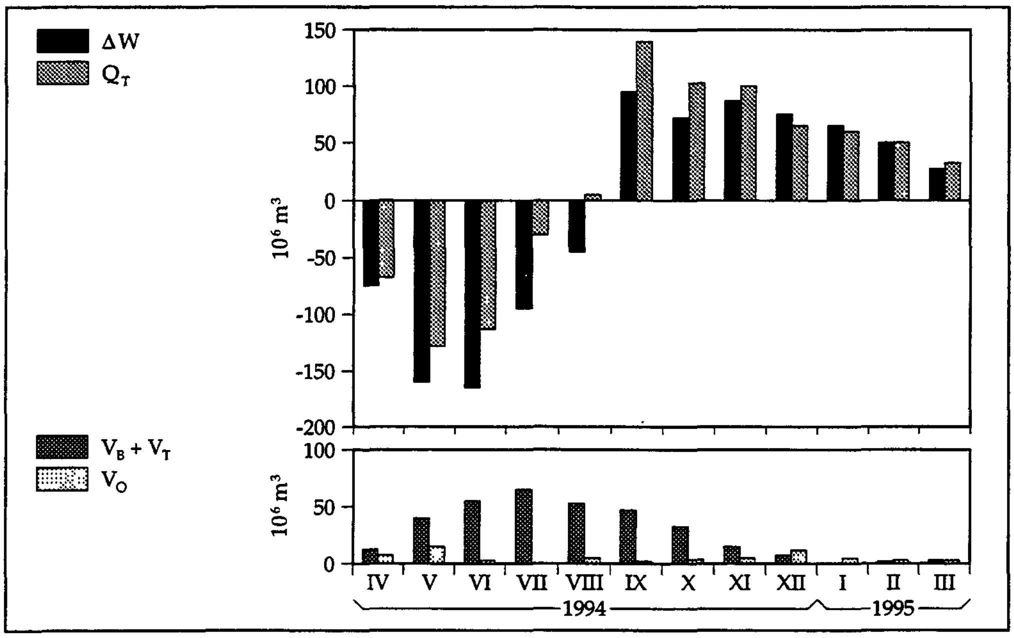


Figure 4. Water exchange between the lake system in function of water level difference

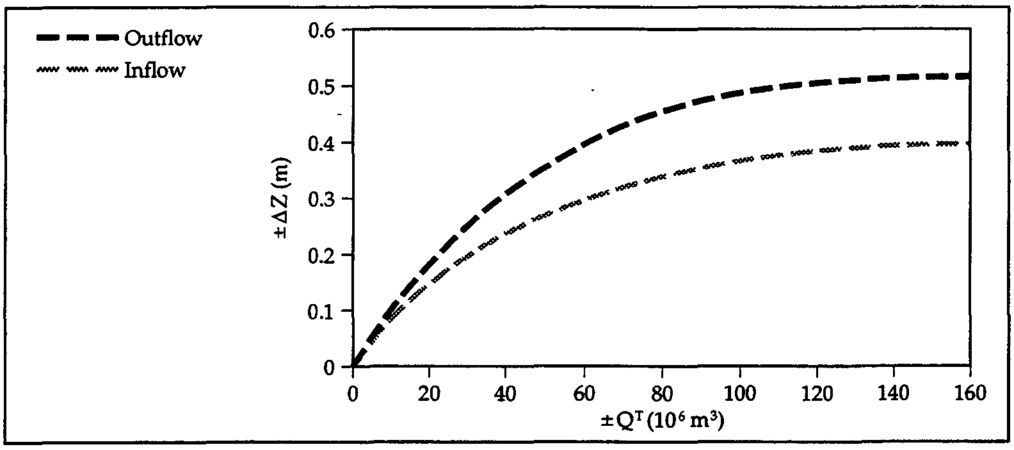
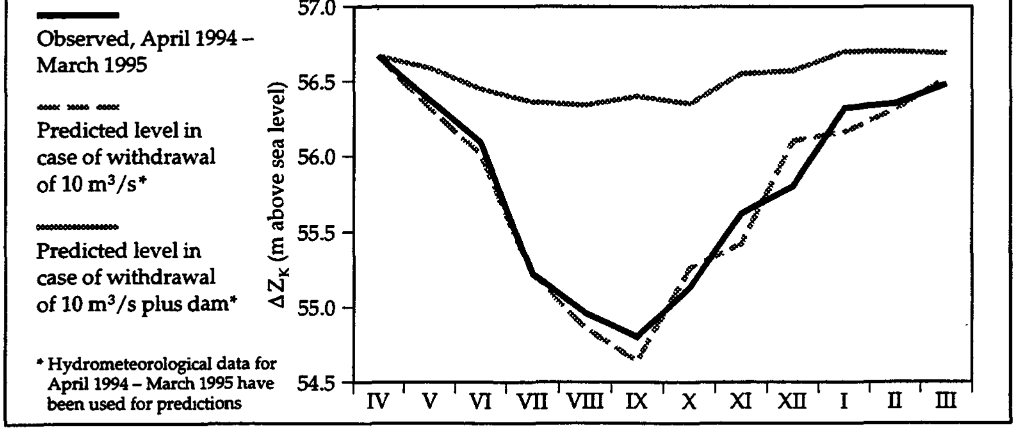


Figure 5. Annual water level of the Kamyshlybash lake system



ESTIMATION AND FORECAST OF THE STATE OF ECOLOGICAL-HYDROGEOLOGICAL PROCESSES AND SYSTEMS

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The subsurface hydrosphere in the arid environment is always affected by technological impacts, even if these seem to influence only slightly some ecosystem components. Their integral effect may be either positive or negative, and thus has to be evaluated and predicted.

The ecological-hydrogeological processes (EHGP) and systems (EHGS) were studied in selected representative areas, within the boundaries of the most vulnerable territories, exposed to anthropogenic load. These areas included the ancient river deltas (Kzyl-Orda), the present Syr-Dar'ya delta (Kazalinsk), irrigated territories and the desiccating part of the Aral Sea depression.

The integral representation of the eco-hydrogeological system with its biotic and abiotic sub-systems was studied by monitoring the basic indicators: salinity and chemistry of subsurface water, including micro-components, isotope and gas content, pH, Eh and temperature; soil salinity, filtration and migratory parameters, successions of main plant associations, their transpiration and mass transfer interacting with the groundwater regime. Ample use was made of satellite imagery and information.

Technogenic influences can be subdivided into three types, from the point of view of energy and matter fluxes:

- techno-exogenous influences, associated with inward directed fluxes of external matter and energy into the EHGS;
- techno-endogenous influences, associated with outward fluxes of energy and matter; and
- mixed-type influences.

The technological and natural EHGS, as parts of the environment, are thus considered as open thermodynamic systems, which receive natural and technological impacts and convert them into a sequence of quasi-equilibrium states, by the synergy of ecological and geological processes.

In the state of quasi-equilibrium, between the transition events, the technogenic evolution can be simulated by deterministic modelling. In the transition phases (or bifurcations), however, the biotic subsystem is most unstable and its trends and evolution can be assessed only in probabilistic (stochastic) terms.

In the arid conditions of the Aral Basin, the main abiotic factor of the EHGS is the regime of subsurface water, mainly groundwater, whereas the other components of the biotope are more stable. With prognostics in mind, we thus concentrated on the groundwater regime and the associated vegetation, at geo-botanical level (without detailed analysis of biocenoses).

The groundwater in the Aral Basin is an integral part of the natural water system (hydrosphere), and thus a component of the general water and salt balance, which in the last decades suffered great changes, due to intensive hydro-economic activities in the basin.

The Aral Sea depression, located at the lowest part of the Turan plain, is the terminal base not only of surface runoff, but also of the subsurface flow, arriving from the recharge areas, i.e. in the mountains on the fringes of the catchment. The latter is clearly indicated by the concentric groundwater level isolines, sloping towards the Aral Sea depression.

In the last two decades, the rapid subsidence of the Aral Sea level, the uncovering and self-discharging of artesian wells and increased exploitation of high-pressure artesian resources, as well as water management measures and irrigation, deeply influenced the ecological and hydrogeological conditions of the groundwater, and its contact with river and sea water, resulting in a profound change of the water and salt balance.

By the end of 1993, the level of the Larger Sea (after separation from the Smaller Sea in 1987) was 36.93 m, the dry sea bottom area was 37,750 km^2. In the last decade, the rate of water level subsidence has been 0.84 m/year, and the annual increase of the dry sea bottom is of the order of 1,000 km^2.

The eco-hydrogeological system and its evolution are determined by the change of the sea bottom from sub-aqual to sub-aerial conditions, affecting the soil, its salinity and groundwater regime. In the first year after the regression of the Sea, marshy solonchak soil develops, populated by seasonal 'solyanka' pioneer vegetation. In the next 2-3 years, the drying solonchak transforms into coastal soil, populated by halophyte associations, and later on, under exogenous influences (mainly deflation by wind), it becomes a typical, anthropogenic desert.

According to the data obtained by monitoring, the water-salt regime of the drying sea bottom is very dynamic. By the end of the first year, the groundwater level (GWL) of marshy solonchaks drops about 70-90 centimetres below the surface. The groundwater salinity (GWM) exceeds several times that of the sea water; for instance, it reaches 48-75 g/l, while the sea water salinity is 32‰. Soil salinity is 2-4% in the top layer (0-30 cm). In the next zone of coastal solonchak, the groundwater level drops to 100-150 cm below the surface, with salinity increasing up to 10%. In the zone of anthropogenic desert, the drying time is 10-15 years, and the groundwater level stabilizes around 3-4 meters below the surface. Groundwater salinity is variable: it is lower in permeable soils, and higher in impermeable ones, but generally, it stabilizes and decreases with time (after 15 years).

Development trends in the drying soils were studied through the relationships between the parameters of the water-salt regime and the distance L from the water edge, as this distance can be considered as an averaged indicator of the desiccation process. The increase of the thickness of the aerated layer in the soil, which is equal to the rate of sinking of the groundwater level V, is expressed in function of the distance L [1]:

$$VL^a=b$$

L [km], V [metre per year]

The values of the parameters were (Fig. 1):

For the Greater Sea:	a=0.82	b=1.105
For the Smaller Sea:	a=1.94	b=0.83

These relationships show that, with increasing distance from the water's edge, the rate of groundwater lowering decreases 10-100 times, as compared to the beginning of the desiccation.

Statistical analysis has shown that the groundwater sinking rate varies between broad limits - from 0.1 m to 1-2 m per year, reflecting the lithology and morphology of the soil, as well as the effects of evaporation and transpiration in the process of soil desiccation: the predominance of evapo-transpiration in the first stage of drying, and physical evaporation at the later stages of desertification.

The spatial distribution of groundwater salinity reflects two opposed processes: salinization and de-salinization. Salinization is associated with the increasing salinity of the sea water, which is the actual source of soil salinity, as well as with the concentration of salts in the soil by evaporation and transpiration; de-salinization is linked with the decreasing effect of evapo-transpiration and increasing role of precipitation in the water-salt balance of the desertified soils. With an average precipitation of 125 mm per year, and assuming that about 10% of the soil moisture is of atmospheric origin, the total depth of atmospheric water in the soil would be 200-400 mm, for the period from 1960 to 1993. The annually repeated leaching by rain water and deflation-evolution processes leads to a decrease of mineralization with distance from the Sea - from 60-80 g/l to 25-30 g/l, and decrease of salinity in the upper soil layer (0-30 cm) from 6-10% to 1.5-3.5%. In the groundwater and soil, the salts are mainly chlorides and sulfates of sodium and magnesium.

The groundwater and artesian water regimes continue to change in the Priaralye (Aral Sea basin), beyond the limits of the Aral depression. Close to the depression, the groundwater level (GWL) sank 3-4 metres; with distance from the Sea, this value decreases, but is still detected 50-100 km. further away, in the Eastern Aral Sea region. Such an extension of the regional subsidence of the groundwater table is the result, not only of the desiccation of the Aral Sea, but of a general change of the climate; i.e. reduced infiltration of atmospheric moisture. A certain effect may also be caused by the decreasing pressure (piezometric level) of artesian waters in the basin, which are hydraulically connected with both the Sea and the groundwater.

Investigations have shown that the piezometric level of the artesian waters in the Eastern Aral region dropped about 2-15 m from 1960 to 1993, with the highest values observed near the outflow and exploitation of the artesian wells, often far away from the Sea.

The groundwater being in hydrodynamic contact with both the Sea and the river waters, its sinking levels affect the cumulative mass of water and salt transported by subsurface flow (groundwater and artesian waters) in the Aral region: while the flow volume decreases, the transported mass of salt increases, due to the salinity of the groundwater.

The total recharge of groundwater resources (due to infiltration of atmospheric water, river water, irrigation and Sea water, as appropriate) is expressed by the groundwater module (flow per unit area) of the Aral Sea basin aquifer, comprising Quaternary, Cenozoic, Mesozoic and Paleozoic deposits [2].

The highest values of the groundwater module (0.5-5 $l/s.km^2$) were observed in the foothill zone of Karatau-Ugam and the adjoining zone of the Syr-Dar'ya valley, with a total annual volume of 0.86 km^3 per year (Fig. 2).

Towards the Aral depression, the modules drop below 0.05 $l/s.km^2$, with an annual volume of 1.95 km^3/year However, only a very small part of this huge volume of groundwater reaches the Sea, most of it being discharged into gullies and local depressions close to the recharge sources.

In the recharge area, the highest values of salt modules (3.5 g/s.km^2) were observed in the coastal zone of the Eastern Aral Sea basin, where the groundwater is most saline - from 20-30 to 80-100 g/l, transporting the total mass of salt of about 1.1 million tons per annum. The salt modules remain high also in the foothill zone and the Syr-Dar'ya delta - from 1 to 3 g/s.km^2, with an annual salt mass transport of 1.6 million tons per year. Thus, the total annual mass of dissolved salt transported by the groundwater is 8.9 million tons per year, and this quantity is mostly deposited outside of the Aral depression, causing soil salinization. While up until 1960, the groundwater contributed significantly to the water-salt regime of the Sea, nowadays it has lost the hydraulic contact with the Sea and gets discharged over the territory of the dry Sea bottom.

The artesian waters flow from the recharge zone (mountain fringes) towards the Aral depression, through the over-one-kilometer-thick Mesozoic-Cenozoic deposits. The highest modules of artesian water (over 5 l/s.km^2) were observed in the foothill zone, where about 1.5 km^3 of stratum water is formed annually. Along the eastern boundary of the Eastern Aral Sea basin, where the groundwater modules are not lower than 1 l/s.km^2, a total of 1.9 km^3 per year artesian water is recharged annually. Most of that water is discharged over the territory of the Aral Sea basin and only about 10% will reach the Aral depression, which is the terminal region of subsurface flow (Fig.3).

The salt modules of artesian water (2-5 g/s.km^2) are the highest in the foothill zone and near the depression of the Eastern Aral Sea basin, where the modules of water and salt transport are in inverse relationship. The total mass of dissolved salts transported by artesian water is 9.64 million tons per annum.

The artesian water which reaches the Aral depression, discharges partly into the Sea, and partly over the dry sea bottom. The total amount which reaches the Sea decreased with the shrinking of the Sea, from 0.21 km^3 in 1960, to 0.12 km^3 in 1993, and it is expected that until the year 2000, it will be reduced to 0.06 km^3. At the same time, the annual volumes discharged over the dry sea bottom increased from 0.014 km^3 in 1970 to 0.082 km^3 in 1993, with a trend of further increase, in proportion with the increasing surface of the dry sea bottom.

The total amount of salt transported by the artesian waters increased from 5.6 million tons per year in 1960, to 9 million tons in 1993. At the same time, the amount of salt discharged into the Sea decreased from 6.2 million tons in 1970 to 4.4 million tons in 1993, while the salt discharge over the dry bottom increased from 0.03 million tons in 1970 to 4.8 million tons in 1993 (Fig. 4).

Summarizing, the total subsurface flow into the Aral depression does not contribute more than 1% to the water and salt balance of the Aral Sea. Consequently, the main source of salinity in the dry bottom is the water and salt runoff of the newly generated groundwater in the silt deposits. The mass of salt which was discharged over the dry Sea bottom from 1960 to 1993 is estimated in the following way: assuming the average depth of the layer is 1.5 m and porosity 50%, the volume of shallow (silt) groundwater would be 28.3 km^3. The mass of salt in this volume of water would then be 594 million tons, assuming an average salt concentration of 21 g/l (10 g/l in 1960 and 32 g/l in 1993). This mass represents the salt potential which affects the territory of the Aral Sea basin.

Future ecological and hydrological developments depend not only upon the water level of the Aral Sea (which influences strongly the area close to the Sea and its depression) but also on microclimate, surface and groundwater regime, water management and other technogenic processes in the basin. As the trends and intensity of these factors are fairly well understood, their summary effects on groundwater levels can be predicted up to the year 2000.

Accordingly, the greatest drop of piezometric levels of artesian water is expected in the Cretaceous deposits in the south-eastern Aral Sea basin. Thus, at a distance of 60-100 km from the Sea, in the section 'Arys-Vozrozhdenya Island', the piezometric levels are expected to be lower by 20-23 m in 1995, and by 23-30 m in 2000, as compared to the levels in 1960. The rate of sinking slows down with the loss of pressure, which reduces the discharge of artesian wells.

In the Karatau-Ugama foothill zone and along the right bank of the middle reach of the Syr-Dar'ya, the piezometric levels will change little. At other parts of the Eastern and Northern Aral Sea basin, the amplitude of sinking will diminish and become 9-13 m in year 2000.

Due to lower pressure, the outflow of artesian wells decreases and less artesian water is fed to the groundwater, enhancing the decline of the water table and accompanying desertification processes. This will be sustained also by the continuing subsidence of the lake level, which influences the groundwater levels in the depression zone, this effect being reduced with the distance from the lake, to 3 - 1 m and less (Fig. 5).

In the general conditions of groundwater subsidence (due to the lowering of the Sea level), infiltration mounds develop on the irrigated surfaces.

The large irrigated areas in the Syr-Dar'ya basin are located close to the river, and their hydrogeological and meliorative conditions interact strongly with surface waters (both river and irrigation water). Under the influence of seasonal rises of the groundwater levels, water logging, salinization and swamps develop on the irrigated land and expand beyond its limits. The Syr-Dar'ya has become a collector drain for irrigation and groundwater, heavily loaded with toxic chemicals. The annual input of chemicals attains 10-60 tons from a hectare of irrigated field, and the water of the Syr-Dar'ya is already heavily polluted by chemicals as it arrives from Uzbekistan. On the average, at low water stages, the permitted limit concentrations in the river water are substantially exceeded: for petroleum products - twice, for nitrates - 5 times, for hexachlor - twice, for DDT and propanids - 6 times.

The ecological and hydrogeological trends in the Syr-Dar'ya basin were established by statistical multi-component analysis of the chemical composition of surface and groundwaters.

Subsurface waters are influenced by evaporation and biogenic factors, affected also by the lithology and atmospheric conditions. The chemical composition of groundwater varies with the seasonal infiltration cycle, phases of biological transformation of organic matter and seasonal variations of biogenic elements. In the Spring, the contamination of groundwater by organic matter diminishes, including the most aggressive components - NH_4, NO_2, O_2 and NO_3, the latter being the end-product of organic processes.

Toxic chemicals and organic contaminants, including DDT and heavy metals, arrive into the Syr-Dar'ya from irrigated land, industry and urban settlements.

The salinity of soil and groundwater in irrigated fields increases towards the Syr-Dar'ya delta, with the presence of Na, CO_3, HCO_3 and pH>7.

The Aral Sea basin is a region of ecological disaster. Lasting disturbance of the natural water balance in the Aral Sea basin led to an acute water deficit and deterioration of the quality of surface and groundwater - the traditional sources of drinking water in the region. In such circumstances, the potable water supply must be directed towards the uncontaminated, deep underground aquifers.

Scientific and applied hydrogeological research has proved that lightly saline (up to 3-5 g/l) deep underground water is present in a large part of the considered territory, and in several water-bearing layers: Albian-Cenomanian and Upper Pliocene-Quarternary to the East and North of the basin; Cenon-Turanian - to the East and North-East, Eocene and to a certain extent, Middle Upper Cretaceous - to the North and North West of the basin.

The potential of water bearing layers was assessed several times. In the present study, reference is made to the results of two such approaches.

According to the first approach, the projected operational resources of underground water (PORUW) are defined by the lowering of natural storage and attracted flow of natural underground water resources. A lowering of maximum 150 m of the storage is assumed, attracting not less than 50% of the natural underground water resources. Taking into account the interactions with surface water sources, the assessment of PORUW embraced, on an average, only 52% of the territory, excluding zones where no underground water exists with salinity below 5 g/l, all further areas not suitable for economic utilization and any other territories where these waters could hardly be exploited or extracted in very limited quantities only [3].

The projected operational underground water resources with salinity below 5 g/l in the Kazakstan part of the Aral basin amount to 196.2 m^3/s (or 6.2 km^3 per annum), including fresh water (below 1 g/l) 103 m^3/s (over 3 km^3 per annum). The greatest portion of these is located in the Shymkent province, 96 m^3/s and 66 m^3/s, respectively; an important portion in the Kzyl-Orda province 77.3 m^3/s and 27 m^3/s; and the smallest portion in the South-eastern part of Aktyubinsk province 22.6 m^3/s and 10 m^3/s (Table 1).

The projected operational resources of underground water (PORUW) are highly heterogeneous both in terms of the productivity of major exploitable aquifers (with well productivity in the range from less than 1 l/s to over 60 l/s) and salinity (from 0.3 g/l to 5 g/l). With this in mind, the territory is subdivided into 8 zones (Table 2, Fig. 6), from the point of view of the potential of the PORUW to cover the water demands of consumers:

Zone 1: PORUW can cover the demand of big consumers (cities and agricultural centres), situated mainly in the central part of the Syr-Dar'ya artesian basin. The operational discharge of wells reaches 20-50 l/s and water salinity is below 1 g/l.

Zone 2: PORUW can cover partially the demands of big consumers; situated in the Northern Aral basin. Well productivity is 20-50 l/s, salinity is up to 3 g/l.

Zones 3-4: PORUW can satisfy demands of medium water consumers (regional and other agricultural centres, small scale industry, urban type settlements, etc.); cover a part of the Northern Aral basin and Eastern Aral-Syr-Dar'ya basin. Well productivity is 10-20 l/s, salinity 1-3 g/l.

Zones 5-6: PORUW can fully or partially satisfy the needs of small consumers and pasture watering situated around the edges of the artesian basins.

Zone 7: PORUW may satisfy the needs of small consumers and pasture watering; covers a limited area in the north-western part of Karatau. Although the water is mainly fresh, well discharges do not exceed 1 l/s.

Zone 8: PORUW can be mainly used for pasture watering, being highly heterogeneous, with well productivity between 1 l/s and 10 l/s, salinity from less than 1 g/l to 5 g/l.

The second approach to assess the PORUW is related to planning water intake structures spread uniformly over the territory, which would secure water supply for at least 50 years, with lowering of maximum 250 m, but not deeper than half of the aquifer thickness [4].

The potential underground water resources (salinity below 10 g/l) in the Kazakstan part of the Syr-Dar'ya artesian basin is estimated at 725.3 m^3/s, including water-bearing layers: Upper Neogen - Quarternary sediments: 418.45 m^3/s; Upper Turonian-Cenomanian: 247,78 m^3/s; Upper Albian-Cenomanian: 63.1 m^3/s (Fig 7).

The prospective operational resources (with salinity below 3 g/l), have been estimated at 200 m^3/s, of which the storage[1] accounts for 167.41 m^3/s. The distribution of these resources by aquifers is variable: Upper Neogen - Quarternary sediments account for 143.83 m^3/s, and the Upper Albian-Cenomanian for 56.16 m^3/s.

The underground water resources of the Aral basin are reliable sources of domestic potable water supply (DPWS), agricultural (AWS) and industrial water supply (INWS), irrigation (IRWS), and pasture watering (IPWS). According to official sources[2], the underground resources of the Syr-Dar'ya basin supplied 463 million m^3 of water (500 million m^3 according to the KazGeologia data), groundwater extraction representing 4.3% of the total water intake in the basin. In certain water management regions, this percentage drops to fractions of a percent (Kazalinsk-Syr-Dar'ya estuary - 0.9%; Kergelmes-Kzyl-Orda - 0.6%; Tyumen-Aryk - 0.5%), while in others, it rises to tens of percent (Arys - 14.7%; Arystandy - 29%; Ikansu - 34%; Karachik - 68%). Underground water resources cover the demands of different consumers to various extents: 81% of municipal water demand, 80% of industrial water demand (totalling 152 million m^3), on the average, while the demands of light industry, petrochemical industry and metallurgy are covered by 96-100%. Municipal and industrial water supply used about two thirds of the total underground water extracted in the basin (Table 3).

The overwhelming majority of great water consumers (cities, settlements of urban type, regional centres) are at present provided with central water supply facilities, on the basis of underground water contribution. Rural settlements (in total - 662, among which 97 in Aktyubinsk province, 375 in Kzyl-Orda province, 190 in Shymkent province) also use underground water resources, as surface waters are polluted and thus not recommended for potable water supply. However, only one fourth of these, i.e. 161 settlements, have water supply conduits, out of which 148 use local supply sources, and 18 have group water supply facilities.

Based on data of different sources[3], the water supply of the region (including three districts of Aktyubinsk province) is distributed to economic sectors as follows: domestic potable water supply - 34%; agricultural water supply - 13%; industrial water supply - 28%; irrigation - 11%; pasture watering - 13%. At the same time, in the different provinces, the following percentages were used of the attested[4] resources: Aktyubinsk - 16%, Kzyl-Orda - 25% and Shykment - 46% (Table 4).

At the same time, significant quantities of water were extracted from resources which were not attested by the State Commission for Useful Mineral Resources and the Territorial Commission for Mineral Resources. So, in Kzyl-Orda province, the

[1] Attested by the State Commission for Useful Mineral Resources (SCUMR) and the Territorial Commission for Mineral Resources (TCMR).

[2] State Inventory of Water Resources of the Ministry of Water Management, 1990.

[3] Institute of Hydrogeology and Hydrophysics of the National Academy of Sciences of the Republic of Kazakstan, and the Information Bulletin on groundwater records of the KazGeologia.

[4] By the State Commission for Useful Mineral Resources and the Territorial Commission for Mineral Resources.

annual extraction of water from such resources was 72.1 million m^3, which is 7.4 times the volume drawn from the attested resources. In Shymkent province, in addition to the 312 million m^3 removed from attested resources, 105 million m^3 were taken from non-attested ones; in the three districts of Aktyubinsk province, about 9 million m^3 were used in this way. In total, more than 186 million m^3 of underground water were extracted from non-attested resources.

The attested underground water resources, the level of their present and projected exploitation (till year 2006), indicate that the region has satisfactory water supply resources, in general. The existing and planned local and grouped water supply systems are based on identified, concrete resources. Up to the year 2006, central water supply systems will provide water, in addition to cities, district centres and large industry, 512 rural settlements, with 93% of the population. For the remaining rural population, desalinisation plants are planned, also on the basis of underground water.

Powerful district and inter-district water supply conduits, with ramified networks, can be developed owing to the available, highly productive underground water resources.

For this purpose, over the period 1983-2000, using underground water resources, 6 main group conduits have to be constructed and put into operation in the Kzyl-Orda province, of a total length of 1,209 km and a production of 50,000 m^3/day, providing water to 1,222 km of rural distribution networks (till 1995); 7 such water supply conduits have been foreseen in Shymkent province. Whereas the construction of these facilities does not require large capital investments, comparatively, it improves the water supply of the territory and promotes the automation of water delivery to consumers. Notably, for a number of settlements in the Aral region, where no other sources exist for domestic water supply, water is at present provided from the Tolagai aquifer, by the Aral-Sarybulak water supply conduit. In Kzyl-Orda province, on the basis of aquifers already known or yet to be explored, new group water conduits are planned for a total length of over 1,700 km and a production of 70,000 m^3/day, thus providing water for domestic use of 148 settlements and to irrigate 650,000 hectares of land, including pastures.

Unfortunately, these most necessary measures are being implemented very slowly. First, at present only 11% of attested resources of 7 aquifers are being used. Second, of the 9 main conduits, only the Aral-Sarybulak conduit (2nd priority) and Kzyl-Orda right bank conduit (1st priority) are under construction. No project documents have yet been prepared for the other conduits. Until now, the volume of construction works of rural supply networks has not been established for the districts and farms. According to the State Committee for Nature Protection, only 67% of the settlements in Kzyl-Orda province have been provided with a central water supply, and 10% from other water sources.

One of the most promising tasks for the improvement of the ecological and hydrogeological environment in the Aral basin consists in prudent and rational use of the underground water resources, which is the most valuable asset of the region. Therefore, it is urgently needed to close 1,145 flowing artesian springs of a total discharge of 2.5 m^3/s (215,000 m^3/day) and to control their flow by valves. This measure would re-establish the piezometric pressure, which has fallen in many places to 15-20 m. As regards groundwater, its quality and prospects of utilization are directly dependent on the ecological environment, especially that of the irrigated land.

At the same time, the recovery of pressure in the deep aquifers, which interact with the shallow groundwater, would raise the level of the latter, and mitigate desertification processes in the Aral basin. Raising the level of the Aral Sea, which is in hydraulic contact with both the deep and shallow aquifers, would reinforce this effect.

In parallel with the beginning of implementation of the concepts of local rehabilitation of the Aral basin by the restoration of the Smaller Sea, preparatory work has started also on the modeling of the related ecological-hydrogeological processes (EHGP) and systems (EHGS). A three-layer mathematical model of the EHGS of the left bank of the Smaller Sea has been established and calibrated for Small Sea levels of 53, 51, 48, 43 and 38 m. The model will be used for the prediction of EHGS related to transgressions of the Small Sea.

References

1. Poryadin, V.I.: Ecological aspects of investigating the regime of the drying bottom of the Aral Sea, (in Russian), Geoekologia No.1, 1994, pp.76-87.
2. Water and salt transport by underground water flow in the Aral Sea Basin, Alma-Ata, (in Russian), 1983, 160 p.
3. Sydykov, Zh.S., V.I. Poryadin, T.N. Vinnikova, S.K. Nizhnikov: Underground water resources and their use in the ecological crisis of the Aral Sea Basin, (in Russian), International Congress on "Water: ecology and technology", Moscow, 1994, pp.297-307.
4. Syr-Dar'ya artesian basin (Mathematical modeling of underground water resources in conditions of technogenesis, (in Russian), Alma-Ata, 1991, 200 p.

Table 1. Projected operational resources of underground water in the Kazakstan part of the Aral Sea basin

Province	Yield m³/s				Natural resources km³
	Total	Level of salinity g/l			
		Up to 1	1-3	3-5	
Aktyubinsk	22.6	9.7	10.6	2.3	
Kzyl-Orda	77.3	27.2	39.8	10.3	
Shymkent	96.3	65.6	30.7	-	
Total:	196.2	102.5	81.1	12.6	983
Geological layers:					
Cretaceous	97.4	36.0	50.2	11.1	745
Paleogenic	11.0	4.3	5.7	1.0	63
Neogenic	0.5	0.4	0.1	-	2
Neogene-Quaternary	77.7	52.7	25.1	0.4	162
Quaternary	9.6	9.6	-	-	11

Table 2. Underground water resources in the Kazakstan part of the Aral basin (Fig. 6)

Zone No.	Area 1000 km²	Resources m³/s	Resources by province			Module of predicted resource l/s.km²
	Total / *Considered*	Total / *Mineralization below 1 g/l*	Aktyubinsk	Kzyl-Orda	Shymkent	
1	35	45.6	-	5.1	40.5	1.7 - 2.5
	20.5	*45.6*	-	*5.1*	*40.5*	
2	56	45.2	6.5	19.4	19.3	1.6 - 2.3
	26.4	*7.2*	*2.4*	*4.1*	*0.7*	
3-4	77	65.2	8.2	33.8	23.2	0.7 - 2.1
	42	*37.5*	*3.6*	*14.7*	*19.2*	
5-6	51	25.7	6.9	7.7	11.1	0.96
	25	*11.9*	*3.7*	*3.1*	*5.1*	
7-8	56	14.8	1.0	11.3	2.2	0.65
	22.1	*0.3*		*0.2*	*0.1*	
Total	275	196.2	22.6	77.3	96.3	1.4
	136	*102.5*	*9.7*	*27.2*	*65.6*	

Table 3. Underground water abstraction by sectors of economy

Ministry/Dept.	Underground water abstraction		Share of underground water in water abstraction of the sector %
	mill. m³	% of total amount	
State Committee/Agriculture	120.9	29.2	8.2
Ministry of Energy	4.8	1.0	16.6
Ministry of Metallurgy	110.5	23.9	96.2
Ministry of Petroleum	2.4	0.5	100.0
Ministry of Textile Industry	2.5	0.6	100.0
Ministry of Local Industry	0.13	-	68.4
Ministry of Water Management	24.4	5.8	0.2
Ministry of Housing	127.9	27.7	96.4
Others	65.5	14.3	-
Total	468.0	100.0	

Table 4. Distribution of underground water extraction in the region

Province	Attested resources $10^6 m^3$/year *(m^3/s)*	Water extraction						Projected resources m^3/s
		Total *(incl. non attested)*	DPWS	AWS	INWS	IRWS	IPWS	
Aktyubinsk 3 districts	247.4 *(7.9)*	39.0 *(8.9)*	19.3	2.8	11.8	0.6	5.3	22.6
Kzyl-Orda	323.2 *(10.25)*	81.8 *(72.1)*	32.4	13.4	18.9	–	17.1	77.3
Shymkent	860.8 *(27.3)*	417.5 *(105.1)*	132.2	56.5	121.1	59.7	48.0	96.3
Total	1431 *(45.4)*	538.3 *(186.1)*	183.9	71.9	151.8	60.3	70.4	196.2
Per cent %		100.0	34.2	13.3	28.2	11.2	13.1	

DPWS - Domestic potable water supply
AWS - Agricultural water supply
INWS - Industrial water supply
IRWS - Irrigation
IPWS - Pasture watering

Figure 1. Water-salt regime of the dry bottom of the Small Aral Sea and of the eastern coast of the Large Aral Sea

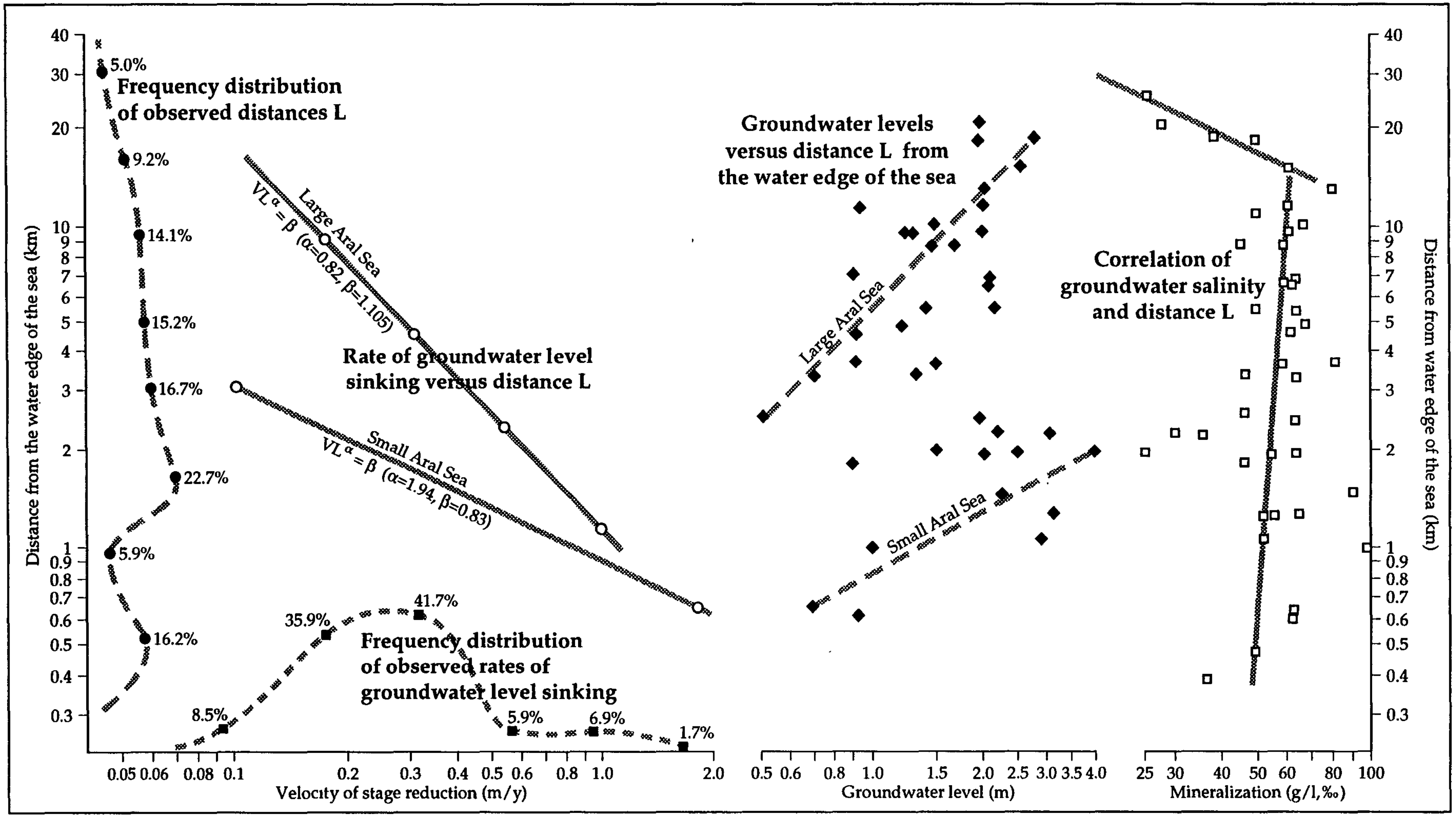


Figure 2. Groundwater flow and salt transport in the Syr-Dar'ya basin

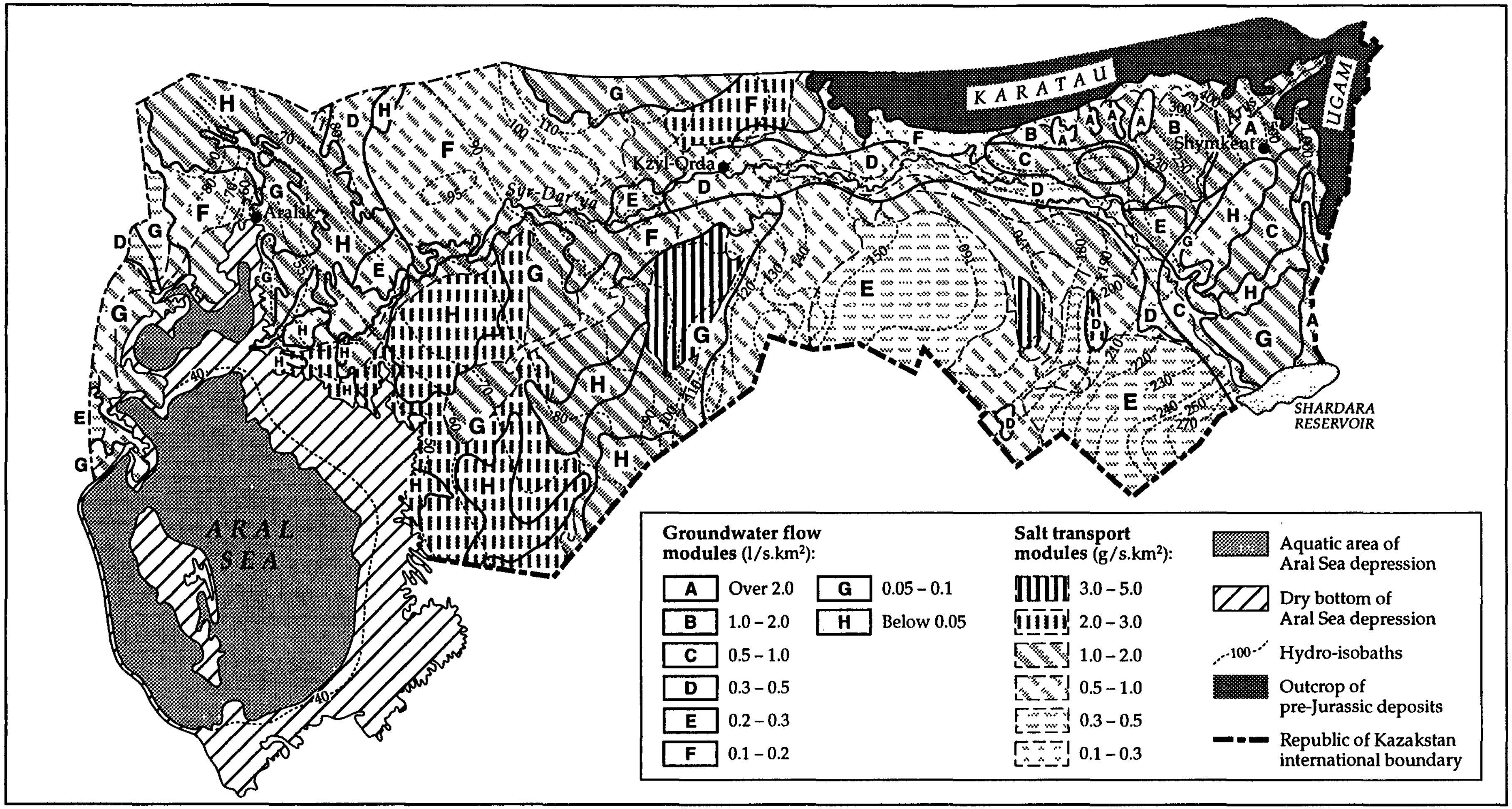


Figure 3. Artesian flow and salt transport in the Syr-Dar'ya basin

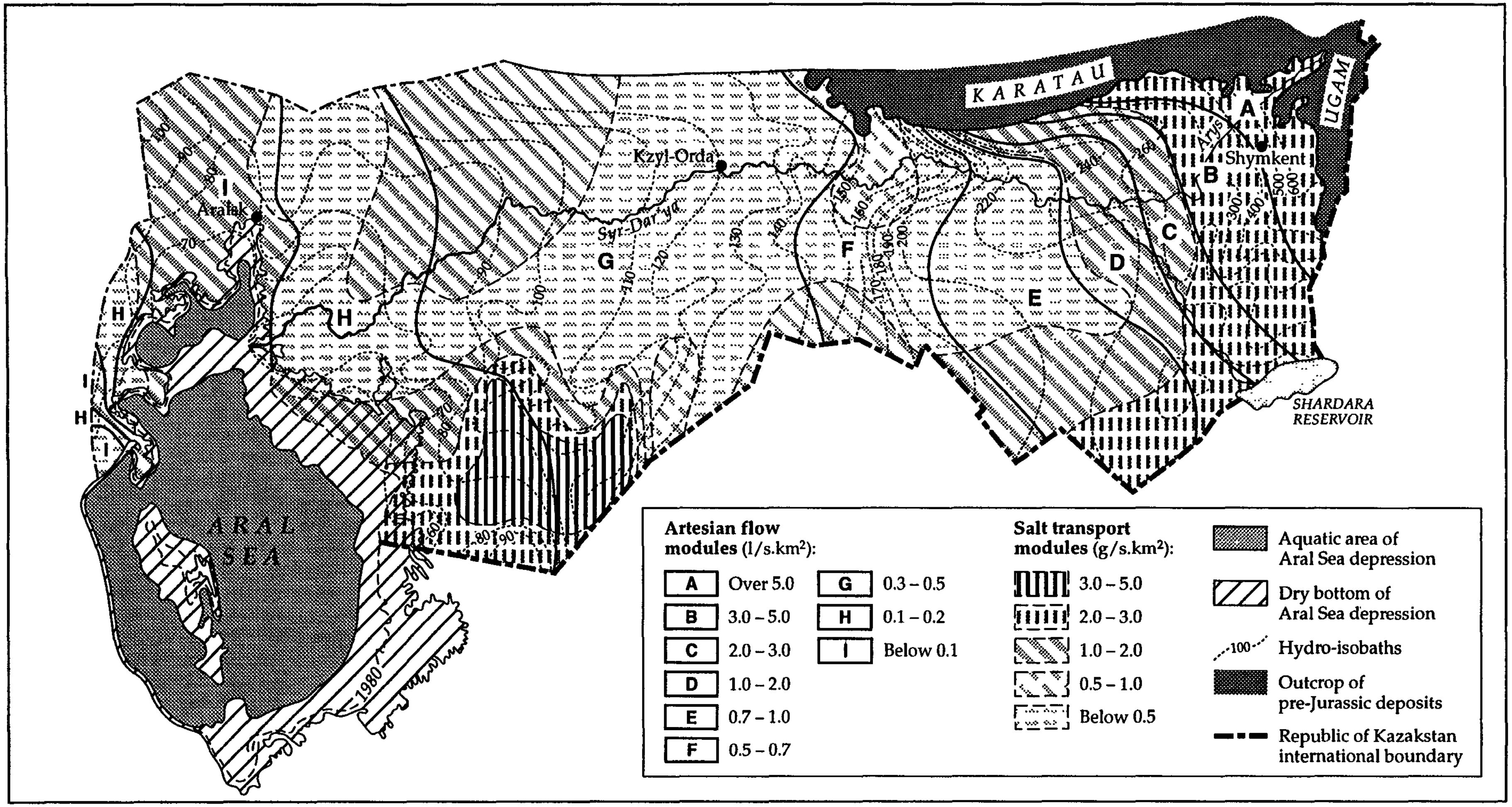


Figure 4. Artesian flow and salt transport in the Aral depression

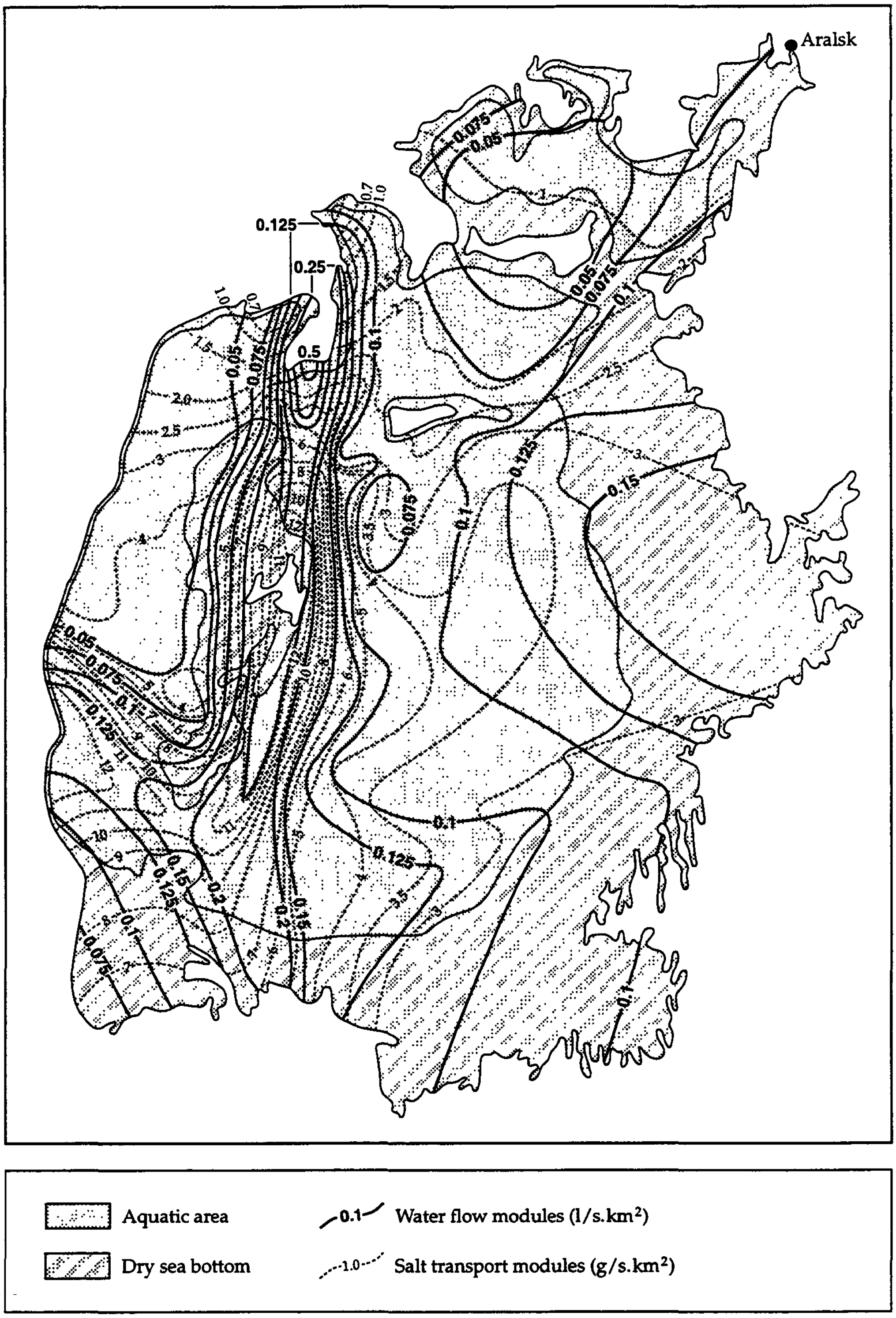


Figure 5. Present status and forecasted technogenic changes (2000) of the natural hydrogeological environment of the Kazakstan part of the Aral basin

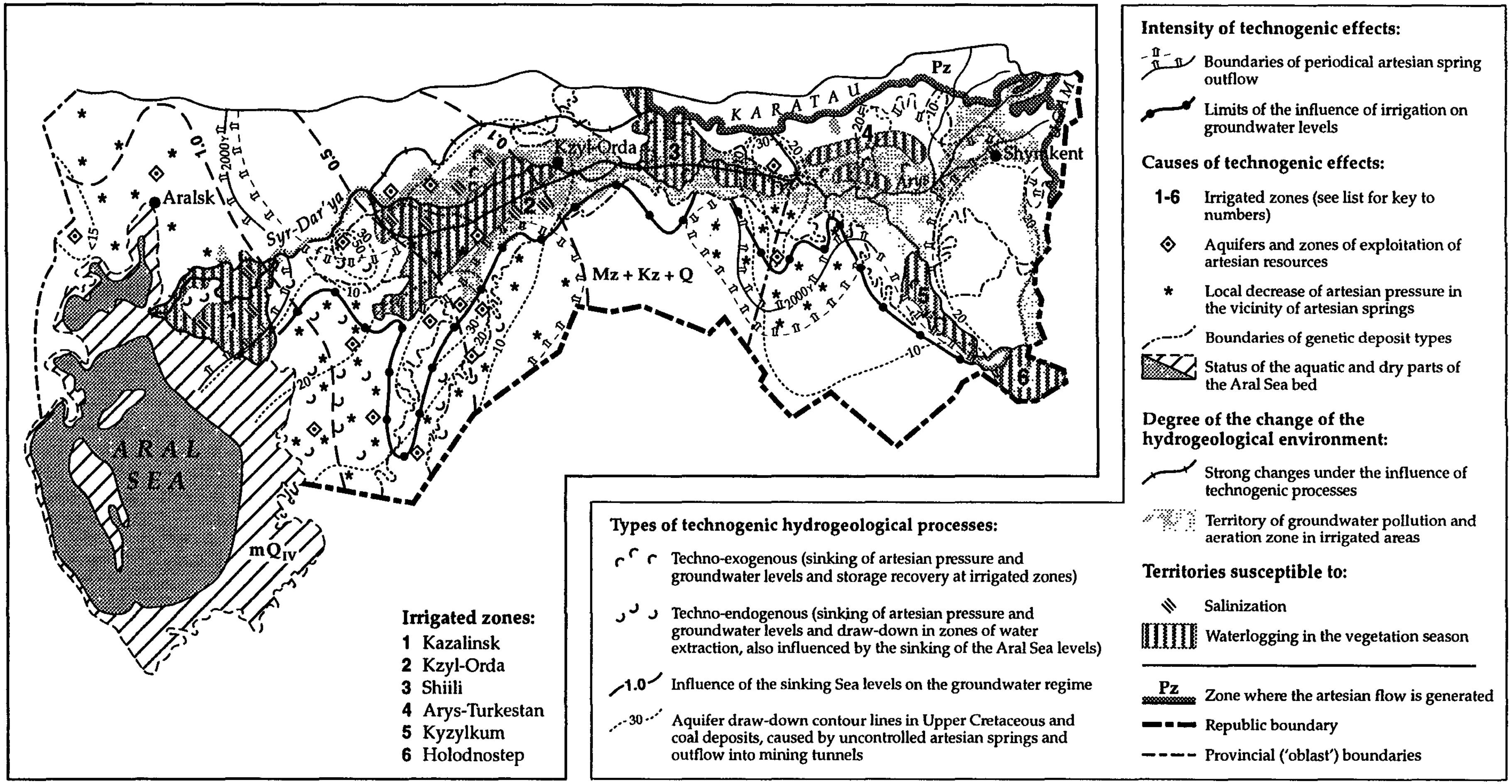


Figure 6. Projected operational resources of underground water (PORUW) in the Aral Sea basin

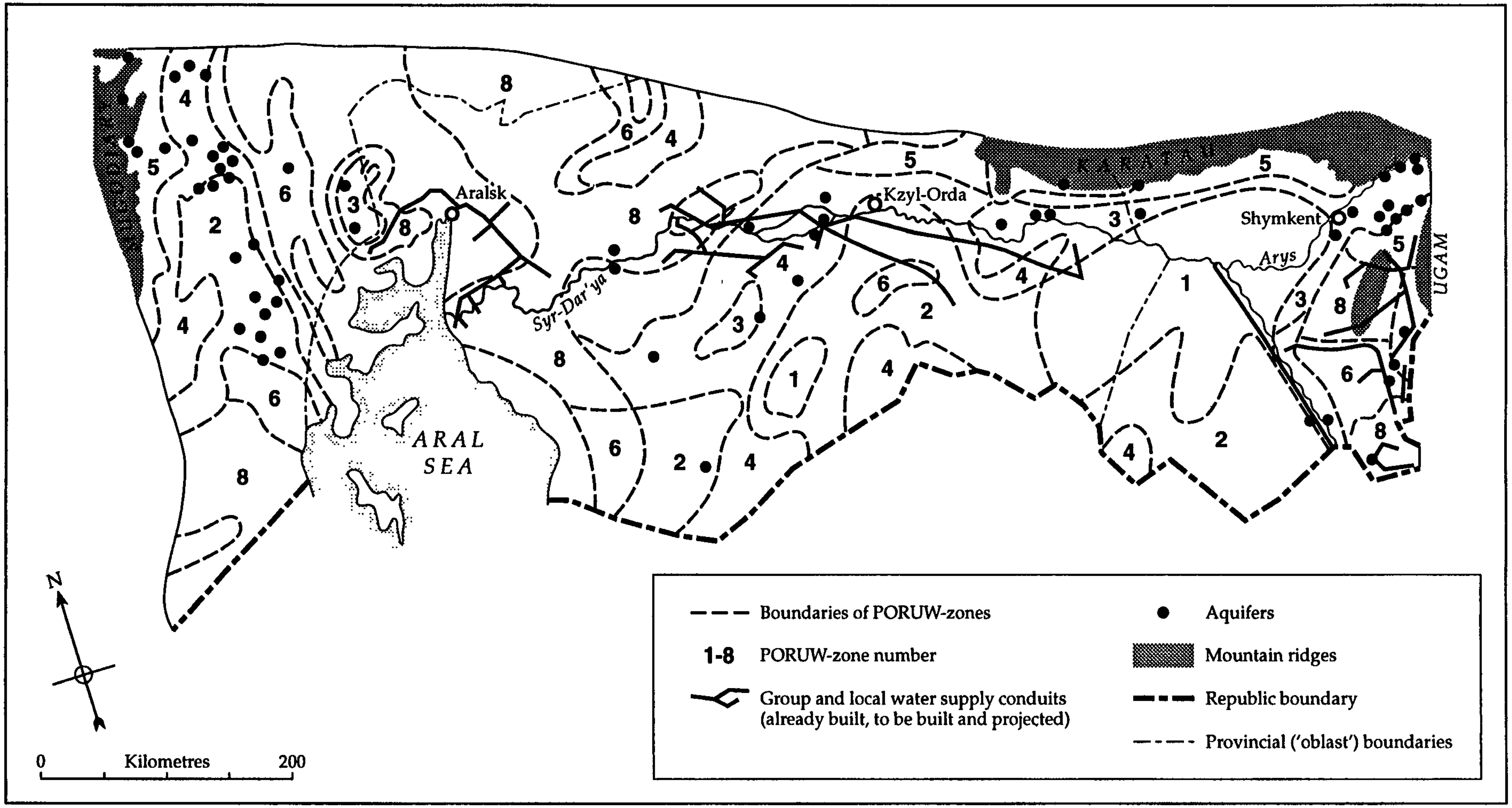
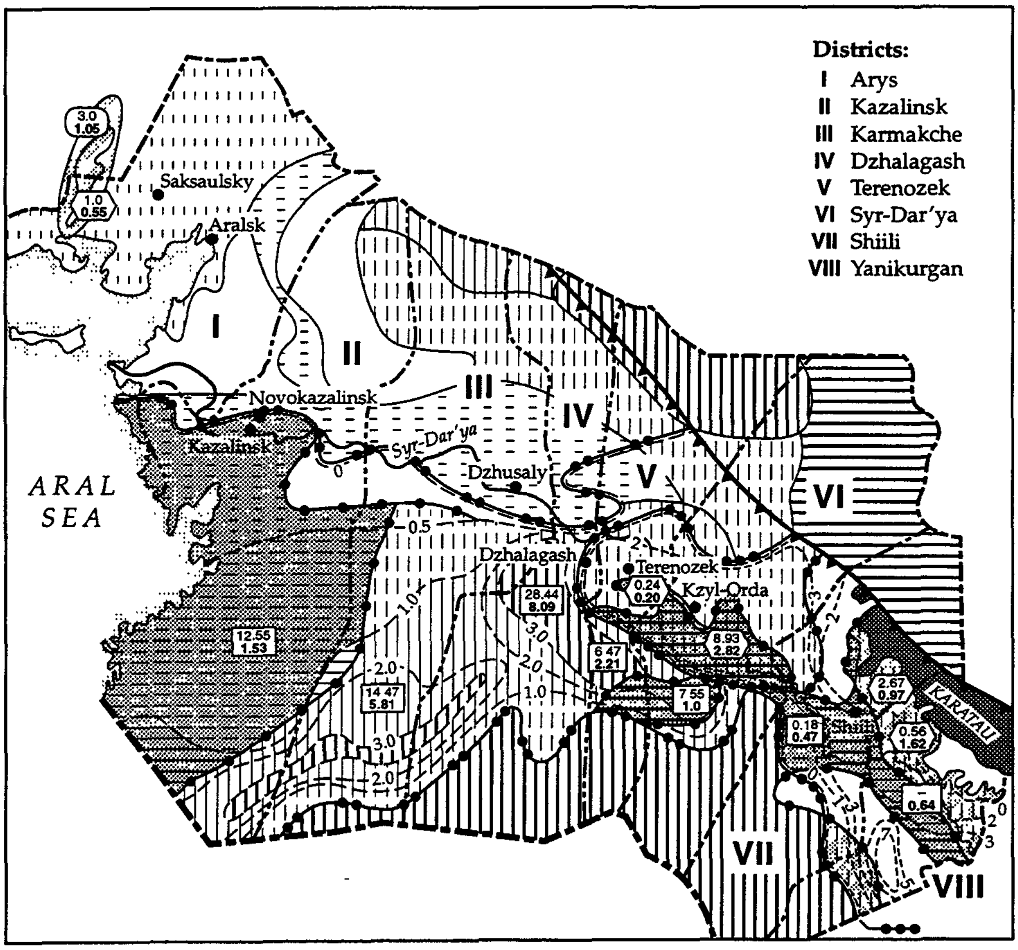


Figure 7. Prospective provision of underground water in Kzyl-Orda province ('oblast')



Limits of prospective aquifers:

- Upper Neogen and Quaternary (N_2+Q)
- Upper Cretaceous (K_2)
- Paleogene (P)

Isolines of prospective resource exploitation modules (PREM) (l/s.km²) of aquifers:

- 1.0 N_2+Q
- 2.0 K_2

Operational underground water resources (m^3/s) per aquifer:

- 0.24/0.20 K_2
- 0.56/1.62 N_2+Q
- 3.0/1.05 P

Upper (thin) number: forecasted resources
Lower **(bold)** number: attested resources

Prospective water supply by administrative districts ('regions') and prospective resource exploitation modules (PREM) (l/s.km²):

- Good (3.0 – 10.0)
- Satisfactory (1.0 – 3.0)
- Nearly satisfactory (0.5 – 1.0)
- Unsatisfactory (less than 0.5)

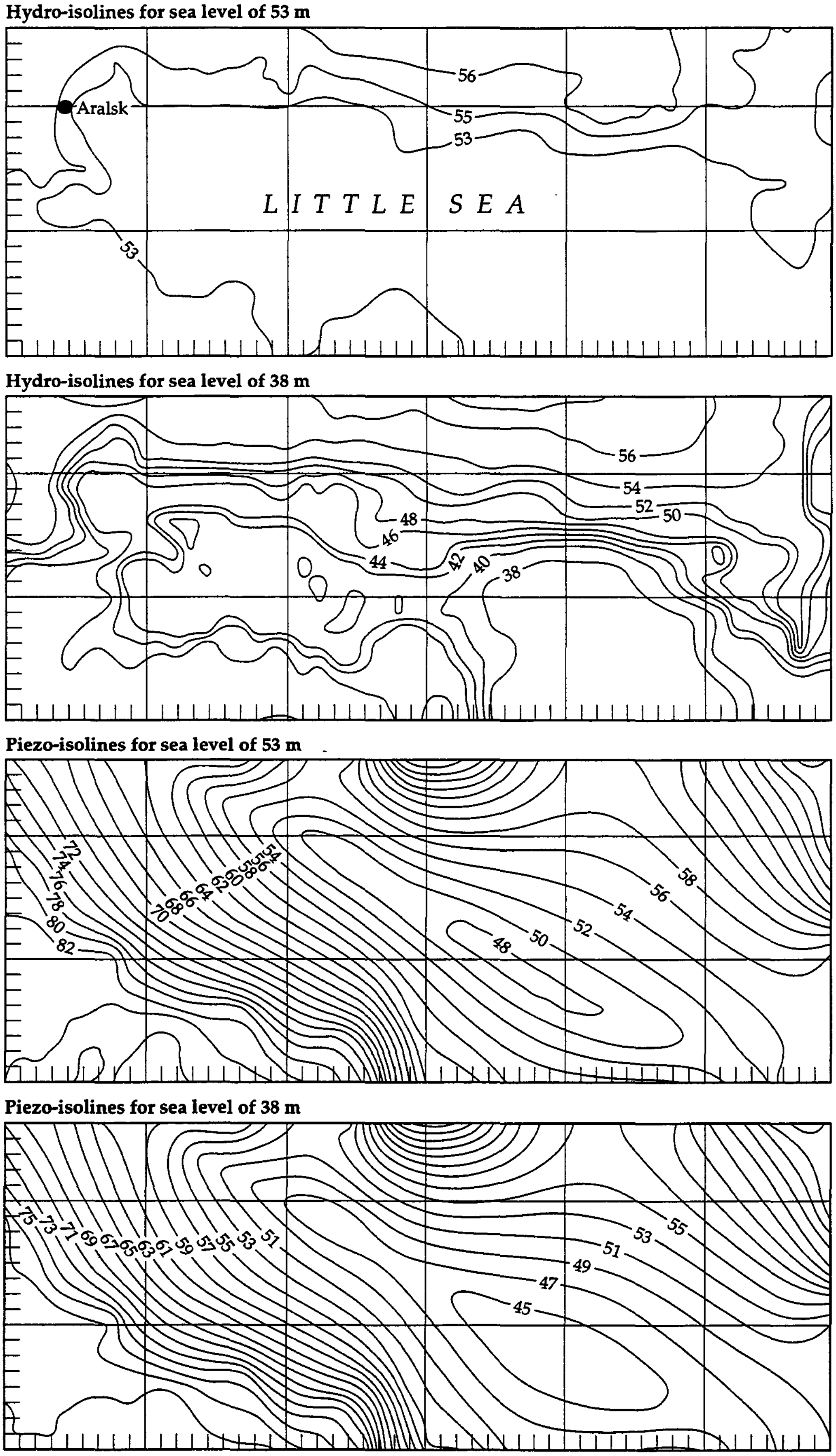
Mineralization 1.5 – 3.0 g/l
Mineralization 1.0 – 1.5 g/l

Underground water mineralisation (g/l):

- 1.5 – 3.0
- 1.0 – 1.5
- Less than 1.0

- Karataus's lineament
- Republic of Kazakstan international boundary
- Kzyl-Orda province ('oblast') boundary
- District boundaries (see list for key to numbers)

Figure 8. Mathematical models of the underground water regime of the Little Sea



HYDROBIOLOGICAL REGIME AND ANTHROPOGENIC EUTROPHICATION OF THE MUINAK BAY, ARAL SEA

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Introduction

Rational use and preservation of water bodies is impossible without in-depth knowledge of the aquatic ecosystem, which integrates the interrelated abiotic and biotic factors. One of the main issues is the investigation of the microbiological characteristics of the Priaral water bodies, which are exposed to anthropogenic loadings.

The aim of this work is to estimate the water quality in the Muinak Bay, after ecological and sanitary indices.

Investigation methods

The hydrochemical and hydrobiological survey of the Muinak Bay was carried out over a period of four years (1992-1995). Biological data were collected from eight spots, covering the whole water surface of the basin. Samples were taken from three stations (Central, North-eastern sectors, and inflow zone of the Glavmiaso canal), once a month during 1992-1993, and once a week in 1994-1995; furthermore, two or three times a week during the high discharges in Summer and Autumn.

Bakterioplankton was sampled from each depth layer (0-4 m), by means of glass bottles. Bacteria abundance was determined by membrane filters "Sinpor", with pore diameter 0.23 after being coloured by erythrosin. Volumes of coccidia and bacteria cells were determined separately. The water content in the bacteria cells was assumed to be 80% and carbon content 50% of the biomass. The quantity of heterotrophic bacteria was determined by means of cultivation on fish pecton agar (GAN), and the colonies were counted on the 15th and 20th days after incubation. Moreover, bacteria were cultivated also on GAN diluted 10 times (GAN/10). For direct counting and cultivation on GAN, the water samples were filtered on the spot, or in the laboratory, 2-3 hours after sampling. Phytoplankton samples were taken with the Ruttner bathometer, from surface to bottom. The samples were fixed by 40% formalin, concentrated to 20-50 ml and counted with a Nayotta camera, 0.05 ml in volume. The biomass of algae was determined by volume.

Algae were determined according to the USSR Guide for Fresh Water Algae.

The water quality was estimated on the basis of saprobic organisms according to Kolkovits and Marsom (cited by Makrushin, 1974), with respect to species content, number of hydrobionts, concentration and qualitative composition of the organic substance introduced into the water bodies. Primary production and decomposition of organic matter were determined by the bottle method in oxygen modification (Winberg, 1960). Bottles were exposed during 24 hours on the same horizons where the qualitative samples of phytoplankton were taken. The integral production and decomposition, per unit area and for the whole bay, were calculated with regard to the volume of the respective depth layers. The saprobic level was estimated on the basis of the saprobic indices after the method of Pantle-Buck, modified by Sladecek (1975). The calculated indices were then applied by using the following scale:

0-1.0	xenosaprobic	1.5-2.0	β-mesosaprobic	3.5-4.0	polysaprobic
1.0-1.5	oligosaprobic	2.5-3.5	α-mesosaprobic		

General conditions of Muinak Bay

With the discontinuation of the Amu-Dar'ya discharge into the Aral Sea, the Muinak Bay dried up. But, from 1983, it was flooded again by the river waters (to create a lake for fishery). The length of the lake is 23-24 km, width 7-10 km, depth 0.5-4.0 m. The bottom is sandy silt, covered by soft granular carbonate sediment - sand with shells. Transparency is 0.7 m. and in calm weather, the lake bottom is visible. In Winter the water in the bay freezes, and in Summer the water temperature rises to 30°C. Dissolvable oxygen content in the water is 4.5-11.6 mg/l, the active reaction to the environment is alkaline (pH = 7.9 - 8.7).

Oxygen saturation in the water is generally 87-158%, seldom exceeding 200%, and only occasionally reaching 215% as a result of intensive photosynthesis of the phytoplankton and macrophytes. Free carbon dioxide is found only in the bottom layers, among the ticket of macrophytes. The content of ammonium nitrogen varies from 0.132 to 0.465 mgN/l; nitrites: 0.043-0.187 mgN/l; nitrates: 0.146-0.718 mgN/l; phosphates: 0.026-0.90 mgP/l. The content of organic matter in the water is rather high: BOD 2,75-16.2 mgO_2/l; permanganate oxidation (PO): 10.8-39.5 mg/l; bichromate oxidity (BO): 97-180 mg/l.

The off-shore part of the lake is covered by reed. Aquatic vegetation is represented by *Phragmites communis, Typha angustifolia, T. laxmanii.*

Bacterioplankton

In the course of the four years of investigation, the total number of bacteria varied between 0.13 and 4.81 mln cl/ml[1] (Table 1). In the central part of the Bay, the density was 1.78 mln cl/ml, and 2.06 mln cl/ml in the shallow off-shore zone. The highest number of bacteria was observed in Summer and early Autumn; the lowest, during the coldest part of the year. The first peak of bacterial abundance usually arrives in May-June, when the water is warm and all biological processes become active. The second peak falls in the second part of Summer and early Autumn (from the end of August to mid September).

Bacteria abundance was high in the Kusatau-Karakchi spawning ground (1992-1993) and in the coastal part of Dzalangash Island in 1995, (Table 2). Abundance was high in the surface layer in Summer, when the water temperature went up to 30°C. For 1992-1995, the values of biomass are shown in Table 1.

On a rich nutrient medium (GAN - Growth on Agar Nutrient), the number of heterotrophic bacteria in the water samples from Kussatau-Karakchi spawning place and Dzalangash Island, amounted to 138-283 cells/ml. Such indices characterize eutrophic status of water bodies in the continental zone. Bacterioplankton is abundant also in the zone close to the Glavmiaso Canal and in the south-eastern part of the Bay, although less than in the rest of the Bay. The maximum abundance of saprophyte bacteria reached 16,000 cl/ml. Daily specific production did not exceed 1.4 g/m^3.

In the north-eastern part of the bay, the number of saprophyte bacteria reached 18,000 cells/ml, daily specific production 5.1 g/m^3 and 1.92 g/m^3. In Summer, the bacteria

[1] million cells per millilitre

content was determined by organic substance of plankton origin, and in Autumn, by macrophytes and waste from the fish factory, and stirred up by wind from the sea bottom.

The spatial distribution of heterotropha is, generally, similar to that of the total bacterioplankton. Judging from the base of heterotrophic bacteria, the coastal part of the lake along the Muinak fish factory is polluted by easily dissolved organic substances. During the vegetational season, the abundance of heterotropha was 2.0-2.7 times higher than in the central part of the bay, and 2.6-3.0 times higher than in the western deep sectors. The portion of heterotrophic bacteria, grown on GAN/10, varies during the vegetational season from 1,500 cl/ml to the maximum of 2,305 cl/ml by the end of July. Numerous tests on bacteria content grown on poor nutrient medium (GAN/10) showed that their number was 5-10 times lower than the number of bacteria grown on GAN. However, such a dependence could not always have been observed. There were cases when more or less bacteria could be detected on the plates, and their proportion to usually observed heterotropha varied in the range from 1:1 to 1:100.

Phytoplankton

Altogether 593 species, varieties and forms of algae could be detected in the Bay:

Cyanophyta	160	Dinophyta	37
Chrysophyta	3	Euglenophyta	25
Bacillariophyta	227	Chlorophyta	135
Xanthophyta	2	Rhodophyta	4

The diversity of algae was highest in the north-eastern sector, and the lowest around the outfall of the Glavmiaso Canal (Table 3), where it became reduced owing to the high concentration of suspended particles, shallowness and turbidity.

In all sectors, by the number of species, Diatomis and blue-green algae prevailed: Diatomis algae were the most diversified in the plankton of the Dzalangash Island, while they were blue-green algae in the Kusatau-Karakchi spawning place. By the number of species, the green algae were third, the highest diversity of which was detected in Dzalangash sector. The taxonomy of golden and pyrrphyte algae was approximately the same in all sectors. Euglenophyceae were largely developed in the Kusatau-Karachi spawning place. Yellow-green algae are represented in all investigated sectors by one or two species. The seasonal dynamics of phytoplankton composition are shown on Table 4.

The main background of algae consists of:

Variety	Spring	Winter
Diatomis	53.4%	63.5%
green	18.8%	11.9%
blue-green	18.3%	12.7%

In Summer, blue-green and green algae varieties increase 2.5-3.0 times, Euglenophyceae 5 times, while the varieties of Diatomis algae decrease to 34.4%. In Autumn, the phytoplankton composition is similar to that of Summer, with changes in the percentage of some groups of algae: Diatomis algae increase to 41.9%, blue algae decrease to 21.9%; blue-green algae remain unchanged, and Euglenophyceae decrease to 2.6%.

Out of the 593 species and varieties of algae found in the Muinak Bay, 32 belong to the prevailing forms. The development of the phytoplankton substantially changes due to anthropogenic influences (Table 5).

The average biomass in the investigation period fluctuated from 0.01 to 168 g/m³ and its abundance from 490 to 63075 mln cl/m³. In 1983-1990, according to A.E. Elmuratov (1990), the biomass and abundance of the Muinak Bay phytoplankton were at a very low level (0.01-39.00 g/m³ and 285-10,500 mln cl/m³). In 1992-1995, as compared to the preceding period, the abundance increased six times, owing to the strong development of some species, like *Merismopedia, Microcystis, Oscillatoria.*

When the Muinak Bay was re-filled with water in 1983, a large area of the desiccated sea bottom was also flooded. In March-May, the phytoplankton began to develop intensively at shallow places, where the water warmed up quickly, and in early Spring (February-March), the biomass in these sectors was higher (0.869-0.970 g/m³) than in the deep water zone (0.230-0.4509).

In the inflow zone of Glavmiaso Canal, due to the turbidity of the water, the abundance and biomass are considerably lower (1005-1506 mln cl/m³ and 0.36-0.52 g/m³), than at other places in the Bay. In April and May, the phytoplankton biomass increased considerably, from 0.70 to 20.65 g/m³ (Table 6). High phytoplankton development occurs in Summer, the biomass increasing 14 times as compared with Spring, fluctuating between 1.70 and 105.70 g/m³. On the whole aquatory, intensive development was observed of blue-green algae: *Microcystis aeruginosa, Oscillatoria limosa, O. irrigua.* They accounted for 27-32% of the total biomass. In Autumn, the drop in temperature leads to the decrease of phytoplankton biomass, especially in shallow places (Table 6): the same species which in Summer created the main background, diatomic algae, represented 38%-55% of the biomass - from 0.21-36.00 g/m³. In Winter, the gross mass of phytoplankton consisted of Diatomis (*Melosira moniliformis, Diatoma elongatum, Fragliaria crotensis*), and by their abundance, blue-green algae (*Merismopedia tenuissima, Oscillatoria irrigua, O. terebriformis*). However, the biomass of blue-green algae made up only 23-27%, due to their small cell size.

Maximum abundance and biomass were recorded in the central zone, with a decrease towards the canal outfall zone, minima being reached in shallow places of the coastal part. Table 6 shows that in recent years the number and biomass of the phytoplankton increased greatly. This indicates the deterioration in water quality.

Of the 593 recorded species and interspecies. more than half are indicator species (Table 7). Most of these are indicators of mesosaprobic status. and somewhat less in number are indicators of oligosaprobic status. Xenosaprobic and xeno-oligosaprobic algae, which indicate clean water, are rare and were found only in the outfall zone of the Glavmiaso canal: *Cymbella gracilis, Eunotia pectinalis, Synedra amphicephala, Aphonothece stagnina*. Considerably less numbers of species - indicators of water pollution (Polysaprobic and poly-alphasaprobic: *Anabaena constricta, Oscillatoria minima, Euglena caudata, E. deses, Carteria caudata,* etc) - could be found in the Kussatau-Karakchi spawning ground and around the Uchsay settlement.

The saprobic indices after Pantle-Buck (1955) vary considerably with the annual season, in all parts of the Bay (Table 8). In the Kusatau-Karakchi spawning place and Dzalangash Island, the indices change from α-mesosaprobic in early Spring to β–α mesosaprobic in Autumn. In the zone of the Glavmiaso canal outfall, β-mesosaprobic conditions were indicated during the whole investigation period.

Zooplankton

81 species and forms of zooplankton were identified: Rotatoria - 46 (56.8%); Cladocera - 17 (21.0%); Cyclopodia - 13 (16.1%); Calanoida - 2 (2.5%) and Harpacticoida - 3 (3.7%). The dominant complex of plankton fauna is composed of widely spread forms which are typical for continental inland water bodies (Table 9).

Side-by-side with lake organisms, forms were found which are capable of living in conditions of high content of humus in the water: *Euchlanis dilatata, Alona rectangula, Microcyclops* sp., *Harpacticoida* sp.. Most of these arrive from the Amu-Dar'ya through the Glavmiaso Canal.

The abundance of rotifera in Spring increases from the outfall zone (46.580 sp/m^3) towards the centre of the bay (273.060 sp/m^3), and decreases again in the western (138.907 sp/m^3) and north-western sectors (272.150 sp/m^3). Entomostracean crustacea species are evenly distributed, except for the Kusatau-Karakchi spawning ground, where they were not found. The abundance of copepoda species increased towards the centre, and then gradually decreased in the canal outflow reach to 35.820 sp/m^3 and south-eastern sectors to 29, 510 sp/m^3. At Dzalangash and northern sectors of the shoal, their number decreased but their biomass increased substantially, thanks to the mature crawfish predominance in these zones, noting that elsewhere, other species were dominant. Generally in the Bay, *Synchaeta pectinata* and *Euchlanis dilatata* were dominant as regards abundance (61.5% - 89.4%) and copepoda species, as regards biomass (44.4% - 86.5%).

Maximum phytoplankton abundance was recorded in the central sector (425.180 sp/m^3), while maximum biomass 35.4 g/m^3 was noted in the shoal of Dzalagash. Species diversity decreases from the north-western sector (0.23) along Uchsay (0.04), averaging all over the water body 0.042. Diversity expressed by Shannon's index H, related to both abundance and biomass, had the same trend of decreasing from the north-eastern sectors to lower Uchsay, averaging all over the bay H = 1.81 and H_b = 0.75 respectively.

The biomass of predatory forms, represented by *Synchaeta pectinata* and *Euchlanis dilatata* (47% and 52% of the total biomass) as well as 11 species of Copepoda, related to the biomass of non-predatory forms in the ratio 2:1.

In Summer, zooplankton diversity became minimal - 21 species, out of which: rotifera - 16, cladocera - 2, copepoda-crustacea - 3. At the same time, their quantitative development was very high: abundance 457.860 sp/m^3 and biomass 4.87 g/m^3. By quantity, *Keratella quadrata* (Mueller) (17.2%), *Synchaeta pectinata* (15.0%) and *Euchlania dilatata* (13.5%) were predominant. As regards abundance, rotifera dominated (57.3%), whereas by biomass, crustacea were dominant (90.5%).

In Summer, the maximum abundance of zooplankton was observed in Kusatau-Karakchi shoal and maximum biomass in western, deep sectors (depth over 3.5 m.). Species diversity D of zooplankton varied between narrow limits (0.015-0.026). Diversity index N reached the values: 2.43-2.99 for abundance and 1.46-2.51 for biomass.

In Autumn, 56 animal forms were observed, out of which: rotifera - 46, cladocera - 6 and copepoda - 4. However, the quantitative development of the zooplankton was low. The zooplankton abundance varied within the range of 49,380-2,665.705 sp/m^3, biomass 0.70-3,352 g/m^3. Rotifera prevailed everywhere, among which: *Euchlanis dilatata* (21.6%), *Lecane lunaris* (17.2%), *Keratella tropica* (Apstein) (13.8%). Copepoda were abundant in Autumn (61.3% of biomass), among which *Synchaeta pectinata, Synchaeta* sp., *Brachionus angularis, Brachionus urseus, Brachionus calyciflorus* (Pallas), *Brachionus quadridentatus*. Maximum abundance (1,056.370 sp/m^3) and biomass (25.96 sp/m^3) were recorded in the north-eastern sector. In the central and western deep water zones, the zooplankton was more abundant (109,500 and 453,075 sp/m^3 respectively), than in Kusatau-Karakchi and Dzangalash shoals (77,580 and 105,322 sp/m^3), with biomass 1.07 and 1.38 g/m^3 respectively. The index D which reflects species diversity, decreases strongly from the Glavmiaso Canal inflow (0.37) and north-eastern sectors (0.73-1.06) towards the western deep water zone (0.10-19.050

sp/m^3). The index H, reflecting cenose diversity, averaged 1.78 bit/sp in biomass 1.956 bit/mg.

In Winter, the majority of zooplankton passes into an immobile, resting stage. Under-ice plankton displays the lowest diversity - 27 forms only, out of which: rotifera - 18, cladocera - 5, copepoda crustacea - 4. As regards biomass, copepoda crustacea were dominant - 90.7%, out of which 47.3% were young specimens. Low abundance and biomass were found in the central and western deep water sectors (6.320 and 9.065 sp/m^3, with biomass 0.03 and 0.06 g/m^3. The least zooplankton was detected along the coast (161-205 sp/m^3, biomass 0.03-0.06 g/m^3). The value D decreased from the canal outfall (0.31) to the south-eastern sector (0.036), while the index H changed in the same way, from 2.69 to 0.03 bit/sp and from 3.80 to 2.07 bit/mgr.

Saprobic indices of the zooplankton differed greatly in different sectors of the Muinak Bay (Table 11).

Comparison of results obtained in 1980-1990 (Kazakhbaev) with the new data showed that the saprobic level of the zooplankton did not alter significantly. By other indices, however, the water quality deteriorated. So, out of 65 zooplankton species, only 13 had an index over 2.6, indicating considerable water pollution. In Kusatau-Karakchi and Dzalangash islands, blue-green algae developed intensively, with an increase of saprobic level over 2.5 times. The natural selection in favour of limnophylics should also be noted.

Water quality improvement and ecological balance depend upon the interaction of two opposed processes: production by photosynthesis and decomposition of organic matter. As shown on Table 12, these two processes are not in balance in Muinak Bay.

The highest primary production was noted in the central and western deep water sectors, particularly in the warm season. In the shoals, it was much lower. Decomposition had the same trend. Production and decomposition were very low in Kusatau-Karakchi and Dzalangash sectors.

During intensive photosynthesis, the phytoplankton absorbs nitrites, which is reflected in the negative correlation between the nitrite content and phytoplankton biomass.

At phytoplankton biomass (from 0.60 to 3.09 g/m^3) the content of nitrate nitrogen decreases to a minimum. Average phytoplankton biomass in Summer and Autumn at 3.6-7.5 g/m^3 nitrogen concentration fell to 1.3-1.85 of the total nitrogen content. Later, with the massive decay of the phytoplankton, the nitrate concentration increased considerably, with highest values in August (2.3 mg/l) and October (2.01 mg/l). During April-July, nitrate concentration was less than 0.704 mg/l and in September - 0.680 mg. With the increase of the phytoplankton biomass, the ammonium content increased greatly, owing to the reduction of nitrate to ammonium in the algae cells. The trend of change of ammonium and organic nitrogen was the same. The relative content of ammonium was at its maximum in July (16.3%) and of organic nitrogen in early September (82.5%), when the water flowering begins.

Biogene elements transported through the Glavmiaso Canal are intensively used by diatomic algae in Spring and Autumn. In June, the number of these decreased considerably, leading to the decrease of organic nitrogen concentration to minimum. In Summer, due to the intensive development of green-blue algae, the content of organic nitrogen increased to 3.1 mg/l. The nitrogen content forms are correlated with the species composition of the phytoplankton. Thus, nitrates, nitrites and ammonium have different values in different stages of phytoplankton development. Nitrates were predominantly absorbed.

Mineral phosphorus concentration in Muinak Bay varied between 0.001 and 0.317 mg/l, total phosphorus content between 0.10 and 0.48 mg/l. Strong correlation was found between the phytoplankton biomass and the content of total and organic phosphorus, at n=16, the correlation coefficient was 0.95, showing that the total and organic phosphorus is the determining factor of phytoplankton development. In the future, deterioration of water quality and accelerated eutrophication could be expected. The composition of bacterio-plankton, of a considerable part (41-75%) was associated with suspended particles of the detritus, showing that it has an important role in the decomposition of organic matter.

The content of nitrophilic bacteria, which are indirect indices of nitrofication, varied from 300 to 510 cl/ml. The degree of water quality was estimated on the basis of abiotic and biotic criteria (Winberg, 1981), by using the ecological and sanitary classification of surface water quality proposed by the Institute of Hydrobiology of the Ukrainian Academy of Sciences (UAS) (Zhukhinski et al., 1981). The following water quality variables were assessed: transparency, colour, pH, ammonium content, nitrates, nitrites, mineral phosphorus, oxygen, permanganate, biochromatic oxidization, BOD_5, abundance and biomass of phyto- and zooplankton, bacterioplankton, production and decomposition of organic matter, seasonal p/B coefficients. The results are presented in Table 13.

For comparison, the system proposed by the countries of the former SEA (1977-1982) was also applied, with the following indices: average degree of oxygen saturation, phosphate content, total phosphorus, nitrogen (non-organic and total), saprobic index after Pantle-Buck (1955), with Sladchenko's modification (1967), and additions by Dsubana and C.P. Kusnetsova (1981). The results are presented in Table 14.

Both the Ukrainian Academy of Science (UAS) and SEA classification systems were used to estimate integrally the Muinak Bay water quality, as shown in Table 15.

By the majority of water quality indices, the central sector and the inflow zone of the Muinak Bay is of the 3rd class ("fairly clean"), which corresponds to β-mesosaprobic zone; by the lowest indices, it belongs to 2nd class ("quite clean"), or β–α mesosaprobic zone; by the highest values, to 4th class ("moderately polluted"), or α-mesosaprobic zone.

The water quality in the western deep sector is of the 4th class ("moderately polluted-strongly polluted") or α-mesosaprobic zone; by the lowest indices it would be of 3rd class ("fairly clean") or β–mesosaprobic zone; by the highest indices 5th class ("strongly polluted") or polysaprobic zone (Tables 13-15).

The highest maximal value of indices was obtained for Kusatau-Karakchi and Dzalangash sectors - 5th-β category ("maximum pollution").

The north-western and north-eastern sectors, where the waste waters of the fish-plant discharge into the bay, are of 4th class, and the south-eastern sector of 3rd class; by the lowest index values, water in all sectors would be of 3rd class (Tables 13-15).

In the course of investigations, the lowest water quality indices were obtained in June-September, the peak of deterioration being in June in the upper sectors, July-August in the central sector, and August-September in the lower sector. The water quality was in this period greatly influenced by dissolved oxygen content, mineral phosphorus, ammonium nitrogen. In the upper sectors, these were supplemented by permanganate and bichromate oxidisation.

References

Winberg G.G. (1981): 'Progress in limnology and hydrobiological methods of inland water quality control / *Scientific bases of water quality control by hydrobiological indices*' (in Russian). Gidrometeoizdat. pp 16-65.

Elmuratov A.E. (1981): 'Composition and repartition of the phytoplankton in the southern part of the Aral Sea' (in Russian). Tashkent. *"Fan"*. p.144.

Elmuratov A.E. (1990): 'Ecological aspects of investigating the role of phytoplankton in the formation of quality of the lake- and drainage water in the Priaral region' (in Russian). *Nukus Vestnik KKOANRU.* No.1. pp. 23-30.

Elmuratov A.E. (1995): 'Phytoplankton of the Sudochye Lake in the time of anthropogenic eutrophication' (in Russian). *Proceedings of the Conference "Ecological problems of the Amu-Dar'ya basin in Central Asia".* Bukhara. pp. 95-98.

Elmuratov A.E., Sagidullaev N.S. (1992): 'Successions of algae and bacteria in the residual lakes of the Aral Sea and their role in the productivity of the water bodies' (in Russian). Nukus. *Vestnik KKOANRU.* No.1. pp.15-23.

Zhukinski. V.N., Oksiok O.P., Oleynik G.N., Koshleva. S.I. (1981): 'Principles and experience of setting up an ecological classification of quality of inland surface water' (in Russian). *Journal of Hydrobiology Vol. 17. Kiev* No.2. pp.38-49.

Kazakhbaev S.K. (1988): 'Present status of the zooplankton of Sudochye lake / *Structure of hydrobionta communities in the Amu-Dar'ya plain*' (in Russian). Tashkent. pp.29-38.

Oksiok O.P., Zhuravleva L.A., Lishenko A.B., Bashmakova I.H., Karpezo Y.U.I., Ivanov A.I. (1992): 'Water quality characteristics of the Ukrainian reach of the Danube' (by general indices) (in Russian). *Journal of Hydrobiology. Vol.28. Kiev* No.6. pp.3-11.

Pantle K., Buck H. (1955): 'Die biologische Uberwachung der Gewasser und die Darstellung der Ergebnisse'. *Gas und Wasserfach.* 96. p. 604.

Sladacek V. (1986): 'Diatoms as indicators of organic pollution'. *Acta hydrochimica et hydrobiologica.*14.5. pp. 555-556.

Meyer F.P., Burkley L.A. (editors) (1990): 'Water quality standards charts' (modified from ERA. 1986). in *Field Manual for the Investigation of Fish Kills.* US Dept. of the Interior. Fish and Wildlife Service. Res.publ. 177. p.120.

Table 1. Abundance and biomass of Muinak Bay bacterioplankton

Month of sampling	Total number of bacteria	Biomass	Number of heterotrophs 10^6 cells/ml		Heterotrophs %	
	10^6 cells/ml	g/m³	RPA	RPA/10	RPA	RPA/10
1992						
V	1.20	0.57	136	1005	0.011	0.024
VI	1.17	0.59	220	1708	0.020	0.065
VII	1.91	1.08	180	1403	0.006	0.040
VIII	1.73	0.86	196	1320	0.017	0.109
IX	2.00	1.34	265	1530	0.014	0.095
X	1.80	0.87	175	1080	0.009	0.102
XI	1.05	0.37	98	766	0.007	0.024
XII	0.20	0.19	40	395	0.003	0.009
Average p.a.	1.53	0.88	167	1176	0.011	0.064
1993						
I	0.18	0.34	41	230	0.003	0.023
III	0.95	0.43	105	500	0.017	0.031
IV	1.28	0.67	270	1300	0.024	0.052
V	1.52	1.02	284	1609	0.031	0.095
VI	2.65	1.40	153	1800	0.019	0.109
VII	2.44	1.08	106	1315	0.013	0.135
VIII	1.36	0.93	292	1300	0.015	0.160
IX	1.88	0.87	93	1107	0.013	0.160
X	1.66	0.69	200	1470	0.017	0.068
XI	1.07	0.75	170	864	0.020	0.057
XII	0.13	0.26	52	370	0.007	0.015
Average p.a.	1.49	0.68	163	1168	0.015	0.079
1994						
I	0.42	0.61	58	475	0.003	0.012
II	1.47	0.82	61	850	0.009	0.030
III	1.70	0.72	118	670	0.042	0.034
IV	1.36	0.70	167	1240	0.007	0.064
V	2.20	1.05	600	1750	0.061	0.038
VI	2.24	0.98	209	890	0.014	-
VII	4.81	1.70	295	1670	0.013	0.032
VIII	2.26	1.15	327	1724	0.018	0.040
IX	2.02	1.40	580	1155	0.024	0.035
X	2.17	1.03	590	1443	0.015	0.103
XI	1.55	0.90	217	1505	0.012	0.010
XII	1.08	0.40	74	854	0.005	0.009
Average p.a.	1.80	0.88	264	1098	0.077	0.036
1995						
I	0.57	0.38	85	453	0.008	0.009
II	0.13	0.30	103	621	0.011	0.014
III	0.80	0.52	104	385	0.016	0.025
IV	1.05	0.69	265	1002	0.023	0.060
V	1.40	1.01	309	1114	0.012	0.103
VI	1.52	1.10	197	1305	0.024	0.650
VII	3.00	1.24	173	1330	0.018	0.900
VIII	3.79	1.39	220	1340	0.025	0.149
IX	1.98	0.95	108	1169	0.017	0.152
X	1.07	0.70	205	1026	0.017	0.094
Average p.a.	1.53	0.83	177	975	0.017	0.076

Table 2. Abundance of bacteria (mln cells/ml) in different sectors of Muinak Bay

Place of sampling	1992	1993	1994	1995
South-east	0.54-8.03	0.76-6.80	0.48-7.16	0.69-6.44
	4.58	*3.15*	*4.70*	*4.06*
Glavmiaso canal mouth	1.02-2.65	1.33-2.57	1.19-3.70	0.90-4.17
	1.45	*2.10*	*2.31*	*3.00*
North-east	1.10-10.63	1.40-4.08	1.27-9.52	1.40-10.75
	6.24	*2.65*	*5.40*	*6.30*
Central	0.40-4.44	0.90-4.56	0.83-5.77	0.78-5.03
	2.69	*2.42*	*3.07*	*2.96*
Northern	1.45-8.10	1.27-9.97	1.19-7.87	3.00-8.10
	4.06	*6.01*	*4.91*	*5.67*
Western	0.93-7.00	1.09-6.69	1.20-5.98	1.30-6.54
	2.05	*3.07*	*3.15*	*4.00*
Kusatau-Karakchi	1.33-3.76	1.28-11.00	1.50-7.91	1.95-10.30
	5.35	*6.13*	*4.30*	*6.11*
Dzalangash Islands	1.17-8.65	1.21-9.85	1.39-10.20	1.80-14.65
	4.04	*5.19*	*6.28*	*8.37*

Table 3. Phytoplankton taxonomy in Muinak Bay

Types of algae	South-east	North-east	Mouth zone	Central	Dzalan-gash	Kusatau Karakchi	Uchsay	North-west
Cyanophyta	61	70	49	103	150	146	135	67
Chrysophyta	2	3	-	3	3	-	2	-
Bacillariophyta	127	139	130	143	200	205	208	138
Xanthophyta	2	-	-	2	-	-	1	-
Dinophyta	14	17	13	20	28	26	20	14
Euglenophyta	6	12	7	10	21	22	18	5
Chlorophyta	64	77	58	75	124	103	105	39
Rhodophyta	1	2	-	3	1	-	-	-
Total	277	320	257	359	527	512	488	273

Table 4. Seasonal dynamics of the phytoplankton floristic composition

Types of algae	Number of species				
	Spring	Summer	Autumn	Winter	Total
Cyanophyta	65	151	136	40	160
Chrysophyta	3	-	2	3	3
Bacillariophyta	190	200	204	138	227
Xanthophyta	-	2	1	-	2
Dinophyta	22	34	27	10	37
Euglenophyta	5	25	13	2	25
Chlorophyta	67	134	108	26	135
Rhodophyta	2	3	3	-	4
West	356	549	494	219	593

Table 5. Abundance of dominating phytoplankton species in million cl/m^3

Species	Saprob indic.	1992	1993	1994	1995
Merismopedia tenuissima Lemm.	b-a	2805	2000	6170	5780
Microcystis aeruginosa Kutz.	a	138	700	1950	2030
Oscillatoria limosa Ag.	a-b	1505	2067	4399	6400
Oscillatoria princeps Vauch.	a	1300	1565	2720	1850
Oscillatoria irrigua (Kutz.) Gom.	a	3270	4090	6645	10300
Oscillatoria terebriformis (Ag.) Elenk		4270	6090	8500	5140
Lyngbya confervoides Ag.	b	1403	1650	2500	2000
Lyngbya aestuarii (Mert.) Liem	b	1100	1800	3088	1700
Melosira moniliformis (O.Mull) Ag.	b	750	2280	2530	3040
Melosira granulata (Ehr.) Ralfs.	b	1100	1800	796	1450
Stephanodiscus hantzschii Grun.	b-a	700	495	850	1005
Tabellaria fenestrata (Lyngb.) Kutz.	b-a	9977	1060	2160	1768
Diatoma elongatum (Lyngb.) Ag.	b-o	1420	785	700	1200
Fragillaria crotenensis Kitt.	o-b	758	1600	2350	2680
Fragillaria capucina Desm.	o-b	893	1070	1320	1705
Synedra ulna (Nitzsch.) Ehr.	b	490	362	702	500
Synedra rumpens Kutz.	a	1380	1803	2269	2500
Synedra rumpens var. *familaris* (Kutz.) Cr.	a	785	1330	1895	800
Cocconeis placentula var. *euglypta* (Ehr.) Cl.	b	1060	1280	2100	2300
Achnanthes lanceolata (Breb.) Grun.	x-b	703	637	452	1005
Amphiprora paludosa W.Sm.	o-b	540	300	145	80
Epithemia turgiba (Ehr.) O.Mull.	o	500	375	406	645
Rhopalodia gibba (Ehr.) O.Mull.	o	472	205	373	407
Bacillaria paradoxa Gmel.	b	1205	1801	2360	1500
Cymatopleura solea (Breb.) W.Sm.	b-a	569	773	1005	676
Nitzschia vermicularis (Kutz.) Grun.	b	300	805	1060	1205
Euglena caudata Huber	p-a	60	37	80	103
Euglena oxyuris Schumarda	p-a	7	12	10	25
Carteria caudata	p	1090	755	1300	1540
Chlamydomonas ehrenbergii Goroch	a	1425	640	1300	2000
Scenedesmus quadricauda (Turp) Breb.	b	7260	3630	10150	8900
Cladophora fracta (Vach.) Kutz.	b	105	92	109	170

Table 6. Distribution of average monthly phytoplankton biomass (g/m³) in Muinak Bay at depth of 0-0.4 m

	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
South-east	1992	-	-	-	-	-	2.30	2.70	2.64	2.80	0.72	0.38	0.17
	1993	0.64	0.09	0.31	0.73	1.52	4.03	3.00	5.90	4.20	3.20	1.65	0.62
	1994	0.17	0.36	0.95	0.70	1.80	3.094	5.25	5.00	5.54	3.01	1.90	1.77
	1995	0.52	0.44	0.80	1.20	1.63	5.40	6.03	5.90	7.11	-	-	-
Glavmiaso canal mouth	1992	-	-	-	-	-	1.70	3.41	6.00	3.70	0.90	0.72	0.11
	1993	0.78	0.60	0.74	0.86	1.67	2.09	2.50	3.70	3.91	1.50	1.49	0.20
	1994	0.45	0.69	0.63	1.27	2.00	3.90	4.62	4.18	4.00	1.07	0.91	0.80
	1995	0.26	0.37	0.85	3.05	3.38	7.49	7.03	5.00	8.20	-	-	-
North-east	1992	1.82	3.36	4.50	4.03	7.50	9.11	20.20	37.40	31.60	6.48	2.87	2.00
	1993	3.01	3.75	4.00	5.12	8.08	11.43	17.65	45.05	37.61	7.03	2.93	3.02
	1994	3.47	5.90	6.67	8.40	10.09	15.70	26.06	58.64	41.02	18.65	4.00	3.64
	1995	2.08	1.62	3.49	6.70	13.11	18.50	34.65	42.10	33.75	20.03	-	-
Dzalangash	1993	0.03	0.32	0.24	3.80	7.02	14.76	58.04	97.86	89.80	13.50	4.16	1.47
	1994	0.28	1.94	1.70	6.35	9.70	20.35	61.52	93.07	77.13	28.05	6.00	0.99
	1995	0.17	0.52	0.30	5.70	10.56	32.41	75.03	80.93	65.70	35.80	-	-
Kusatau-Karakchi spawning ground	1993	0.02	0.08	0.65	2.79	9.75	11.40	32.06	79.06	90.80	54.56	2.00	0.70
	1994	0.15	0.13	1.00	3.65	13.40	33.54	65.05	99.88	94.15	30.21	5.65	0.93
	1995	0.10	0.18	0.62	5.07	20.65	62.32	104.70	36.15	80.70	38.44	-	-
Central	1992	0.93	2.60	2.79	1.35	3.54	7.63	9.14	7.00	13.40	5.31	3.85	3.00
	1993	1.08	0.76	2.86	1.92	3.40	9.01	12.50	14.06	11.70	7.50	6.40	3.71
	1994	2.00	3.28	2.03	2.48	4.35	10.91	15.26	19.00	20.56	15.09	10.03	6.45
	1995	4.69	2.70	3.50	5.00	3.78	7.52	9.19	15.35	-	-	-	-
Uchsay settlement	1993	2.35	2.60	2.89	3.74	7.20	18.02	24.80	17.90	30.50	10.09	5.68	2.00
	1994	2.67	3.10	3.44	6.05	8.01	16.51	63.35	40.50	52.03	14.25	7.30	4.09
	1995	0.80	0.64	1.30	4.52	10.58	25.30	105.70	96.43	103.80	-	-	-
Western	1993	1.77	1.06	2.59	2.80	7.44	6.33	15.41	9.66	9.00	7.30	5.65	1.18
	1994	1.03	1.02	2.18	5.23	5.80	14.70	21.63	28.05	33.08	11.02	7.24	1.69
	1995	0.71	2.43	1.94	3.09	8.03	20.30	36.90	34.73	-	-	-	-

Table 7. Distribution of saprobic indicator species in the bay

Saprobity level	South-east	North-east	Mouth zone	Central	Dzalan-gash	Kusatau Karakchi	Uchsay	North-west	West
x. x-o	8	3	10	6	-	-	2	-	-
o	26	17	31	24	20	16	16	18	20
o-b. b-o	64	80	56	109	126	130	122	67	61
b	75	90	43	142	144	142	124	70	90
a-b-a	7	12	4	7	22	25	19	18	18
p. p-a	-	4	-	1	5	7	5	3	1
Total	180	196	144	200	317	320	288	176	190
% of indicator species out of total number of species									
	65.0	61.3	61.3	50.7	60.2	62.0	59.0	64.5	68.6

Table 8. Saprobic indices of the phytoplankton biomass in Muinak Bay

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
South-east	1.0	1.0	1.1	1.6	1.7	1.5	1.4	1.8	1.9	1.3	1.4	1.3
North-east	1.8	1.7	2.0	2.3	2.0	2.0	2.6	2.7	2.6	1.9	2.0	1.6
Mouth zone	0.8	1.3	1.2	1.0	1.5	1.4	1.4	1.6	1.9	1.8	1.3	1.3
Central	2.0	2.2	2.3	2.7	2.7	1.9	2.8	2.8	2.6	2.5	2.5	2.2
Dzalangash	2.0	2.1	1.9	2.0	2.4	2.8	2.9	4.0	4.0	3.8	3.6	3.5
Kusatau-Karakchi spawning ground	2.3	2.3	2.4	2.5	3.0	4.0	4.7	4.0	3.8	3.6	3.6	3.5
Uchsay	2.0	2.1	2.0	2.3	2.3	2.4	2.5	2.6	2.5	2.3	2.6	1.0
North-west	1.9	2.3	2.2	2.4	2.7	2.7	2.0	2.4	2.8	2.6	2.0	2.5
West	2.0	2.1	2.0	2.1	1.9	2.4	2.5	2.5	2.0	2.3	2.1	1.8

Table 9. Dominant complex of the Muinak Bay zooplankton

Species	Spring	Summer	Autumn	Winter
Synchaeta sp., sp.	31500	1726	2280	1408
Lecane (M.) lamellata (Daday)	240	867	4152	85
Colurella adriatica Ehrenberg	674	19638	570	57
Brachionus quadridentatus (Herm.)	1625	769	3807	300
Brachionus g. hypha lomyros	4520	2867	3005	103
Brachionus g. brevispinus	40230	1085	998	114
Alona rectangula (G. Sars)	307	253	492	63
Chydorus sphaericus	1023	510	768	45
Paracyclopus fimbriatus	18272	1091	1306	500
Microcyclops sp.	2145	437	250	34
Microcyclops leuckarti (Claus)	18500	1165	740	105
Harpacticoida sp.	985	152	220	74

Table 10. Weighted average biomass (g/m³) of zooplankton in Muinak Bay

Year	Season	South-east	North-east	Central	Kusata Karakchi	Northern	North-west	West
1992	Spring	10.52	7.20	5.00	13.28	0.08	3.05	2.45
	Summer	2.93	4.04	2.72	6.19	3.32	4.60	2.73
	Autumn	33.14	18.85	5.24	9.56	12.05	15.28	24.09
1993	Spring	5.00	1.23	1.07	6.03	1.38	0.94	0.50
	Summer	9.45	3.90	2.65	1.87	2.09	6.53	3.71
	Autumn	10.76	13.02	5.18	16.54	6.25	9.65	8.03
1994	Spring	2.70	3.67	0.73	0.80	0.14	0.20	3.79
	Summer	1.93	2.00	1.95	4.00	2.80	1.55	2.16
	Autumn	2.06	3.90	5.00	2.65	1.47	2.07	7.00
	Winter	0.08	0.24	0.17	0.02	0.01	0.02	0.19
1995	Spring	0.17	4.60	0.62	1.20	0.73	0.46	0.32
	Summer	26.40	32.91	1.10	11.63	3.40	1.65	1.05
	Autumn	12.63	9.55	0.38	2.19	1.07	1.03	0.97

Table 11. Variation of the Pantle-Buck saprobic index in the Muinak Bay

	Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
South-east	1992	-	-	-	-	2.10	-	2.40	2.34	1.95	-	-	-
	1993	-	1.86	-	1.70	2.37	2.10	2.12	2.30	2.39	1.94	2.03	1.80
	1994	1.75	1.73	2.00	1.91	1.80	2.30	2.09	2.15	2.20	2.14	1.85	1.97
	1995	1.32	1.50	1.80	2.35	2.41	2.50	2.60	2.00	2.35	-	-	-
Mouth of the Glavmiaso canal	1992	-	-	-	-	2.03	-	1.95	1.67	2.03	-	-	-
	1993	1.78	2.01	1.80	-	2.50	2.34	2.43	1.65	2.01	1.72	2.03	2.05
	1994	2.14	2.20	1.93	1.78	1.80	1.66	1.64	1.85	1.80	1.74	1.67	1.49
	1995	1.60	1.86	2.07	1.95	2.06	1.92	2.02	1.60	2.44	2.17	-	-
North-east	1992	-	-	-	-	2.19	2.60	2.25	2.38	2.41	-	-	-
	1993	2.17	-	2.30	2.40	2.28	2.23	2.57	2.52	2.48	2.60	2.09	2.12
	1994	1.95	1.97	2.06	2.46	2.50	2.60	2.58	2.55	2.59	2.59	2.48	2.30
	1995	2.25	2.06	2.39	2.34	2.45	2.52	2.68	2.94	2.40	2.38	-	-
Dzalangash	1993	-	-	-	2.30	2.35	-	2.60	2.61	2.59	2.48	2.45	2.48
	1994	2.03	2.00	2.10	2.13	2.10	2.58	2.60	2.60	2.57	2.59	2.55	2.53
	1995	1.78	1.66	2.08	2.65	2.70	2.70	2.79	2.55	2.80	2.40	-	-
Kusatau-Karakchi spawning ground	1993	2.40	2.40	2.39	2.35	2.40	2.42	2.55	2.53	2.57	2.48	2.50	2.54
	1994	2.36	2.20	2.40	2.37	2.35	2.60	2.58	2.61	2.59	2.57	2.58	2.50
	1995	2.37	2.41	2.53	2.29	2.70	2.49	2.38	2.80	2.83	2.65	-	-
Central	1992	-	-	-	-	2.01	-	2.15	2.09	2.26	-	-	-
	1993	1.80	1.75	1.78	1.91	1.90	1.80	1.90	2.17	2.30	2.17	2.15	2.10
	1994	1.94	2.00	1.91	1.95	2.03	1.77	2.00	2.09	2.03	2.01	1.93	1.91
	1995	2.00	2.17	2.35	2.50	2.53	2.00	1.99	1.85	2.15	2.24	-	-
Uchsay settlement	1993	-	1.96	1.98	2.05	2.09	-	2.18	2.24	2.16	2.09	2.15	-
	1994	2.02	2.17	2.05	2.40	2.35	2.50	2.58	2.37	2.50	2.43	2.40	2.42
Western	1992	-					-	1.86	2.00	1.90	-	-	-
	1993	1.79	1.78	1.69	1.73	1.85	1.80	1.88	2.06	2.17	1.93	1.90	1.78
	1994	2.00	1.80	1.77	1.92	1.98	2.07	2.05	1.94	1.98	1.86	1.83	1.85
	1995	1.92	2.30	2.07	2.47	2.15	1.93	2.17	2.03	2.11	2.05	-	-

Table 12. Monthly average values of daily production and decomposition of organic matter (gO_2/m^2, at depth of 0-3 m)

Station	m.	P	D	P/D	Station	m.	P	D	P/D
				1992					
North-east	IV	0.07	0.35	0.15	Kusatau-Karakchi	V	0.05	0.74	0.18
	VI	2.50	2.73	0.97		VI	2.17	3.00	0.75
	VII	3.00	3.62	1.11		VII	2.55	3.10	0.92
	IX	1.03	1.36	0.83		IX	2.00	2.73	0.81
Central	IV	0.90	1.80	0.45	Dzalangash	III	0.03	0.59	0.28
	VI	4.72	4.60	0.92		VI	2.61	3.17	1.20
	VII	7.69	5.26	1.30		IX	1.72	2.25	0.65
	IX	3.46	4.79	1.03		X	0.49	1.03	0.38
				1993					
North-east	V	2.00	3.36	0.84	Kusatau-Karakchi	V	0.13	0.69	0.28
	VI	3.42	3.60	0.96		VI	1.35	2.03	1.00
	VII	4.60	4.26	1.35		VII	1.82	2.15	1.07
	IX	1.18	3.94	0.80		IX	0.64	2.00	1.30
	X	0.70	1.43	0.49		X	0.20	1.34	0.45
Central	V	2.65	2.52	0.93	Dzalangash	V	0.47	1.43	0.49
	VI	5.07	4.13	1.18		VI	2.52	2.65	0.36
	VII	8.62	5.79	1.35		VII	2.64	2.80	0.49
	IX	3.80	3.70	1.42		IX	0.79	1.72	0.53
	X	0.82	1.59	0.98		X	0.09	0.94	0.13
				1994					
North-east	I	0.03	0.65	0.55	Kusatau-Karakchi	II	0.01	0.33	0.28
	II	0.03	0.58	0.49		III	0.05	0.60	0.70
	III	0.07	1.27	0.75		V	1.85	2.00	0.95
	IV	0.63	1.80	0.98		VI	3.09	3.46	1.10
	VI	3.72	3.63	1.03		X	2.00	2.45	0.84
	VII	4.60	3.82	1.40	Dzalangash	II	0.03	0.41	0.76
	IX	2.41	2.55	0.94		III	0.03	0.80	1.13
	XII	0.16	1.70	0.62		V	2.62	2.13	1.44
Central	II	0.95	1.04	0.70		VI	3.00	3.30	1.31
	III	0.82	1.26	0.63		VIII	2.46	3.18	1.07
	V	3.88	4.00	1.00		X	1.32	2.00	0.80
	VI	6.20	5.65	1.98	West	II	0.04	0.17	0.35
	VII	8.15	3.80	2.50		V	2.96	1.82	1.19
	VIII	5.30	4.39	1.44		VI	6.72	4.30	2.05
	IX	3.49	4.06	1.09		VII	8.03	3.17	2.20
	X	2.86	3.13	0.78		VIII	6.14	4.42	2.00
	XI	2.05	2.48	0.60		IX	4.35	4.60	0.74
	XII	1.14	2.26	0.59		X	2.53	3.08	0.80
						XI	1.90	2.15	0.65
						XII	0.77	1.42	0.80
				1995					
North-east	I	0.08	0.11	0.05	Kusatau-Karakchi	V	6.83	2.95	3.00
	II	0.11	0.17	0.07		VI	6.50	3.54	2.52
	III	0.19	0.22	0.13		VII	5.94	4.80	1.98
	IV	0.75	1.10	0.32		IX	5.06	4.87	0.20
	V	3.04	2.30	1.28	Dzalangash	V	7.02	3.07	4.90
	VI	4.18	3.75	1.40		VI	7.10	5.13	2.03
	VII	6.00	4.27	1.16		VII	5.49	4.95	0.64
	VIII	4.50	5.03	0.92		VIII	5.03	5.64	0.61
	IX	3.62	4.00	1.03		IX	4.94	5.70	0.76
Central	IV	2.70	1.18	0.75	West	I	0.15	0.39	0.14
	V	4.53	2.64	1.80		III	0.38	0.67	0.32
	VI	6.80	4.00	2.01		VI	6.00	3.23	2.80
	VII	5.47	5.27	0.23		VII	5.98	3.54	3.08
	VIII	5.06	4.53	0.48		VIII	5.67	4.18	1.62
	IX	3.54	4.05	0.49		IX	4.40	5.06	1.13

Table 13. Ecological-sanitary water quality classification Muinak Bay 1992-1995

Indicator values	Indic. number	Average rank indicator	Category of water quality	Saprobity zone	Water quality class
From Kusatau-Karakchi to Dzalangash Island					
Minimal	16	2.90	(2a) "very clean"	β-oligosap-robe	clean
Dominating	24	5.00	(3a-3b) "clean enough"	β–α-mesosap-robe	satisfactory clean
Maximal	16	6.75	(5a-5b) "temp clean polluted"	α–α-mesosap-robe	polluted
South and North-east section					
Minimal	16	1.86	(2a) "very clean"	β-oligosap-robe	clean
Dominating	24	4.60	(3a-3b) "clean enough"	α–β-mesosap-robe	satisfactory clean
Maximal	16	6.10	(4a) "temp polluted"	α–α-mesosap-robe	polluted
Central and West section					
Minimal	16	1.85	(2a-2b) "quite clean"	β-oligosap-robe	clean
Dominating	24	4.10	(3a) "clean enough"	β-mesosap-robe	satisfactory clean
Maximal	16	5.90	(4a) "temp polluted"	α–α-mesosap-robe	polluted
The whole Water Body					
Minimal	16	1.90	(2a) "very clean"	β-oligosap-robe	clean
Dominating	24	4.80	(3a) "clean enough"	β-mesosap-robe	satisfactory clean
Maximal	16	6.20	(4a-4b) "temp polluted"	α–α-mesosap-robe	polluted

Table 14. Water quality estimation after SEA classification Muinak Bay 1992-1995

	O_2 mg/l	PO mg/l	BO mg/l	PO_2 mg/l	P_{gen}	gen. mg/l
1. Mouth zone and South-east	5.0	5.0	2.5	3.6	5.0	3.5
2. North-east and Uchsay settlement	3.0	2.5	3.6	6.0	4.3	3.6
3. Central and Western zone	4.0	2.5	3.6	5.0	4.0	3.5
4. Kusatau-Karakchi	3.0	2.5	4.5	6.7	5.0	3.6
5. The whole reservoir	4.0	2.5	3.8	5.7	4.3	3.5

Average ball	Quality class	Bacterioplankton		Phytoplankton		Zooplankton	
		numb. mln/ml	Biom. g/m³	Pantle-Buck	Class	Pantle-Buck	Class
1. 4.0	3.0	3.0	3.2	1.85	3.0	1.65	3.0
2. 4.5	4.0	3.0	3.2	1.87	4.5	1.70	4.5
3. 4.0	3.0	3.2	3.2	1.85	3.0	1.80	3.0
4. 4.8	5.0	3.2	3.2	1.90	5.0	1.75	5.0
5. 4.5	3.0	3.2	3.2	1.87	4.0	1.73	4.0

Table 15. Integral estimation of water quality and sanitary situation Muinak Bay, vegetation period, 1992-1995

Classification system	Index values	Number of parameters	Average rank of SEA classification	Saprobity zone	Quality class	Trophic level
Kusatau-Karakchi and Dzalangash Island						
Institute of Hydrobiology, Ukrainian Academy of Sciences	Minimum	16	2.90	oligosaprobic	slightly	mesotrophic
	Dominant	24	5.00	mesosaprobic	satisfactory, clean	slightly eutrophic
	Maximum	16	6.75	mesosaprobic	considerably polluted	strongly eutrophic
Central and Western Section						
	Minimum	16	1.85	oligo-saprobic	clean	oligotrophic
	Dominant	24	4.10	meso-saprobic	satisfactory	mesotrophic
	Maximum	16	5.90	meso-saprobic	clean polluted	slightly eutrophic
SEA	Dominant and maximum	15	3.50	meso-saprobic	considerably polluted	strongly eutrophic

HYDROBIOLOGY, MICROBIOLOGY AND TOXICOLOGY OF SHALLOW RESERVOIRS IN THE ARAL SEA REGION

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Consumptive water withdrawal, industrial and agricultural pollution of water and hydraulic engineering development in Central Asia have radically changed the hydrological, hydrochemical and hydrobiological regimes in the lower reaches of the Amu-Dar'ya and Syr-Dar'ya rivers and delta areas. The resulting changes of the aquatic ecosystems and landscapes are reflected in the biota – the totality of biocenoses, which react to autochthonous chemical influences by quantitative and taxonomic changes.

Investigations were conducted during the very dry year 1989, the wet years 1990-1994 and the dry year 1995. The five main reservoirs of the Amu-Dar'ya delta, being fed in different ways, were monitored till 1993, whereas in 1993-1995 two reservoirs – Mezhdurechye and Muinak – were studied in detail, both of these being important for drinking-water supply and fishery. The Tuyamuyun hydropower storage reservoir was also investigated, in order to obtain local background data, for the sake of comparison.

In the course of the wet period, the volume of some delta reservoirs almost doubled, causing dambreaks and flow into the Aral Sea. The average depth of water in the studied reservoirs was between 0.5 to 1.5 metres, with an area of 100-200 km^2. The Muinak Bay and Mezhdurechye reservoirs are fed from the Amu-Dar'ya. Water is stagnant in Muinak Bay, with seepage of excess water only during floods; in the northern part of Mezhdurechye the water slowly circulates, while it is stagnant in the rest of it, overgrown with half-immersed macrophytes. Only about 20% of the surface area of Mezhdurechye is free of growth. The water temperature varies with the season, within a range of 30°C (from 0.6°C in January to 31°C in July). Dissolved oxygen content is around 4.4-10.6 mg/dm^3, BOD - 0.72-2.88 mg/dm^3. Total salinity is around 0.6-4.7 g/dm^3, depending upon the season and water discharge. The water is not suitable for drinking, but the mineralization does not exceed the critical levels for fresh water flora and fauna. The total hardness exceeds the drinking water standards (9.0 to 28.1 mmol/dm^3). Major ions are sodium group type 2 in Muinak Bay, calcium-sodium group type 3 in Mezhdurechye, and chlorine-hydrocarbon-sulphate class in both reservoirs. Classification after Alekiu [10].

Hydrobiological investigations were made by non-traditional methods, some were new in the region, such as the reverse (soft) filtration through nuclear-pore filters, with pore diameter of 1 to 2 microns and filter surface diameter 82 mm, allowing to capture fine particles, down to the nanoplankton range. The phytoplankton quantity units were selected depending on the possibility of identification at different morphological levels (separate cells, colonial entities, cenobii, trichomes). The

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[5] Institute of Water Problems
[6] Institute for Pisciculture

biomass of diatom algae (Bacillariophyta) with a cell diameter over 10 μm was determined by the volume of photosynthetic active plasma close to the boundary. The phyto-plankton carbon content was determined by using the transfer coefficients of Strathman, Bermann and Pollinger [1,2]. Concurrently with the visual determination of the periphytic composition, the abundance (numerical frequency of occurrence) was determined by a microscope scale. By adding up these indices for each taxonomic group, the relative importance of the taxons in the biocenoses periphyton was evaluated. The saprobic index by Pantle-Buck [3] was supplemented by the regional biotic periphyton index (BPI) of Talskikh [4]. The BPI varied from (10-9) for the very clean background reservoirs in the mountain zone, to (2-1) of the polysaprobic reservoirs. Moreover, in describing the periphytic communities, the average geometric product of cumulative abundances (determined by the microscope scale) was used to present integrally the importance of each taxon, or entire biocenoses. The characteristics of ecological invariant states of the periphyton ecosystems were represented by letters (from background to degraded ones (A,a, B,b)).

Most significant for primary production is the phytoplankton size group over 2 μ, i.e. over the upper limit of nanoplankton. Though the phytoplankton taxonomy in Muinak Bay and Mezhdurechye reservoirs is very close, other bio-indicators show that the saprobic and trophic status of Muinak Bay is worse. In the summer of 1993-1995, Muinak Bay was eutrophic-mesotrophic, with saprobic index 3.1, while Mezhdurechye was mesotrophic, with saprobic index 2.1-2.9. In the autumn, both reservoirs were mesotrophic, with saprobic indices 2.3 and 1.5-1.8, respectively. The trophic and saprobic status becomes worse near the exits and stagnant parts of the reservoirs. In parts of the reservoir with flowing water, the resuspension of fine deposits containing microphytobentos makes it difficult to classify the degree of organic pollution. 120 taxons could be determined in both reservoirs, including:

Bacillariophyta	over 40
Cyanophyta	- 25
Chlorophyta	20
Pyrrnophyta	10
Euglenophyta	2

The number of identified species was by 10-15 less in Mezhdurechye than in Muinak Bay. The dominant communities are Bacillariophyta-Cyanophyta in the Summer and Autumn, and Bacillariophyta in the Spring. The surveys in May 1993 and April 1995 have shown very weak development of phytoplankton (only 26 varieties, of which 15 Bacillariophyta). In the Spring, indicator species could be used only in Muinak Bay, of a general beta-meso-saprobic status with a saprobic index 1.7-2.2. By the abundance criteria, i.e. the biomass expressed in carbon content, over 300 mg/m^3, the reservoirs could be classified as mesotrophic-eutrotrophic. In the Summer of 1989, blooming of chlorophytae was observed in the Sarbas reservoir, with signs of dystrophy (polysaprobic species, eutrophication). In the Summer and Autumn, all the reservoirs of the Southern Aral were eutrophic, according to the Thunmark index (abundance ratio of Protococcales versus Desmidiales), as well as the Nygaard index (abundance ratio of the sum of Cyanophyta, Protococcales, Centrales and Euglenophyta, versus the Desmidiales).

Phytoplankton indices differed greatly in the dry year 1989 and the subsequent wet period, and again in the dry year 1995. In 1989, the microalgae concentrations considerably exceeded the fishery standards (910 g/m^3). The phytoplankton quantity was, in the 1990s, generally lower and fluctuated from practically zero (April, May), to 90 million specimens (July), biomass up to 15 g/m^3, carbon content – up to 1.8 g/m^3. Maxima were noted in Muinak Bay, which was entirely eutrophic, with phytocenoses down to the bottom. Phytoplankton was absent in the inflow reach of Mezhdurechye, because of the high silt content. In wet years, the rising water levels from Spring to

Summer did not permit the algae to invade the whole reservoir. Thus, the phytoplankton development is inversely proportional to the annual runoff volume. The biomass and carbon content decreased with increasing Pyrrnophyta development. In Spring, "clean water" phytoplankton was usually observed, with an increase in Summer of saprobic and trophic indices, and a general abundance of species. Besides the massively observed non-toxic species (*Merismopedia* and *Gomphosphaeria*), toxic species were also present (*Anabaena variabilis, Nodularia spumigena, Aphanizomenon flos-aqua*), and species such as *Microcystis aeruginosa* developed in large quantities at some places.

As the reservoirs are very shallow, vertical stratification is insignificant. Appreciable temperature gradients near the bottom could be observed only in deep parts of Mezhdurechye. In the flat-bottomed Muinak Bay, the thermocline either coincided with the top of the sludge layer, or was entirely absent. In deep reaches of Mezhdurechye, the biomass substantially decreased at depths 2-3 times that of the thermocline. In such cases, the thermo- and picnoclines were below the lower limit of the eutrophic layer. The biomass decreases insignificantly in the upper, quasi-homogeneous layer. In Muinak Bay, maxima of gross and primary production were observed at depths of 0.5-1.0 metres. Decomposition was the most intensive at a depth of 1.5 metres. The ratio of gross primary production versus decomposition varied between 1.96 to 7.18, so that the reservoir could be considered as eutrophic. In Mezhdurechye, the surface layer was investigated only, with a daily gross primary production of 0.2 mgO_2/dm^3 and decomposition 2.2 mgO_2/dm^3. Their ratio was less than unity, indicating the absence of organic pollution in the investigation period.

The storage reservoir of the Tuyamuyun hydropower plant was monitored in 1994-1995, in order to obtain local background data. The reservoir levels fluctuate very strongly and the shore line is not well constituted. No seasonal difference in species variation could be detected. About 60 species were identified. It is interesting to note the presence of Chrysophyta algae, which could not be found in the reservoirs at the lower river reaches. They substitute here the two species of Euglenophyta algae, observed in Mezhdurechye and Muinak Bay. Rare species, such as *Dinobrium sertularia* (Chrysophyta) or *Ceratium hirudinella* and *Prorocentrum obtusum* (Pyrrnophyta), were not detected in the water bodies investigated, from the foothills down to the reservoirs.

In July and October 1993, the taxonomy and abundance of zooplankton in both Mezhdurechye and Muinak Bay were investigated. Altogether 20 species were identified, half of which Rotatoria, 8 - Cladocera and 3 - Copepoda. The quantity of macro-zooplankton amounted to 2.1-10.1 thousand specimen per m^3, with the maximum in the free part of Mezhdurechye. In numbers, the most abundant were Rotatoria (1-6 thousand specimen per m^3. With regard to biomass, the relative importance of groups was different: Copepoda – 10-200 mg/m^3, Cladocera – 4-40 mg/m^3, and Rotatoria – 2-7 mg/m^3. These results prove that the trophic status is moderate and the nutrient supply for fish is medium developed. The protozoic microplankton, which was observed in parallel with the phytoplankton, was mainly represented by infusoria, less frequently by flagellata, alpha-meso, and at massive growth, by polysaprobes. The significant development of heterotrophic nanoplankton gives evidence of a well developed nutrient base for this kind of pico-producers.

The periphytic communities were studied regularly from 1993 to 1995 in the reservoirs Mezhdurechye and Muinak Bay, the connecting canal Glavmyaso, as well as in the Tuyamuyun hydropower storage reservoir (chosen to provide the local background level). Moreover, periphyton samples collected in 1990-1991 in the same reservoirs, as well as in the Sarbas storage reservoir, in the West Ramitan collector drain, and the Amu-Dar'ya river downstream from the Tuyamuyun barrage, were also analyzed. Thus, for 1990-1995, in the above-mentioned water bodies, 389 taxons of the following species were identified:

Bacillariophyta	254	Xantophyta	2
Cyanophyta	78	Chrysophyta	1
Chlorophyta	47	Pyrrnophyta	1
Euglenophyta	6		

The domination of bacillariophyta in the Aral Sea algae flora was thus confirmed, followed by cyanophyta and chlorophyta. The high diversity confirms the favourable conditions for periphytic development in all reservoirs. For instance, the observed species and algae varied in the following range:

Water body	**Summer**	**Autumn**	**Spring**
Tuyamuyun Reservoir	45-51	41-72	49-58
Mezhdurechye	55-91	40-68	82-98
Muynak Bay	84-109	39-48	77-91
Sarbas Reservoir	64	57	
Amu-Dar'ya (1)	76		
Amu-Dar'ya (2)	36		

(1) close to the Tuyamuyun barrage
(2) increases

In the water bodies Amu-Dar'ya, Glavmyaso and West Ramitan, due to higher water turbidity, the periphytic taxonomy is less developed than in the lacustrine ones (Tuyamuyun, Mezhdurechye, Muinak Bay and Sarbas). The decrease of diversity and quantity of Cyanophyta and Chlorophyta in the Autumn and Spring, confirms the seasonal character of successions in the Aral region and Central Asia.

The spatial distribution of growth in the water bodies is non-uniform: at different measuring points, the same species may be dominant, sub-dominant, or barely present. This is particularly so in the littoral zone, of which some parts are overgrown, others free from algae, some reaches are shallow, others deep, with very different flow conditions, thermic regimes, and other micro-conditions. Thus, the general conditions, spatial and temporal trends at the observed points and water bodies, need to be described by average values.

The periphytic diversity increases almost two-fold in the sequence Tuyamuyun – Mezhdurechye – Muinak Bay, with 1230, 225 and 244 taxons, respectively. In the same sequence, there are also increases in diversity of Cyanophyta (Chrolocoreales, Anabaenaceae, Oscillatoraceae), Chlorophyta plankton (Protococcales) and thready colonial algae (Fig. 1), showing the increasing trophic levels of the water bodies. The same finding could also be confirmed visually: the water colour changes from green-blue to brown-green, the thickness of silt deposit increases, with an increasing content of detritus, the water has an transient marsh-sludge or hydrogen sulphate smell, diatoms of the species of *Rhopalodia, Epithemia, Amphipleura* – which are typical for the accumulation of plant detritus – markedly develop in the periphyton. Moreover, the sequence Tuyamuyun–Mezhdurechye–Muinak Bay marks the progressive development of brackish-water kinds of diatoms, from the species of *Synedra, Navicula, Nitschia, Mastogloia, Amphora, Amphiprora, Pleurosigma, Tropidoneis, Campylodiscus*, etc.

The water bodies investigated do not differ as regards organic pollution. Seasonal and multi-annual variations of saprobic index (SI) values remain within the limits of beta-mesosaprobic zone (Fig.2). Nevertheless, the highest SI values are found in

Mezhdurechye near to the Shege settlement and towards the exit reach, confirming the higher degree of organic pollution at these reaches.

The fresh-salty/halophylic (FS/HP) index, which reflects the ratio between fresh water-saltish water species and halophil-brackish water diatom species, decreases in the ecological sequence Tuyamuyun – Mezhdurechye – Muinak Bay. This index has high values in the fresh water where the run-off is generated. For example, in the moderately polluted water bodies which were chosen as the regional background level for anthropogenic pollution, these values approach 10.0, and the halophil complex is about 9% of the algae.

The mean values and respective percentages found in the different water bodies are as below:

Water body	FS/HP	%	BPI
Tuyamuyun	3.29	26	5-6
Amu-Dar'ya			4.5
Mezhdurechye	1.99	33.9	4-4.5 (mainly 4.5)
Muinak Bay	1.17	48.2	4-4.5 (mainly 4)
Sarbas	1.68	36.8	4
Glavmyaso	0.47	68	4
West Ramitan	0.8	53.7	4

The table reflects the gradual increase of water salinity, in the same order. The integral estimation of water quality is indicated by the biotical periphyton index (BPI). The decrease in BPI shows the change of taxonomy of the periphytic communities, in accordance with the increasing level of pollution (mineralization, secondary pollution processes, etc.).

Fig.3 shows the change of water quality and ecological status of the investigated water bodies. It can be concluded that Tuyamuyun and Amu-Dar'ya, which provide the local background level, are moderately polluted and can be considered as having a satisfactory ecological status, in conformity with the regional background level for the anthropogenic zone.

The water quality and ecological status of Mezhdurechye can be classified as transitional, whereas Muinak Bay, Sarbas, Glavmyaso and West Ramitan belong to polluted waters. In these water bodies, the taxonomy of periphytic communities changes significantly as compared to the local and regional background levels (degradation of the initial biocenoses): their ecological status is unsatisfactory.

The macro-zoo-benthos of the Aral region was investigated from 1993 to 1995, in the water bodies of Mezhdurechye, Muinak Bay, Glavmyaso Canal, and the reservoirs of Tuyamuyun Hydropower plant – Kaparas and the river reach of the Tuyamuyun storage reservoir. Altogether 76 species were identified:

Insects - 60 species
Crustacea (*Paramysis* and *Palaemon*) - 3 species
Arachinida (*Aranei* and *Hydracarina*) - 2 species
Mollusca - 5 species
Oligochaeta - 7 species

The most diverse group of insects is the Chironomidae larvae. Coleoptera fauna is represented by 9 species. Other groups are less diverse – Ephemeroptera, Trichophera, Odonata, Diptera about 3-4 species in each group. Most typical at different points are Heteroptera of *Sigara limitata*, Chironomidae of *Cladotany tarsus*, *Polypedium*, and also *Paramisis lacustris*.

The largest number of species (50) was recorded from 11 groups, mainly of phytophil benthofauna. The number of species at different points in the bay varied from 12-17 in the Spring, to 16-30 in Summer; the abundance of organisms varied between 400-950 specimen/m^2 in Spring and 300-1900 specimen/m^2 in Summer, and the corresponding biomass between 3.2-7.3 and 1.9-6.3 g/m^2, respectively. The higher upper limits in Summer are due to better feeding conditions and higher trophic levels, owing to the warming up of the water in the reservoir. Here, in the Spring, 4 m. deep profundal samples, taken from the stagnant part of the Bay, have given evidence of 10 species from 4 systems groups, with abundance of 416 specimen/m^2 and biomass 0.49 g/m^3. These values are high for benthofauna of silty deposit profundals, which – together with the well developed coastal zoobenthos – shows how favourable are the conditions for living organisms in the Muinak Bay.

In the Mezhdurechye reservoir, 27 species of macrobenthos organisms were recorded. In the Summer of 1994 the diversity fluctuated within the limit of 10-15 species, with 6 species observed in the coastal silt profundal; in Spring 1995, less than 9 species were found near the coast and only 2 in the stagnant part of the Bay. The abrupt drop of quantitative indices (2-3 times) was not observed in the North-Western part of the Bay, around the inlet of the Marinkin Canal where, due to the abundant presence of *Paramysis*, the total abundance and biomass remain high. These changes can be related to the progressive eutrophication of the Mezhdurechye Reservoir, accumulation of carbon dioxide in the deposits, and toxic products of biochemical decomposition of the detritus.

The rocky coastal soils of the Tuyamuyun Reservoir are the least colonized, owing to the unsteady water level fluctuations in the course of the operations of the hydroelectric plant. Only 15 species were found here during the whole investigation period. At certain points, in Summer and in Spring, only 3-4 species were identified, with an abundance of 15-30 specimen/m^2 and biomass 0.11-2.4 g/m^2. The higher biomass in Spring 1995 is explained by the presence in the sample of large shrimps of *Palaemon* genus.

The Chironomidae larvae dominate at most observation points; in a number of cases, however, it is the *Paramysis* which dominate. As regards to biomass, the *Paramysis* are the most important in the phytophil biocenoses – Odanata larvae, Mollusca, Coleoptera. Quantitative indicators mostly correlate well with the qualitative diversity of the biocenoses, and in all seasons, the decreasing order Muinak Bay–Mezhdurechye–Tuyamuyun is maintained. Planktonic communities are comparatively weakly colonized in the stagnant areas of Mezhdurechye.

The benthos communities in the Glavmyaso Canal are moderate in both qualitative and quantitative aspects, and comprise mainly brackish water species of different systems groups.

Four ecological indicator groups were selected for water quality assessment: brackish water, phytophil, polysaprobic and eurybiontal (neutral) species groups. The quantitative ratios of species from the above groups indicate the dominant influence of certain conditions and to estimate the extent and character of pollution in the investigated water bodies and bed layers. Making use of this method, and also of our modification of the Budywiss biotic index, it could be established that from sanitary and ecological points of view, the best waters are those of the Tuyamuyun reservoirs, with water quality class III-III-IV. The Mezhdurechye Reservoir is moderately polluted, with water quality near the shore changing gradually from the north-western end (inflow of the Marinkin Canal) towards the outlet of the Glavmyaso canal, from class III-IV to III-IV-IV, respectively, and IV-V in profundal of stagnant zones. The Muinak Bay is exposed to organic pollution and heavy mineralization. From the north-western and eastern dike, the water quality changes from class III-IV-IV to III-IV. In the Glavmyaso canal, water quality belongs to class III-IV.

The macrobenthos investigations have shown that conditions for aquatic life are generally favourable, except in the Mezhdurechye Reservoir, where the benthic organisms suffer from the toxic products of biochemical decomposition of plant detritus in the sludge deposits. This has been confirmed by the degradation of benthic communities in 1995, as compared to 1994.

Immersed vegetation growth was observed only in the Mezhdurechye Reservoir and Muinak Bay and is represented by seven species: *Najas marini, Ceratophylum demersum, Potamogeton crispus, Potamogeton pectinatus, Potamogeton perfoliatus, Myriophyllum* and *Chara* sp.

While in the Mezhdurechye Reservoir only feeble growth of *Najas marina* was observed on the dark-gray clay deposits around the Glavmyaso Canal outflow, macrophytes were well developed in the Muinak Bay, covering vast areas in its shallow zone. Vegetation begins in early April, flowering of the majority of *Potamogeton, Myriophyllum* and *Ceratophyllum* species was in June-August. The last ones are widely distributed up to 3 metres depth.

Of the half-immersed plants, *Phragmites* and *Carex* sp. are widely distributed. Owing to their biological features, *Phragmites* grow fast along the coast of the Muinak Bay, and from April till June create populations of different importance, from sparse growths, to 10-15 metres wide, dense strips. Thus, the main vegetation cover in Muinak Bay is *Phragmites communis* and *Ceratophyllum demersum*. All species found in Muinak Bay are of high ecological valence and indicators of significant mineralization.

Bacteria play a very important role in reservoir biology of the arid realm, as the surplus of bio-energy activates micro-biological processes of the transformation of organic matter. The water bodies are rich in stable organic matter, because the oxygen content often exceeds the biological oxygen demand (BOD). As regards the ratio of easily oxydisable organic matter to the stable one, the reservoirs of Mezhdurechye and Muinak are eutrophic (35-98% of the ratio of full BOD vs. oxydisability). The productivity of the water bodies is determined by the general abundance, biomass, cell sizes, rate of bacterial reproduction and bacteriacenosis. The quantity of bacteria varied from 0.6 to 2.6 millions of cells/ml, indicating the mesotrophic type of the studied reservoirs. The trophic index of the shallow water bodies was over 4, which indicates moderate organic pollution. Only around the entry into Muinak Bay, the index becomes 2. In the Glavmyaso Canal, the abundance of bacteria is about the same as in the Amu-Dar'ya 0.1-0.2 millions of cells/ml. A useful index for the estimation of water quality is the ratio between saprophytes and total number of bacteria, in the group of heterotrophic bacteria. According to this criterion, the water in Mezhdurechye is moderately clean (the said ratio being 0.11-0.13), in the Glavmyaso Canal and Muinak Bay - polluted (0.23-0.43). In river waters depleted by organisms, cocco-form and in Muinak Bay, bacillus-form bacteria dominate. The same is confirmed by the size of bacteria cells, the larger ones correspond to higher organic pollution of the water (Muinak Bay). The specific breathing intensity (0.12-0.42 mg/dm^3 per day), oxygen demand of microbe population and microbe destruction, the contribution of which to the total BOD is 47-90%, give evidence of the increase of organic pollution from Mezhdurechye to Muinak Bay, and high bioactivity of bacteria-plankton, in general. By considering the destruction, the bacteria-plankton was found to be the key component of the ecosystem, influencing the hydro-chemical regime. The coefficient of heterotrophic activity is defined as the ratio of oxygen demand of bacteria after 24 hours incubation in samples with added organic matter, to the oxygen demand in samples without added organic matter. This coefficient increased from Mezhdurechye (1.3) to Muinak Bay (5.0). Very often, the higher coefficients coincided with high BOD_5 and oxidability values. By these criteria, the waters could be considered as moderately polluted. The efficiency of the use of energy assimilated by the bacteria, for bacteria production by volume was from 3-61%, with maximum in the stream and minimum in the stagnant water.

The decline of fishery in the water bodies of the Aral basin is due to many reasons (collapse of economy plan, communication breakdown between parts of the former USSR, etc.), among which is the allochtonous pollution of the aquatic ecosystem of the middle and downstream reaches of the rivers. The pollution of water bodies got out of control. Certain biogenic elements, such as phosphorus, ammonium ions, are at the limits of permissible concentration of the sanitary/hygienic, as well as fishery standards, and some biogenic elements exceeded these standards several times. So, the content of nitrite ions exceeded the limit for fishery 2.8 times, iron 28 times, etc.

Heavy metal pollution of the ecosystem exceeded sanitary and fishery standards several times, for instance copper in Muinak Bay 6 times, in Mezhdurechye 9 times, zinc in Mezhdurechye 3 times, manganese in Mezhdurechye 2.5 times, chrome in Muinak Bay 11 times and in Mezhdurechye 16 times; oil products in Muinak Bay 10-50 times and in Mezhdurechye 10-90 times; phenols – around the background concentration. Accordingly, the investigated water bodies do not satisfy the fishery standards.

Special attention was paid to the study of pesticide accumulation, being of particular risk, owing to their excessive use in Uzbekistan, exceeding global standards 10 or more times. The scale and volume of pesticides used in the region was considered, the degree of their ecological and sanitary hazard, etc. The pollution level of selected pesticides (α-HCH, Lindanee, DDD, DDT, DDE) was determined in ecosystem components – water, bed deposits, submerged and emerged plants, seston, zooplankton, fishes. The study was carried out in a number of large hydrosystems in the region – Arnasay lake system (middle reach of Syr-Dar'ya, within the Aral Sea basin), the Muinak and Mezhdurechye Reservoirs in Karakalpakstan, Tudakul Reservoir (middle reach of Amu-Dar'ya); fish farms Balikchy, Damaschy, Tashrybopitomnik, etc. It was found that the pesticide accumulation capability is different in the various components of the aquatic ecosystems: it accumulates mostly in fish (consumers), followed by bottom deposits, plants, and insignificantly, in seston. This way, pesticides gradually accumulate in the ecosystem components, leading to a spurious self-purification of the water body, with a possible secondary pollution. As regards chlorine-organic pesticides, neither of the two studied reservoirs meets the sanitary and fishery requirements, Mezhdurechye in particular. The pesticide concentration grows from the entry in the water body towards the middle and the exit, indicating the location of pollution sources. DDT proper is dominant among DDT metabolites. Lindane is most often found and all its isomers are present in almost equal parts. These findings show recent applications of DDT, in spite of the fact that its use has been forbidden for a long time. The level of pollution by phosphorous organic pesticides is not alarming. Long-living chlorine-organic pesticides in the organs of fish, especially predators, exceed the permissible levels. For instance, in the fat of pike DDT was observed (1.6 MPL - maximum permissible limit), in the fat of chub: lindane (1.2 MPL) and DDT (4 MPL), in the muscles DDT (9 MPL); in the fat of Channidae, lindane was present (2.3 MPL) and DDT (2.7 MPL). In Mezhdurechye, in 1993, excessively high concentrations (20 MPL) were found in the muscles of sazan – a species and organ, in which low concentrations would have been expected. High accumulation of pesticides was thus observed in fish fat and muscle tissues, with DDT as the dominant component. The overstepping of MPL standards in all kinds of fish indicates the critical status of the aquatic ecosystems.

The resistance to toxic substances was tested for common carp, silver carp and grass carp, by means of six widely used substances (sulphuric acid, orto-creosol, beef-extract) The analyses were conducted for the main stages of fish ontogenesis. The test-substances were selected according to their practical importance, capability to reflect the main types of ecosystem pollution, and type of action. Fish species resist to toxic substances differently: the most resistant is the common carp, followed by grass carp and silver carp. The ineffective concentrations of polluting substances for early fish ontogenesis were established, which is important for fish farming. Correlation analysis has shown that the quality of fish-offspring depends mainly on the level of pesticide accumulation in the gonads. These data, together with data from the preceding years (influence of the accumulation of pesticides in the livers and gonads on the quality of fish breed), have proved that accumulation of pesticides is most harmful for the ichthyofauna.

The seasonal changes from the cold, physiologically inactive stage, to the active stage in Spring and Summer, bring about an increase of abundance of endogenous hydrobiontes till they reach the climax, and then, a change of the dominant varieties, appearance of extragenous populations, accompanied by a gradual change of the saprobic and trophic status. This pattern is best discernible in the development of plankton algae. The sudden increase of abundance (climax) of a dominant or subdominant variety shows the disruption of stability of the system, which could be a first sign of eutrophication. Usually, this occurs when the biogenic runoff from the land intensifies. The ensuing excess of metabolism products in the area, bacterial decomposition and increased BOD are the signs of secondary pollution. As neooligotrophic-eutrophic succession, which could be caused only by toxic substances or acidification, could not be detected, it could be concluded that the main factor of the general biocenotic status were the increasing eutrophication and mineralization. The latter is especially dangerous, as self-purification can reduce biological pollutants, but not the excess of salts.

In the self-purification processes of ecotopes, ecotone effects on the border of two phases could be observed, such as micro-scale "life compaction" in the form of the unstable film with unsteady activity (at the water-air boundary), and the little-explored bottom sludge biofilm (water-bottom boundary). The ecotone effects may be very important especially when considering macro-scale units, coastal strip (water-land and water-air borders). The bottom film and coastal contact zone are very rich in single-cell and colonial algae, provided they are not destroyed by wind or human activities. The shallowest reaches can be considered as zones of double phase-contact effects, with closely succeeding and almost coinciding water-land and water-air boundaries. In such ecotone-biotopes occurs the maximum possible concentration of micro-organisms and accelerated exchange processes. The decomposition of organic matter in the sludge deposits becomes accelerated by mixing. Overgrowing of the bottom by macrophytes causes disparity between the trophic level and the biogenic content of the bottom deposits.

The data obtained permitted us to ascertain the ecological status of the water bodies, which includes the biocenotic aspect (state of hydrobiontes communities), toxic-ecological aspects (accumulation and migration of pollutants), in interaction with reservoir morphometry and abiotic factors. According to the biocenotic characteristics, the biotop, in general, approaches pasture trophic chains. At one side, at favourable reaches of the water bodies, the highly developed mosaic of micro-biocenoses points to active status of the water body, at the other side, biocenosis uniformity (greater part of Mezhdurechye) indicates the vulnerability of the ecosystem. In general, as compared with the period before the degradation of the delta, significant simplification of the communities can be observed, of their cenotic connections, and food chains from which whole links are missing. The degradation is most evident at the desiccated parts of the Aral Sea, which cannot be considered as lacustrine bays, neither from the evolutionary, nor hydrologic points of views. For instance, on the example of algocenoses, in the last 25-30 years, the quantity of phytoplankton taxons decreased about 6 times (Elmuratov, 1981-88, [7]). The increase of taxonomic diversity which occurred in the nineties, results from the dislodgement of coastal and euryhalin marine varieties by freshwater-brackish water ones, often even by indicators of a higher saprobic and trophic status.

The investigations and bibliographic survey show a very fragmentary knowledge of the periphyton in the Aral Sea region. The general conditions of the water bodies are generally favourable for the development of periphyton communities, as proved by the high taxonometric diversity of water growth at various sampling sites. The main limiting factor of periphyton development is water turbidity at certain reaches.

The spatial succession of the periphyton indicates a progressive mineralization, eutrophication and secondary pollution, in the sequence of water bodies Tuyamuyun – Amu-Dar'ya – Mezhdurechye – Sarbas – Muinak Bay. These processes are reflected in the modification of the taxonometric structure and degradation of the initial periphyton biocenoses, in comparison with the regional background (moderately polluted water bodies of the anthropogenic zone), namely the replacement of the oligotrophic – mesotrophic freshwater algaeflora by eutrophic, brackish water algaeflora. The ecological status of the water bodies in the Aral Sea region is evaluated as transitory or unsatisfactory, and it assumes an intermediate position between the Tuyamuyun storage reservoir and the saline and eutrophic lakes and channels of the drainage system. The macrobenthos research has revealed progressive organic pollution in the Mezhdurechye Reservoir, which requires urgent remedial measures. The oppression of benthos communities may undermine the fodder basis of the ichtyofauna, diminish the fish production and cause economic damage to the region. The findings of the research are graphically summarized in Figures 4 to 11.

References

1. Strathmann R.R. Estimating the organic carbon content of phytoplankton from cell volume to plasma volume//Limnol. oceanogr, 1967, V.1-P.411-418.
2. Bermann T., Pollinger U. Annual and seasonal variation of phytoplankton, chlorophyll and photosynthesis in lake Kinneret // ibid., 1974 -V.9 - P.31-53.
3. Pantle R., Buck H. Die biologische Uberwachung der Gewasser und Darstellung der Ergebnisse // Gas und Wasserfach - 1995-B.96-N.8-S.1-604.
4. Talskikh V.N. Use of biocenosis invariant states conception in ecological monitoring and Pollution rate setting of Central Asia rivers// Ecological modifications and criterions Transactions of International Symposium. L: Hydromet. Izd.:1991, c.163-184.
5. Thunmark S. Zur Soziologie des Susswasserplankton: Eine methodologisch-okologische Studie// Folia Limnol. Scand.-1945-B.Z.-S.1-66.
6. Nygaard G. On the productivity of five Danish waters // Verh. Intern. Vereinig and Limnol.- 1995-V.12-P.123-132.
7. Talskikh V.N. Periphyton community state estimation on bioindication and biotesting of natural waters, Leningrad, Hydrometeoizdat, 1989, 2, c.51-59.
8. Guide on hydrobiological monitoring of fresh-water ecosystems, St. Peterburg, Hydrometeoizdat, 1992, Chapter 2,3; p. 32-104.
9. Elmuratov A.E. Phytoplankton of the southern Aral Sea region, Tashkent, FAN, 1981, 144p.
10. Alekin O.A. Hydrochemistry of the rivers of the USSR., Moscow, Hydrometeoizdat, 1948: 184 pp.

Figure 1. Taxonomic diversity of periphyton

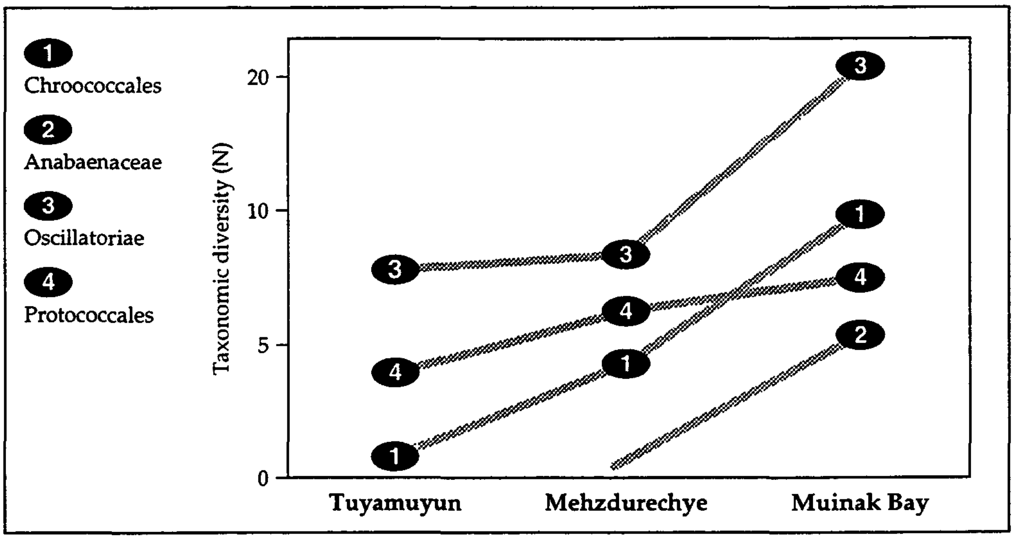


Figure 2. Mean values and range of variation of the saprobic index of the periphyton of different water bodies

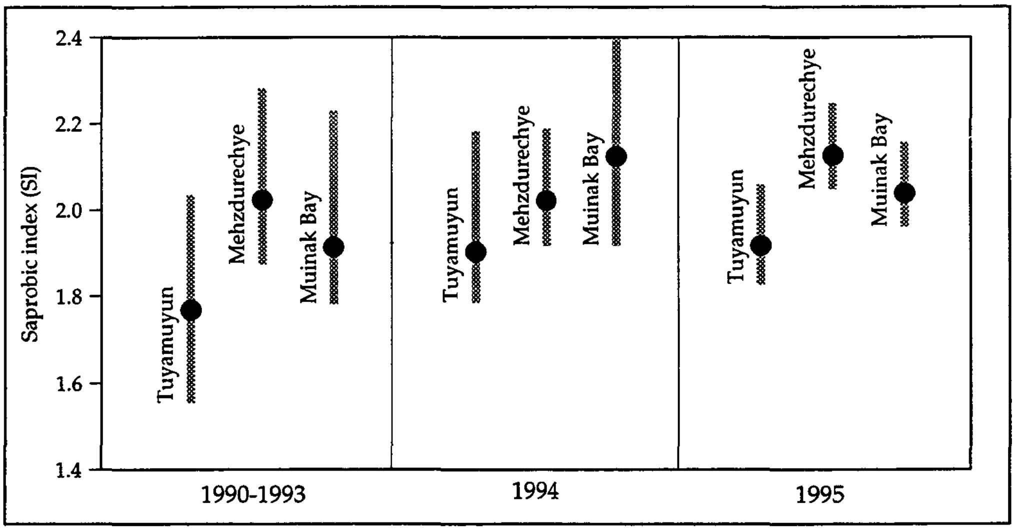


Figure 3. Water quality characteristics and ecological status of water bodies, based on the periphyton indices

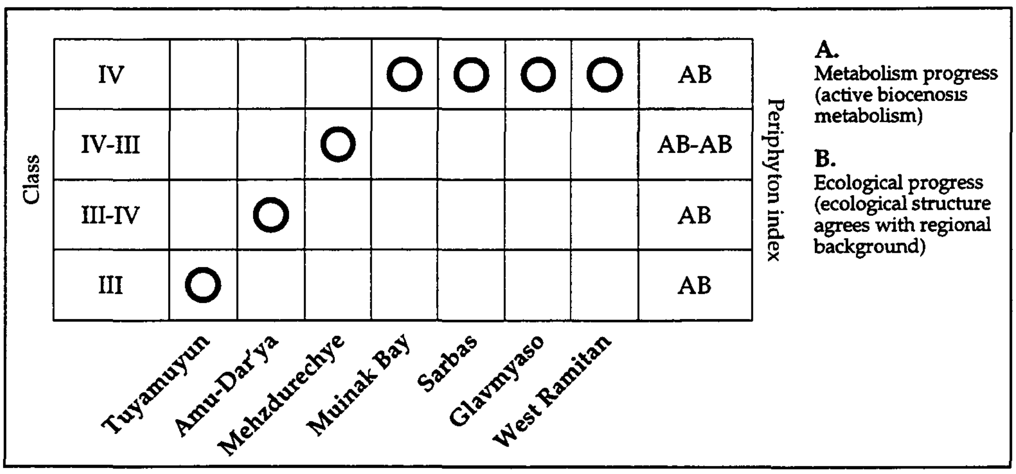


Figure 4. Aral Sea and studied water bodies

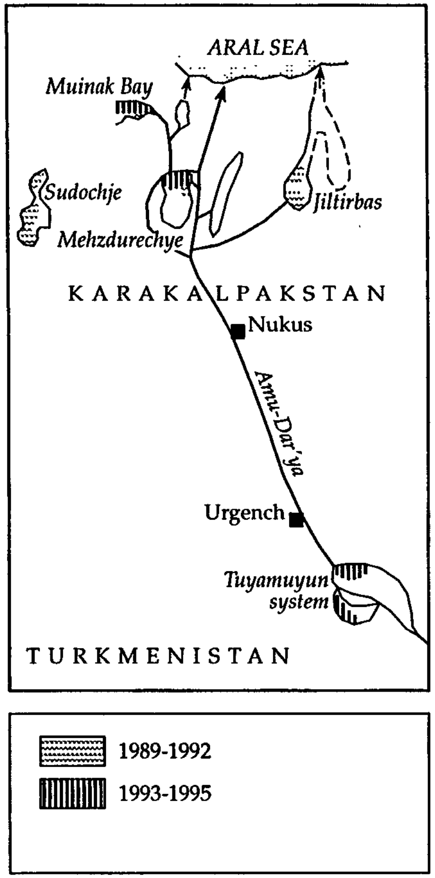


Figure 5. Distribution of organic pollution by phyto-plankton bioindication saprobic level

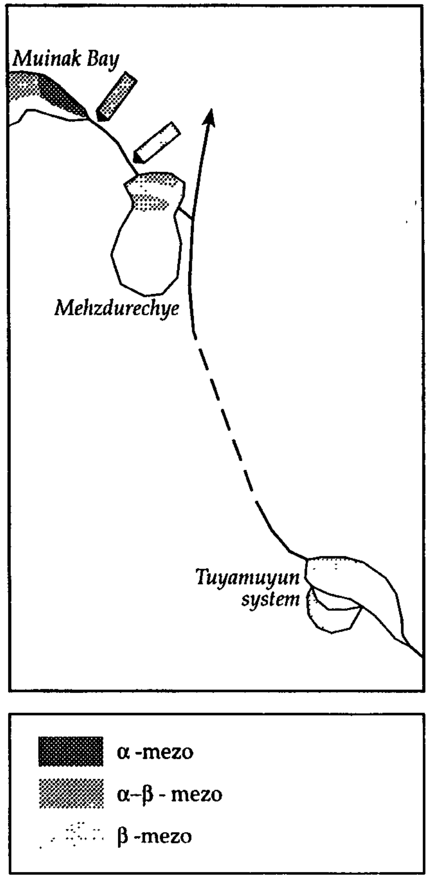


Figure 6. Organic pollution by periphyton bioindication (pollution classes), 1993-1995

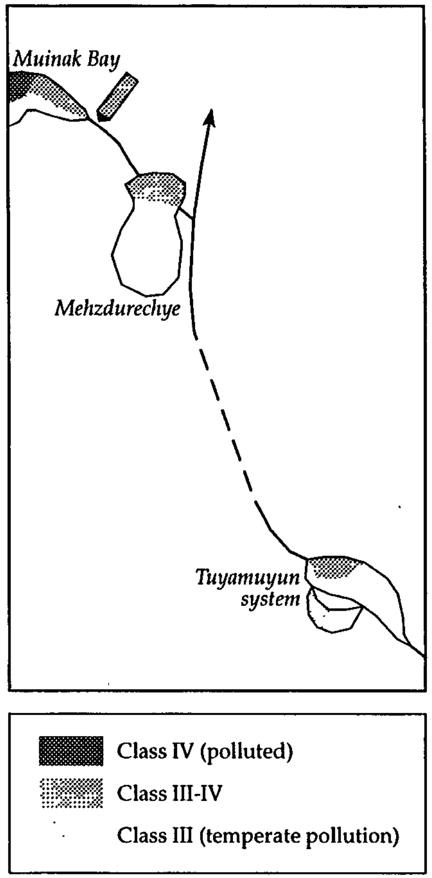


Figure 7. Organic pollution by macrozoobenthos bioindication, 1993-1995

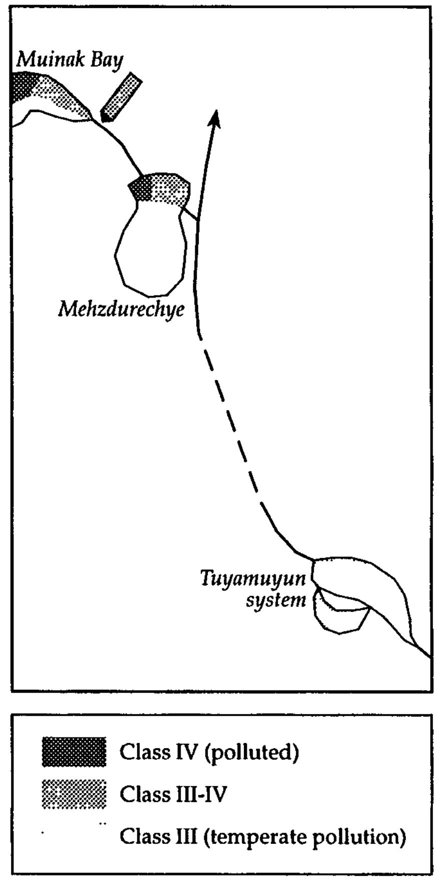


Figure 8. Phytoplankton biomass, 1993-1995

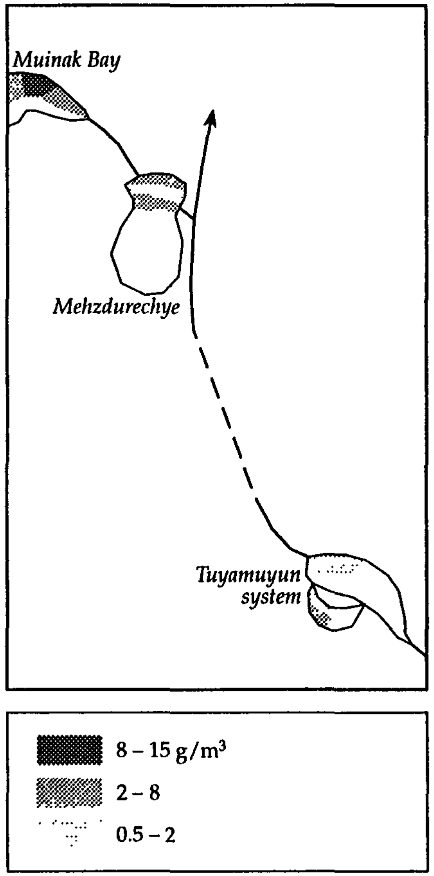


Figure 9. Macrozoobenthos biomass, 1993-1995

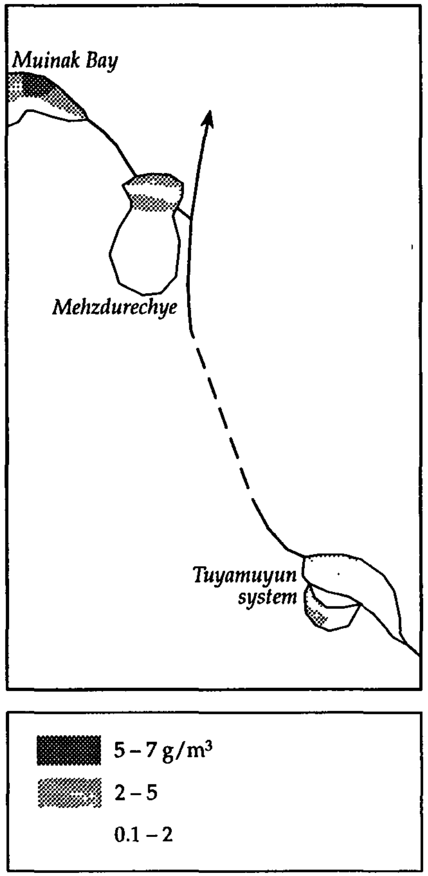


Figure 10. Distribution of mineralization (chemical analyses and bioindication dates), 1993-1995

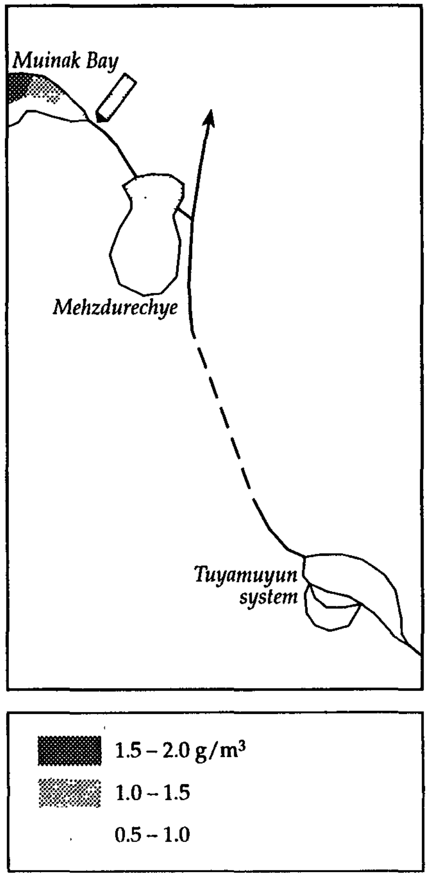
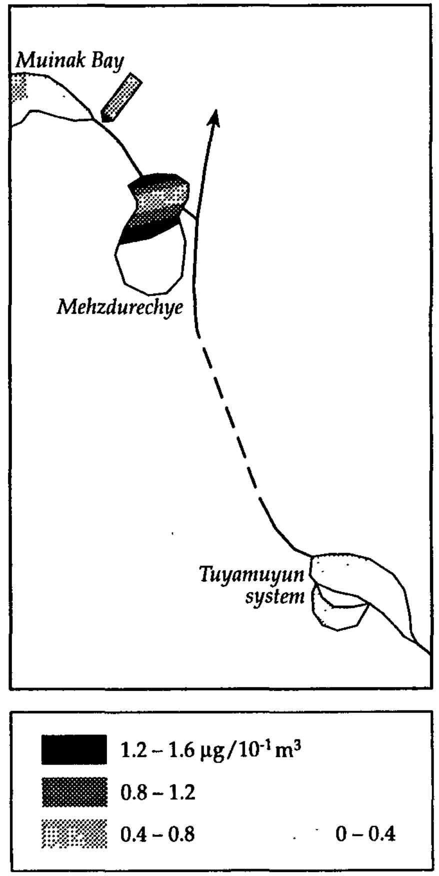


Figure 11. Distribution of chlororganic pesticides (chemical analyses), 1993-1995



Animals of the region

BIOLOGICAL BASES OF FISHERY DEVELOPMENT IN THE WATERBODIES OF THE SOUTHERN ARAL REGION

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Large scale irrigation over the last 25-30 years in Central Asia has greatly affected the landscape of vast territories, modifying the distribution of water resources in the Aral Sea basin and transforming numerous natural reservoirs. New irrigation and drainage infrastructure was built, with storage reservoirs, ponds created by irrigation water overflow, various hydraulic structures for different economic purposes. The anthropogenic impact caused essential changes of the ecosystems, leading to a deep ecological crisis.

The anthropogenic transformation of hydrological and hydrochemical regimes of the Amu-Dar'ya and Syr-Dar'ya had a catastrophic effect on all components of the ecosystem of the Aral Sea and lakes. The biological diversity of autochtone fauna was greatly reduced, impairing the sustainable use of biological resources. The reproduction and growth of fish have been upset, leading to the collapse of the fishing industry in the whole Aral basin. In Karakalpakstan, fishing production diminished ten times, compared with 1960.

The Aral Sea, which was historically the main fishing resource in Karakalpakstan, giving about 95% of all the Uzbek fish-catches, has now lost its significance: its area is shrinking and the water becoming more and more saline. Water salinity is now over 4.2% and all autochtone ichtyofauna has been lost, being entirely composed of fresh-water generative species. From the point of view of biodiversity, the Aral Sea ranked last among saltfish seas of Euroasia (Karpevich, 1975). Although the fish fauna was represented by only 20 species (Fig.1), the Aral fishery was famous for the quality of catches, composed of 10-12 species, mainly carp. Fishtakes reached 50 thousand tons a year. In 1927-1929, acclimatization of fish from other basins was attempted, in order to enrich the Sea fauna and raise the number of catches. In accordance with the planned intensive agricultural land cultivation in the Aral Sea basin in the 1940s, and the anticipated salination of the Sea water, the prevailing direction of the acclimatization measures was the formation of euryhaline salt-resistant fish fauna in the Aral Sea. On the whole, during the period of acclimatisation (1927-1987), 18 species of fish, of 5 families were moved into the Aral Sea. Half of them were brought in accidentally, in the course of the introduction of planned species. However, from the deliberately introduced species only two survived (sprat and flounder glossa), while all the accidental migrants survived. In the 2nd half of the 1980s, along with the rise of sea water salinity over 25‰ of the last autochtone and many newly implanted fish species disappeared from the fish fauna composition. Sea fishery ceased by the end of 1983 (Fig.2). At present, the sea fish population is represented by four species-acclimatizants: flounder glossa, sprat, smelt and monkey goby (Zholdasova and others, 1992; Zholdasova, 1995).

When industrial fishery stopped in the Aral Sea, fish catching in the Southern Aral region was transferred into internal waterbodies – lakes. In 1981-1995, its level reached 1.44-4.36 thousand tons a year, that is 6-18% of former catches in the southern part of the Aral Sea and lakes taken together (in comparison with 1960) (Fig. 3). Fishing was a traditional activity of the lower Amu-Dar'ya population and fish provided the majority of the food. With the collapse of the Aral Sea fishery, a considerable part of the population engaged in fishery and fish processing industry, lost their jobs and the consumption of fish was reduced.

Most actual inland waterbodies of the Southern Aral region, concentrated mainly in the Amu-Dar'ya delta, are historically existent lakes. Among them are the Eastern Karateren, Sudochye, Khojakul-Karajar system, Domalak, Makpalkul, Akhchakul, etc. All of them are well-known from the times when the nature of the Aral region was not affected by anthropogenic transformations, they were fed mainly by the river water, and some of them were connected with the Aral Sea. From the 1970s, new waterbodies were formed by drainage waters from the irrigated fields. Among these are the Sarykamish, Ayazkala, as well as numerous nameless ponds around irrigation outlets.

Since the middle of the 1980s, the number of new waterbodies used for fishery has been increased by artificial waterbodies, created by earth dikes and flooding of the former bays of the dry Aral Sea bottom – Muinak, Sarbas (Rybachye), Ajibay, Jiltirbas. A number of water reservoirs were built (Mejdurechye, Dautkul, etc., Fig.4) for flow regulation of the lower Amu-Dar'ya and improving of the ecological situation. At present, more than 30 waterbodies with a total area of about 200 thousand hectares are used in Karakalpakstan for fishery.

The significance of waterbodies of the lower Amu-Dar'ya for fishery, is not adequate despite their abundance, both because of deficiency of natural possibilities and the quantitative and qualitative regime of inflowing water. From the point of view of economy and ecology, the most interesting waterbodies in the Southern Aral region are the Mejdurechye reservoir, Sarbas-bay, Muinak-bay, lakes Domalak, Makpalkul, Dautkul and others, because they are located in rather densely populated regions with developed fishing and hunting traditions. It is also important that these waterbodies are fed directly by the Amu-Dar'ya waters and thus have better ecological quality than other lakes, which are mainly fed by drainage waters. Thus, relative ecological safety of production is assured. From the above mentioned waterbodies, the Mejdurechye reservoir, Muinak and Sarbas bays (Rybachye) were chosen as the sites of our investigations in Amu-Dar'ya delta zone. The purpose of these investigations is to set up a coherent model of the Aral Sea, the Amu-Dar'ya and Syr-Dar'ya delta ecosystems, in conditions of strong anthropogenic pressure, with the objective of their preservation and restoration. The results of studies conducted in 1993-1995 are presented below.

The Mejdurechye storage reservoir, the Muinak and Sarbas bays are located in the lower Amu-Dar'ya. This region belongs to the arid zone, with markedly continental temperature regimes. The air temperature greatly fluctuates, in the range of about 70°C: the mean temperature of January is -14°C, but sometimes drops to -33°C; the mean temperature in June ranges from +26°C to maximum +45°C. The annual precipitation is 80-100 mm. Frequent north-eastern winds are important factors of the climate in the region, especially in Autumn and Winter, bringing cold air from Siberia (below -38°C). South-western winds prevail in Spring and Summer, bringing sea air from the Atlantic Ocean and the Mediterranean Sea.

The above-mentioned waterbodies receive water from the Amu-Dar'ya river. They are, nevertheless, affected by the drainage waters, since the Amu-Dar'ya itself along its whole length accepts about 10 cubic km of waste waters, with salinity of about 14.2 g/l (Chembarisov, 1989). The Mejdurechye storage reservoir, Muinak and Sarbas bays are artificial waterbodies of lacustrine type, which belong to the Amu-Dar'ya catchment and have an artificially regulated water regime. Mejdurechye reservoir, with an area of 38.7 thousand hectares and water volume of 800 million cubic metres, belongs to the class of great lakes, in accordance with the classification of lakes by their area. The two bays belong to the class of middle-sized lakes, with areas 9.75 and 6.24 thousand hectares and water volumes of 161 and 137 million cubic meter, respectively.

Mejdurechye reservoir is situated between two tributaries of the Amu-Dar'ya – Akdar'ya and Kipchakdar'ya – in a natural depression in which one of the largest tracts of flooded land has been created. Earlier, more than 10 small lakes existed in this depression and river water came there through numerous gaps of the Amu-Dar'ya left bank. At the beginning of the 1960s, the regular inflow of water was discontinued (Rogov and others, 1968) and by 1965, the majority of lakes dried out, with the exception of Shege and Koksu lakes.

In order to provide water to the lakes and hay fields in the adjoining territories, a reservoir was created in 1968, by a temporary earth closure on the Amu-Dar'ya, at Baikhoja. Such closures were constructed many times in the subsequent years (in 1975 – near Baikhoja, in 1978 and 1982 – at Shuak) and they facilitated turning the river flow into the depression. The closure at Shuak still exists at the present time.

The reservoir regime is very unstable. The dikes closing it from the North and North-West were repeatedly washed away (in 1983, 1987, and 1992), with catastrophic consequences for the waterbody: in one month, the reservoir lost half of its water volume into the Amu-Dar'ya. In addition, intensive silting reduced the reservoir volume. During dry years, the water volume retained in the storage reservoir is less than 300-400 million cubic metres.

The Muinak and Sarbas bays are former bays of the Aral Sea, which dried out in the 1970s. In 1979-1980, the Muinak-bay was closed from the western side, with the purpose of expanding irrigation and fishery. Water from the Amu-Dar'ya began to arrive in 1983, through the Mejdurechye storage reservoir – the Glavmiaso canal. The lake, which was formed at the place of the former bay, has, at the western dam, two hydropower facilities which do not operate.

Water inflow into the Sarbas Bay began in 1990, also from Amu-Dar'ya through the Mejdurechye, by the Marinkin canal. The bay is closed by a dam at the nothern side and drains through the Gonchar-uzyak into the Injener-uzyak (a left channel of the Amu-Dar'ya), and further into the Aral Sea. The dam was repeatedly broken through, causing the fall of water levels, and drying out of considerable areas. At present, strengthening of the dam is underway and the construction of a head regulator is coming to an end.

All waterbodies have low banks with a slightly indented shore line, with comparatively shallow depths, not exceeding 2-4 m on the average. Only the depth of the Mejdurechye storage reservoir reaches 5-6 m.

Sediments. The bottom sediments in the waterbodies are black silts with abundant admixture of vegetation remains, subjected to intensive chemical and biochemical processes with high oxygen consumption and, occasionally, formation of hydrogen sulphide. Usually there is no visible oxygen shortage in the lakes, but cases are known when fish died during severe snowy Winters (e.g. in the Winters of 1988-1989 and 1993-1994).

Temperature regime. Temperature is one of the most important development regulators of vertebrate fauna and fish population in the lakes. In consequence of their shallow depths, the waterbodies get warmed through, with maximum temperatures reaching 28-30°C in Summer. Due to constant winds and good mixing, the water warms up evenly in depth, without temperature stratification.

Ice phenomena. As the lakes are located in the zone of markedly continental climate, in Winter they are nearly always covered by ice, the thickness of which reaches 30-40 cm in some years. The ice cover can stay up to 3-3.5 months. According to the classification of O.A. Alekin (1970), the water in lakes is fresh, with salinity in the range of 1-2.4 g/l, and a composition similar to the Amu-Dar'ya water. However, in dry years, considerable areas of waterbodies get dry and salinity at some places increases to 4-5 g/l (Table 1).

Among anions, chlorides and sulphates prevail; among cations – alkaline metals, i.e. the water in the lakes is of chloride-sulphate-sodium type. Calcium and magnesium ions affect the water quality in fishery waterbodies, expressed as the level of total hardness. All natural waters in the lower Amu-Dar'ya region are very hard (11-130 mg-eq/l), except the lakes with river feeding, including the investigated waterbodies, where the water is moderately hard or hard (up to 10.7 mg-eq/l). Sufficient hardness of water is the necessary condition for existence of many hydrobionta, which have a lime skeleton or hard capsule but, at the same time, its high level has an opposite effect to a certain extent (due to the many interlinked factors).

For fishery, the maximum permissible concentrations (MPC) of calcium cations are 180 mg/l, and of magnesium cations – 40 mg/l. The permanent excess of these parameters in our waters is the consequence of drainage water inflow into the Amu-Dar'ya, which was particularly marked in the 1980s. However, they were much lower in the 1990s, owing to the higher runoff in these years.

The surface vegetation in the lakes is dominated by *Phragmites* and *Typha*, occasionally complemented by *Scirpus lacustris, Butomus umbellatus, Salvinia natans, Fagopyrum* water, Polypodaceae (on Kupacs). Underwater vegetation consists of *Charophyta, Myriophyllum, Najas*, several species of *Potamogeton*. The overgrowing of the waterbodies is not equal: most overgrown is the Muinak Bay, where the excessive growth causes waterlogging.

High accumulation of vegetative detritus is observed in the lakes, on account of dying plants, especially in periods of draining and loss of depth of the waterbodies; however, Winter kills were also observed.

As hydrobiological research (phytoplankton, zooplankton, zoobenthos) was the subject of other subprojects, these will not be mentioned here, except by pointing out that from the point of view of zooplankton and zoobenthos, the investigated water bodies are oligo- and mesotrophic, which is important for fishery.

Ecological characteristics of reservoirs and fish-fauna. Although the investigated lakes belong to the same hydrographic net, their ecosystems have their own characteristics, depending upon their mutual positions and relationship to the main water source – the Amu-Dar'ya. The waterbodies differ also by many other abiotical components, development stage and ecosystem stability.

The regulating influence of physical conditions of waterbodies is reflected in the structure and functioning of the biotic components and their communities. This is illustrated by the example of the fish fauna in the Mejdurechye reservoir. In dry years when water levels are low downstream of the Takhiatash dam, the basic ichthyocenose is composed of representatives of the limnophylic complex: carp, pike, roach. On the contrary, in wet years, the fish fauna is dominated by river (rheophylic) species – silver carp, grass carp, and some Aral barbel, but at the same time, components of limnophylic complex (carp, pike, snakehead, sander) are also present. These changes illustrate the strong influence of the Amu-Dar'ya flow on the fish fauna in the Mejdurechye reservoir, which is the largest artificial reservoir in the Southern Aral Sea region.

Lake Sarbas is a young reservoir, created in 1990 on a former bay of the Aral Sea, and fed by river water from Mejdurechye. However, the formation of its own fish population was prevented by a dam break in 1992 in the north-west corner, causing an abrupt drop of water levels and draining of the greater part of the aquatoria and the closure of fish in disjoined shallows. The lake was re-established in 1994 by the construction of the Marinkin feeder canal. In the remaining shallows, overgrown by *Typha* and *Phragmites* around the perimeter of the reservoir, growth of the limnophilic fish complex (carp, goldfish, pike, snakehead) was observed, as well as of silver carp and sander, retained in previous years from Mejdurechye reservoir. This is reflected in the dynamics of marketable catches (Table 2).

More typical lacustrine features are inherent for the fish fauna of Muinak Bay. By fishery criteria, this closed lake with an unstable water regime is of the pike-carp waterbody type. In 1991-1993 (with the best water supply of the whole period of its existence), its fish fauna was dominated by pike, carp and sander. The severe Winter of 1993-1994 and the subsequent decrease in the water supply reduced the number of pike and sander, and increased the number of snakehead and goldfish. Similar fish fauna structure was characteristic for the pioneering stages of lake formation on the place of the former Sea bay in the second half of the 1980s, when the water supply was at its lowest.

Fish fauna

As a whole, the fish fauna of the investigated waterbodies is represented by 36 fish species from 9 families. Most of the species (23) belong to the Cyprinidae family. The other families are represented by 1-3 species (Table 3). The brief biological characteristics of main marketable fish species are given below.

Carp. In the investigated reservoirs, this species is of lake-river form, permanently resides in rivers, channels and lakes, prefers sites with weak current and advanced vegetation. By length and weight structure, the carp population does not differ much in the different reservoirs, with the largest specimens found in Sarbas Bay (Table 4). The fish in catches is from 2 to 6 years old, and 4-5 years old specimens prevail everywhere.

The best growth rate of carp is noted in Sarbas Bay, the worst in Muinak Bay (Table 5).

In all waterbodies, carp reaches sexual maturity in the third-fourth year of life. Males mature one year sooner than females. The highest absolute fecundity parameter of carp was recorded in Sarbas Bay (between 72,200 to 636,000 ova, 284,200 on average). It is lower for the carp from Mejdurechye (from 78,800 to 224,900 ova, 164,900 on average), it is much lower for the carp from Muinak Bay (78,700-106,600 ova, 92,000 on average). Conditions for spawning are favourable in the reservoirs. Carp lay eggs on vegetation, but when the water level drops they may get dried out.

Carp are benthophagic, and nonspecific components prevail in their food in all three waterbodies: vegetative detritus – in the Mejdurechye reservoir and in the Sarbas Bay (up to 54% on weight), macrophytes and vegetative detritus – in Muinak Bay. At the same time high occurence (up to 80-100%) larvae and pupae of chironomids is marked, however their weight importance in the food does not exceed 26% – in Sarbas Bay, and 14 and 19%, in Muinak Bay and Mejdurechye Reservoir, respectively. In Muinak Bay, fish was found in carp's food (up to 10% occurence). Molluscs are present in the food of carp in all three reservoirs, with the highest occurence (up to 67%) in Mejdurechye.

As a whole, the food structure is more diverse for the carp from Muinak Bay (12 food components, in Sarbas – 7, in Mejdurechye – 6). The connection of food spectrum with the fodder base in reservoirs, its qualitative and quantitative development is distinctly visible.

Carp occupy one of the leading places in fishery, the greatest catches being noted in Mejdurechye reservoir (43.6-433.4 tons), the least in Muinak Bay (3.7-22.0 tons).

Sander. This species is presented by sedentary and semi-migratory populations, residing in lakes and in a channel of the Amu-Dar'ya, adjacent to Mejdurechye. It avoids shallow, strongly warmed places. It prefers large waterbodies with large areas and depths, as in Mejdurechye reservoir. Its highest catches were here up to 177.7 tons in 1993. In the mass killing of fish during the severe Winters of 1993-1994, with powerful freezing and high snow cover, a great number of sander was lost, as immediately reflected in the drop of its catches in Mejdurechye (Table 2). The largest sander is found in Mejdurechye reservoir. The rate of its linear growth is high (Table 5). The main source of replenishing sander stocks in lakes is the Amu-Dar'ya, in a channel where its semi-migratory populations spawn. Its juveniles are seen in a chute of Tuyamuyun reservoir on the Amu-Dar'ya. Obviously, the population in lakes is replenished from these sources. Unfortunately, it was impossible to study the spawning of sander in the lakes. Sexual maturity comes in the fourth year of life, but some males matured at the age of 2+. Adult sander feed mainly on goldfish and roach, but eat their own young, too. In the first months of life, their food consists of crustaceans and other invertebrates.

In the structure of market catches, the part played by sander is about 7% in the Mejdurechye reservoir, but in Sarbas and Muinak bays it does not exceed 1% (Fig. 2).

Pike. The number of pike fluctuates strongly. In the dry 1980s their number in the lower Amu-Dar'ya was sharply reduced, but with the approach of a series of wet years at the beginning of the 1990s, it began to thrive again. Thus, in 1990-1994, pike accounted for over 22% of the total catches in the southern Aral Sea area, with the heaviest catches in Sudoche lake and Sarbas and Muinak bays. Of the investigated waterbodies, pike amounted to 25% in Mejdurechye reservoir, significantly less in Sarbas and Muinak bays (5% and 3%, respectively). Both marketable and research catches of pike comprise 3-6 - year old fish, of which up to 70% are four years old (3+). The rate of linear growth of pike is rather high in all reservoirs (Table 5). Sexual maturity arrives in the third year of their life. Pike mainly feed on goldfish and amur goby.

Catfish and asp are valuable marketable fish species, but their numbers were very low: in 1990-1994, they accounted for 0.2% and 0.7%, respectively, of the catch in the three investigated reservoirs. Asp, a semi-migrant kind of fish, normally not settled in lakes, has been found in Mejdurechye reservoir, where it goes in spawning time, more than in the two bays. The catfish in earlier times was not abundant and is now found mainly in Mejdurechye reservoir. It is believed (Zholdasova, Guseva, 1987), that the main reasons which restrain the proliferation of catfish, besides intensive fishing, are a lack of spawning grounds and coverage of the laid eggs by the mobile vegetative detritus in lakes.

Goldfish. This is a prevalent species in the lower Amu-Dar'ya river. In trade statistics it was included earlier in the category of small-sized fish (small fry), together with other minor trade species (rasbor, redeye, ide, white eye and other). However, since 1983, it is listed separately, owing to its appreciable growth in number, on the background of reduced species variety of the aboriginal fish fauna. The goldfish is a tough and undemanding species, capable of surviving in extreme conditions. It has been found in all three water bodies, where it prefers shallow, well warmed sites, with silty bottom and scant vegetation. The dimensions and weight of goldfish are given in Table 4. It is divided into six age groups, of which age groups 3+, 4+ and 5+ prevail in catches. Sexual maturity comes at the age of 2+ to 3+. Females and males are represented in the ratio 2:1 (with some variations). In Muinak Bay, in the initial years of its formation (1985-1986), the ratio of females to males was 4:1. In several reservoirs in the lower reaches of the Amu-Dar'ya ginogenetic populations have also been recorded (Zholdasova, Guseva, 1987).

The goldfish is phytophyl, by manner of reproduction it belongs to portio-spawned fish types. It feeds on algae, seeds of water plants, vegetative detritus and small-sized forms of mosquitoes.

Goldfish make up to 10% of catches, mainly from Sarbas Bay (9.5%), and less – from Mejdurechye reservoir (up to 3%) (Table 2). However, these numbers do not show the real number of goldfish in the reservoirs, as a considerable part is recorded in the category of "small fry". Besides, fishery in Mejdurechye is oriented to larger sized fish, and large cell gill nets are used for fishing.

Silver carp. This species, which is a representative far-eastern fish, appeared in the Mejdurechye reservoir, Sarbas and Muinak bays by self-settling from Amu-Dar'ya and Karakum channel, where young fish, in 1960-1961, was released from the fishery base Karamet-Niyas, along with grass carp and other foreign species. In the lower reaches of the Amu-Dar'ya it was, for the first time, found in 1963 (Ivanov, 1964). Around 1970, silver carp became an important fishery stock and since the middle of that decade it was strongly present in the catches. Since the middle 1980s, it occupies one of the leading places in catches in Karakalpakstan, with 47.7% of total catches in the investigated water bodies. The greatest production of silver carp occurs in the Mejdurechye reservoir and in sites adjacent to the Amu-Dar'ya river channel, and the lowest production has been observed in the Muinak Bay (Table 2).

The length of silver carp varies from 23 cm to 60.9 cm and its weight from 150 g to 3,000 g with an average length of 42.8 cm and an average weight of 1,200 g, most specimens being in the range of 41-48 cm in length and 1,100-1,200 g in weight. The age structure of catches are characterized by the prevalence of two-three year old specimens, which make up more than 80% of the population, while older fishes are few (Table 4). In 1993-1995, the maximum age of silver carp in these waterbodies was about 4 years. In previous years, examples of six-year old fish could also be found. So, in 1988 in a sample of 100 fishes, two specimens of the age of 5+ were noted. According to the observations, the length and weight of fish varies little in the same age group, females being usually bigger than males. According to the calculations, the growth rate of silver carp in the investigated reservoirs is higher than that of the same species in their native environment – the Amur river basin, or in the Dautkul reservoir; it is also higher than the rate of growth in Mejdurechye in previous years (Table 6).

Spawning of silver carp in the lakes was not observed. Replenishment of its population in the lakes of the lower Amu-Dar'ya is wholly carried out at the expense of their progeny carried by currents from the rivers, where this vegetation-eating far-eastern fish successfully spawns (Pavlovskaya, Zholdasova, 1991; Zholdasova, Pavlovskaya, 1995). Silver carp is a well-known phytoplanktophag and the filling up of its intestinum is rather high in all reservoirs. Its main food is blue-green, green and diatoms algae, including a significant part of vegetative detritus. The increasing rates of growth of silver carp in the last years, especially in Sarbas bay and Mejdurechye reservoir (Table 6), show its use as a satisfactory food supply.

Grass carp is also a representative of far-eastern fauna, which simultaneously with the silver carp appeared in the lower reaches of the Amu-Dar'ya and southern Aral Sea (Shamshetov, Sagitov, 1977), owing to self-settling from Karakum canal, downwards on the Amu-Dar'ya. Having successfully multiplied in the Amu-Dar'ya, it became in the 1970s the most numerous of all far-eastern vegetarian fishes. Catching started in 1968 and its most significant catch was recorded in 1979 – 614.3 tons. In the subsequent period, the catches sharply reduced. Its abundance started to increase again in the 1990s. The main stocks of grass carp were located in Mejdurechye reservoir, where its proportion of the 1993 catches was 15% (second place in the catch).

This fish is appreciated for its large sizes, fat and fine meat. The length and weight of marketable grass carp vary from 55.8 cm to 77 cm, and from 2,900g to 6,730g, respectively. Average length is 61.8 cm and average weight – 4,150g. Three-year old fish amount to 89.9% of the population (Table 4). Maximum age of grass carp in the catches in 1993-1995 is 4+ years. However, specimens at the age of 8+ years were also found. The rate of linear growth of grass carp in lower reaches is high and considerably exceeds that in its native environment. An especially high rate of growth is marked in Mejdurechye reservoir in 1993-1995 (Table 7), which demonstrates its good food supply in this waterbody, owing to the intensive growth of water vegetation (*Phragmites, Typha, Myriophyllum, Potamogeton).*

The stocks of grass carp and silver carp, in Mejdurechye and in all lakes in the lower reaches of Amu-Dar'ya, are renewed from the downstream reach of Amu-Dar'ya, where they spawn in the middle reach of the current. The success of reproduction and the productivity of grass carp and silver carp depend on the hydrology of the river and water abundance during the year. The production of both species in the lower Amu-Dar'ya, including Mejdurechye, directly depends on the volumes of runoff below Takhyatash dam. The greatest catches of both species are marked in the years when the flow in the lower reaches of the river was over 10 cubic km (Fig. 3).

The regulation of the Amu-Dar'ya by dams, the reduction and quite often, total absence of flow below the Takhyatash hydro-unit, as for instance in the 1980s and in 1995, restricts the growth of young fishes and abundance of silver carp in lakes connected with the Amu-Dar'ya. As shown in Fig. 3, the catching of these valuable marketable fishes is closely dependent on the hydrological regime of the lower Amu-Dar'ya, and especially, downstream from the Takhyatash Dam.

Therefore, there is a great practical interest in large-scale artificial cultivation of both species in the Mejdurechye reservoir, Sarbas Bay and other water bodies, providing resistant young fishes. Their natural properties satisfy the requirements of growth and feeding of vegeterian fishes. The utilization of vegetation by grass carp will significantly increase the lake productivity. This is confirmed by the high fish production of Sarbas Bay and Mejdurechye Reservoir in 1993, basically on the account of catches of vegetarian fish, 72.9 and 56.5 kg per ha, respectively, as compared with the former 20-25 kg per ha.

Snakehead is also an acclimatized species, brought in by chance and settled in the Amu-Dar'ya and Syr-Dar'ya basins. It is known since 1965 in the lower Amu-Dar'ya, and commercially is recorded since 1968. Abrupt increase of its abundance is noted by 1974 (Guseva, Zholdasova, 1986). In the last decade (with the exception of 1993), snakehead accounted for 20% of the total catches in the water bodies of Karakalpakstan; in the investigated lake systems, it also assumes a leading part of fishery. Snakehead is known as a species which has low requirements as regards the environment. An overgill organ enables it to survive in strained oxygen conditions.

The length of snakehead in catches reaches 70 cm, and its mass – 4 kg, with an average length of 50.1 cm and average mass – 1.5 kg. In the catches, fish with length 45-50 cm and mass 1-1.3 kg prevail. By age structure, it is subdivided into 6 groups, in which the age groups 3+ and 4+ prevail (up to 80%). About 10% of the fish belong to senior groups. The growth rate of snakehead in the investigated water bodies is close to that in the river Amur (Table 8). Some generations, however, had a slower growth rate in the first three years of life, after observations in Muinak Bay and Mejdurechye

Reservoir. As regards feeding, snakehead is a predator – fish-eater. Fish represents about 90% of its meal (Guseva, Zholdasova, 1986). In the food of snakehead, 14 fish species were detected, out of which 9 of commercial importance: carp, sander, grass carp, catfish, snakehead, aral roach, goldfish and others. By weight and frequency of occurrence, aral roach prevails. Of valuable fish species, carp is present with 18% in the snakehead's food, and goldfish of the less valuable ones, with 10.9%. A small part of food is made up of invertebrates (misides, ditiscus, dragonfly larvae and others). Occasionally, frogs and small birds (sparrows) were found in the snakehead's stomach. The sizes of prey-fish in the snakehead's food is in the range of 19-30% of the predator's length. The rate of feeding of this predator is seasonal: at water temperatures below 10°C, it practically stops eating.

The investigations of fish fauna in 1995 in the Aral Sea have shown a fairly stable population of flounder. Significant abundance of this species was recorded, with complex length-mass structure: by size (*l*) from 5 to 35 cm, and by mass (Q) – from 50 to 900 gr. The presence of young fish in the smallcell nets testifies to the spawning of this species and renewal of its stock.

In accordance with the results of these investigations, the authors submitted a proposal to the Association "Karakalpakbalyk" about an industrial-scale pilot test of fishing flounder glossa in the Western basin of the Aral Sea, with details about the timing, sites and tools of fishing, forecasting a catch of not less than 1.5-2 hundred thousand weight of fish for the Winter season 1995-96. The Association "Karakalpakbalyk" accepted this proposal and a short-term pilot campaign was conducted in the zone of Cape Aktumsuk, which confirmed the presence of important stocks of flounder and the efficiency of fishing.

Fish parasitology

The programme has also foreseen parasitological investigations of the fish in Mejdurechye, Sarbas and Muinak bays. 68 parasite species were found in the 17 investigated fish species (pike, roach, black carp, ide, silver carp, asp, aral barbel, bream, rasbor fish, goldfish, carp, catfish, snakehead, sander, perch). The contamination rate reaches 96.5% to 100%. Most abundant are specific Monogenea (28 species), and least abundant are Cocci (1), Mixosporidia (4) and Ciliophora (4 species), from parasitical protozoa. One third of the parasites develop through intermediate hosts.

The investigations have shown a decreased diversity of the fish parasite fauna in the present conditions. In the last 25-30 years, each of the investigated fish species has lost about two-thirds of its parasite species. This process is especially noted in the roach, which lost 23 out of the 28, and in the carp, which lost 20 of the 44 previously recorded parasite species. The acclimatized species lost their original parasito-fauna. Four new parasite species arrived to the Aral together with the grass carp and silver carp. Over 10 parasite species of native fish began to parasite the acclimatized fish species.

In the course of the present investigations no death of fish from these or other diseases was observed. Nevertheless, dangerous parasite species, such as *Eimeria carpelli, Ichthyophtirius multifiliis, Dactylogyrus extensus, Caryophylleus fimbriceps, Bothriocephalus opsarichthydis, Diplostomum spathaceum, Posthodiplostomum cuticola, Raphidascaris acus, Lernaea elegans* and others were also observed in the investigated water bodies. These patogenical parasites may cause fish diseases in appropriate conditions.

Résumé and proposals

The analysis of bio-ecological features of fish has shown the general trend of decreasing abundance and disappearance of the long-cycle aboriginal species (catfish, Aral barbel, asp, etc.) and their replacement by small fry lacustrine forms. The highest development rates were reached by representatives of the limnophilic block, which are phytophyles according to their type of reproduction (goldfish, bream, etc.). Widely spread are species imported from the Far East – plant-eating fishes, snakehead and non-edible species which accompany these. These now occupy prominent places in industrial fishery, replacing the aboriginal species, which were once of high commercial importance.

The ecology of the water bodies and their trophic state is well represented by quality indicators of the fish fauna, their abundance and catches.

The state of marketable fish stocks fully depends on the level of their natural reproduction. In particular, the spawning conditions of most fish species are unstable, due to the unstable hydrological regime. This is reflected in the biological and physiological state of the fish, causing delay in spawning and lengthy resorption processes of unlaid eggs in the gonads of females. Frequent change of water levels causes death of eggs in the vegetation around the shores. Spawning migrations are often interrupted, especially among reophile fish species, mass death of young fish occurs in disconnected ponds, etc.

Poor fodder base forces fish to eat non-typical food, especially in the case of bentophages. Owing to the decrease of species diversity and abundance of Chironomidae (larvae), molluscs and other benthos organisms, many aboriginal fish species became partly predators (carp, roach, sabrefish), or begun to feed intensively on aquatic vegetation and detritus. This is reflected in the lower fatness, slower growth and lesser size of fish in the 1980-90s, as compared to the 1960s.

At the same time, the acclimatized far-eastern species (grass carp, silver carp, bream, etc.) adapted well to the water bodies and acquired stable biological conditions, due to the abundant food supply. For instance, silver carp mainly feeds on phytoplankton, which is abundant in the lakes of the lower Amu-Dar'ya. This species not only significantly increased production, but is important for improving water quality and protecting the water from blooming. Grass carp, which feeds on higher aquatic vegetation, is very effective in fighting aquatic weeds, if introduced into overgrown water bodies. Both these species are pelagophyl, and their spawning and early growth takes place only in the river and irrigation canals, where they enter from the lakes. Hence, their commercial abundance depends entirely on reproduction in the river and on the river flow, which brings the passive larvae into the lower reaches.

In order to find out the role of the Amu-Dar'ya and irrigation canals in the reproduction of fish in the Southern Aral Basin, special investigations were conducted on the transport of eggs and fish larvae in the canal Risovy (Zholdasova, Pavlovskaya, 1995). This is a 127 km long, gravity-flow canal within a large-scale irrigation system at the right bank of the Amu-Dar'ya, with water intake one kilometer upstream from the Takhiatash Dam. The capacity of the canal is 342 m^3/sec.

Larvae of 14 fish species were detected. Out of these, 7 belong to acclimatized far-eastern species (silver carp, spotted silver carp, grass carp, black amur, bream, sawbelly and *Pseudorasbora* larvae), the remaining 7 representing aboriginal species (bream eastern, goldfish, sander, river perch, catfish, eastern bystranka, ostroluchka). Most abundant (72%) were the acclimatized species, among which the silver carp prevails (56.1%). About 14% are aboriginal fish species.

Compared with similar investigations in previous years (Pavlovskaya, 1976), the above results show an abrupt change of the species' composition and quantitative relationships of larvae transported downstream by the stream. While the progeny of imported far-eastern species prevailed, a complete absence was noted of the larvae of

Barbus brachycelhalus (present with 80% in 1960), razorfish and others, still present by the end of the 1980s (Pavlovskaya, Zholdasova, 1991). Almost all aboriginal fish species belong to lacustrine varieties, acclimatized to the Tuyanmuyn Reservoir, and as regards to number, they do not compete with the far-eastern species, having limited presence in the general transport of larvae in the river.

In the course of the two months of observations, over 9 billion larvae were brought in from the Amu-Dar'ya into the Risovy canal, or about 9% of the total number migrating from the Amu-Dar'ya towards the Takhyatash dam (in May-June 1994, the estimated number of larvae upstream of the Takhyatash dam was over 101 billion). At the same time, about 68 billion (about 67%) larvae entered into the other irrigation canals which take water from the Takhyatash dam, while 24 billion (23%) were flushed into the downstream reach. The quasi-totality of the flushed-down fish progeny is carried onto the irrigated fields where they perish, with the exception of some 5-10%, which reach the water bodies (lakes) through the outfall canals. The stock of plant-eating fish, populating Mejdurechye, former Aral Sea bays and other lakes of the Aral Basin, develops from the larvae flushed by the river flow downstream from the dam (tail-race) of the Amu-Dar'ya.

While all lakes are at present economically exploited, it has to be underlined that their use is subject to changes, especially in Mejdurechye and adjacent reaches of the Amu-Dar'ya, and in the Sarbas bay. The reason for this is the unstable water regime of the lower Amu-Dar'ya, the poor quality of dikes around the artificial water bodies, and the absence of flow regulating structure. For instance, the high catches in Mejdurechye and Sarbas in the early 1990s can mainly be attributed to the annual quasi-total catch of all fish when the water bodies emptied after breaching of the dikes. Such occurrences severely damage the stock of fish and hinder the fishery production of aboriginal species, in the first place. The total catch of fish population in the disconnected water bodies does not even attain industrial scale. The abrupt drop of water levels kills the larvae of phytophil fish, which are the main part of marketable species. The practice of salvaging young fish can by no means compensate these losses. Large efforts are needed to develop sound fishery in the investigated water bodies, in the present circumstances of unstable water regime and aggravating ecological conditions of the Southern Aral Basin.

No doubt, the most important task is the stabilization of the ecological situation, by securing sufficient water flow of good water quality, by discontinuing the inflow of drainage water into the river channels and irrigation canals. Moreover, the economical exploitation of the lakes should be improved, by creating stable stocks of fish population. Accordingly, the following complex measures are recommended.

- To carry out works, by which good river quality water would be provided to the water bodies, in quantities needed to maintain optimal water levels in these, especially in Spring and Summer; measures must be taken to prevent excessive siltation and overgrowth by hard vegetation. Priority should be given to engineering works on the Amu-Dar'ya downstream from the Mejdurechye reservoir, for the regulation of water levels and prevention of catastrophic dike breaches during floods; strengthening of bank protection of all water bodies; putting into operation the regulating structures on the western dike of Sarbas bay; increasing the water depth (dredging) close to the shores, and also improving the discharge capacity, to improve the water exchange and gas regime in the overgrown parts of Muinak bay, by the reconstruction of regulating structures at its western dike and increasing the water supply through the Glavmiaso canal.

- To create in the lakes fish populations of certain species, in order to attain the optimal structure of fish population and to protect rare and disappearing aboriginal fish species. Stable fish communities in the lakes can develop if the necessary composition of species is available. However, in the conditions of ecological disaster affecting the Aral basin, certain species have been extinguished, or are critically endangered due to the changing habitat, and also, owing to the imbalance caused by the introduction of a large number of imported fish species. Therefore, aboriginal species need special protection, by breeding in fish farms, which requires the development or improvement of biotechnical methods for the artificial breeding of certain highly valuable species. Among these are barbel, asp, catfish, sander, etc.

- To put into practice the adaptation of water bodies for pasture fishery. Fish stocks must be developed taking into account the ecological conditions and the fodder supply in the water bodies. In the view of the high overgrowing potential of the water bodies and the ensuing accumulation of detritus, it is opportune to foster the development of detritophages – grass carp, silver carp, white bream, etc, by populating the water bodies with their young. At initial stages, it is recommended to introduce annually per hectare about 10-15 one year old fishes. Subsequently, the number of fish per hectare should be adjusted for each water body, taking into account the relationship between the fodder base and the level of its utilization.

- For the replenishment of fish stocks, the maximum arrival into the lakes of young plant eating and other reophyle fish, should be secured during their passive migration down the Amu-Dar'ya, from their spawning places. In order to achieve this, the inflow of river water into the fishery water bodies must be increased and maintained throughout the period of intensive spawning (second half of April-June).

- In order to secure the optimum number of young fish of grass carp, silver carp and carp, as required for pasture fish-breeding, use should be made of the capacities of the Muinak Fishery Company Biotechnical methods of artificial breeding of other fish species could also be developed on the same basis.

References

A.A. Alekin: *Basic hydrochemistry.* L.: Hydrometeoizdat, 1970 444 p. (in Russian).

E.I. Chembarisov: Flow and water mineralization of large Central Asian collector canals // *Water Resources.* 1989. No.1. Pp. 49-53 (in Russian).

L.N. Guseva, I.M. Zholdasova: Morpho-ecological characteristics of snakehead (*Ophiocephalus argus warpachowskii* Berg) – acclimatized in the waterbodies of the lower Amudarya. *Biological Resources of the Aral Sea Area.* Tashkent: Fan. 1986. Pp. 98-134 (in Russian).

S.N. Ivanov: Black carp and silver carp in the Southern part of the Aral Sea // *Works of VNIRO.* 1964. Vol. 5. Ed. 2 (in Russian).

A.F. Karpevich: Theory and practice of acclimatization of aquatic organisms. M.: *Food industry.* 1975. 432 p (in Russian).

N.A. Konstantinova: Some data on age and growth of *Leuciscus walleckii* Dubowsky and grass carp – *Ctenopharingodon idella* Valenciennes// *Works of Amur ichthyological expedition of 1945-1949. 1958.* Vol. IV Pp. 115-125 (in Russian).

N.I. Kulichenko: On the age and growth rate of snakehead – *Ophiocephalus argus warpachowskii* Berg and chinese perch *Siniperca chua-tsi* Basilewsky // *Works of Amur ichthyological expedition of 1945-1949.* 1958. Vol. IY. Pp. 169-174 (in Russian).

L.P. Pavlovskaya: *The aral barbel.* Tashkent: Fan. 1976. 150 p. (in Russian).

L.P. Pavlovskaya: *Food fish of the lower Amudarya and hydro-construction.* Tashkent: Fan. 1982. 100 p. (in Russian).

L.P. Pavlovskaya, I.M. Zholdasova: Anthropogenic changes in fish population of the Amudarya river (based on the research into the downstream migration of fish eggs and larvae) //_*Problems of ichthyology,* 1991. Voi. 31. Ed. 4. Pp. 585-595 (in Russian).

M.M. Rogov, S.S. Khodkin, S.K. Revina: *Hydrology of mouth area of the Amu-Dar'ya.* M.: Hydrometeoizdzat. 1968. 267 p. (in Russian).

P. Shamshetov, N. Sagitov: On the results of study of biology of plant-eating fish of the lower Amu-Dar'ya // *Present state of nature resources of Karakalpakia.* Tashkent: Fan. 1977. Pp. 105-114 (in Russian).

T.K. Sysoeva: Growth and age of amur silver carp – *Hypophthalmichthys molitrix* (Valanciennes) // *Works of Amur ichthyological expedition of 1945-49.* Vol. IY. Pp. 141-147 (in Russian).

I.M. Zholdasova: Limiting role of some factors of habitat of the Aral Sea for *Clupea harengus membras* L. // *Reports of Academy of Sciences of Republic of Uzbekistan.* 1995. No.1. Pp. 47-49 (in Russian).

I.M. Zholdasova, L.N. Guseva: *Ichtyofauna // Reaction of limnic systems on anthropogenic impact. Tashkent:* Fan. 1987. Pp. 76-108 (in Russian).

I.M. Zholdasova, L.N. Guseva, E. Adenbaev: White amur bream *Parabramis pekinensis* in waterbodies of the lower Amudarya, *Problems of Ichthyology.* 1989. Vol. 29. Ed.3. Pp. 475-482 (in Russian).

I.M. Zholdasova, L.P. Pavlovskaya: On the downstream migration of fish progeny in the lower Amudarya // *Proceedings of Conference on Ecological Problems of Pre-Amudarya Region of Central Asia.* Bukhara. 1995. Pp. 83-85 (in Russian).

I.M. Zholdasova, L.P. Pavlovskaya, S. Kazakhbaev, E. Adenbaev: Present state of the Aral Sea fauna // Biological bases of fishery in waterbodies of Central Asia and Kazakhstan. *Proceedings of the XX Scientific Conference.* Bibliography in KazNIINKI scientific works, Alma-Ata. 1992. Ed.1. No. 3675-Ka 92. Pp. 32-38 (in Russian).

Table 1. The salt composition of the water in the lakes (1991-1995)

Years	Total sum of ions	Na^+K^+	Ca^{++}	Mg^{++}	Total hardness mg/l	HCO_3	SO_4	Cl	pH
Mejdurechye reservoir									
1991	1574* / 1380-1768	368 / 360-376	139 / 137-140	59 / 57-60	11.74 / 11.69-11.76	129 / 128-130	629 / 574-672	403 / 396-410	7.8
1992	1019 / 1005-1033	182 / 170-194	100 / 99-101	37 / 36-38	7 / 5.9-8.2	146 / 144-148	319 / 317-320	235 / 233-237	7.7
1994	2271 / 1640-2880	508 / 280-700	141 / 120-170	77 / 60-90	13.4 / 12.0-14.4	297 / 270-340	873 / 550-1320	360 / 280-530	7.7
1995	1207 / 751-2182	236 / 76-455	98 / 66-160	51 / 27-92	9 / 6.0-15.6	116 / 98-125	421 / 202-883	285 / 134-492	7.7
Sarbas Bay									
1991	1310	360	150	47	11.36	168	720	326	7.8
1992	1259 / 1240-1278	241 / 238-243	118 / 115-121	39 / 31-46	9.09 / 8.59-9.54	160 / 156-164	386 / 377-395	316 / 308-324	7.7
1994	2433 / 2380-2520	520 / 490-560	220 / 190-250	57 / 30-80	15.6 / 15.0-16.2	310 / 290-320	920 / 860-1040	430 / 420-440	7.8
1995	2225 / 2023-2338	427 / 398-449	156 / 145-168	106 / 82-128	16.6 / 14.62-18.3	94 / 80-110	822 / 624-893	603 / 520-637	7.8
Muinak Bay									
1992	3643 / 1743-4796	753 / 336-1005	272 / 123-363	153 / 53-208	26.2 / 10.49-35.22	315 / 149-172	1384 / 576-1824	974 / 456-1266	7.7
1994	1876 / 1310-2670	407 / 250-650	147 / 80-230	50 / 10-70	11.5 / 9.60-12.8	263 / 200-320	680 / 400-1180	320 / 250-430	7.7
1995	1800 / 845-3446	423 / 228-752	125 / 82-220	75 / 32-149	12.5 / 6.8-23.3	105 / 84-123	570 / 254-1104	501 / 165-1098	7.6

* Numerator - the average values, mg/1; denominator - the limits, mg/1.

Table 2. The catches for 1989-1994

Species of fish	1989					1990						1991					
	I*	II	IV	V	V1	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Roach	1.7					14.7	0.7	2.1		2.8	19	14.8	4.7	6.3	0.5	11.5	78
Sander	100.5	5.1	0.2	5.3	5	161.1	31.0	5.9		36.9	23	250.0	164.2	11.3	6.7	182.2	73
Carp	498.7	43.6	8.2	51.8	10	273.6	48.6	14.4	9.0	72.0	26	261.3	60.9	42.1	3.7	106.7	41
Bream	40.6					27.3						68.3					
Sabrefish						0.2											
Catfish	13.7	6.9		6.9	50	1.0	0.1			0.1	10	2.3	0.2			0.2	9
Pike	6.4	1.1		1.1	17	233.6	172.4	11.8	0.3	184.5	79	1282.4	739.4	156.8	28.4	924.6	72
Silver carp	270.8	31.9	0.1	40.0	15	132.5	14.7	3.4		18.1	14	73.2	8.4	0.2		8.6	
Snakehead	658.9	74.5	25.7	100.2	15	410.1	52.0	15.0	45.0	112.0	27	588.6	184.7	40.1	38.6	263.4	45
Grass carp	78.7	6.0		6.0	8	41.4	0.2	2.0		2.2	5	168.3	141.8	1.5	1.3	144.6	86
Goldfish		9.9	4.9	14.8		96.8	16.0	9.1	13.9	39.0	40	152.2	45.8	42.0	4.4	92.2	61
River perch	2.5																
Asp	9.3					5.9	2.5	0.4		2.9	49	9.2	7.1	0.1	0.2	7.4	80
Small fry	13.6	2.2	0.3	2.5	18		33.5	5.0		38.5		71.8	40.6	8.3	3.5	52.4	73
Total	1780.4	181.2	39.4	228.6	13	1443.7	381.7	69.1	68.2	519.0	36	2942.4	1397.8	308.7	87.3	1793.8	61

*I - Karakalpakstan; II - Mejdurechye; III - Sarbas Bay; IV - Muinak Bay; V - total catches in reservoirs II-IV; VI - total catches in reservoirs II-IV in % from the total catches in Karakalpakstan.

(continued on next page)

Table 2. The catches for 1989-1994 (continued)

Species of fish	1992**					1993						1994					
	I*	II	III	IV	V	I	II	III	IV	V	VI	I	II	III	IV	V	VI
Roach	11.9	0.4		0.1	0.5	2.5	1.5	0.9	0.1	2.5	100	1.6	0.5			0.5	31
Sander	473.9	61.4	4.8	7.2	73.4	211.0	177.7	13.2	11.9	202.8	96	86.2	6.0	6.9	4.8	17.7	21
Carp	256.6	61.5	7.1	12.6	81.2	502.4	433.4	27.5	5.1	466.0	93	392.8	44.3	21.0	22.0	87.3	22
Bream	27.8					7.6						17.7					
Sabrefish																	
Catfish	7.0	0.1			0.1	14.6	11.8	0.7		12.5	86	4.1					
Pike	991.9	164.9	11.5	33.4	209.8	498.6	270.0	84.8	82.5	437.3	88	121.2	6.7	32.3	15.0	54.0	45
Silver carp	1076.3	90.1	0.5	0.7	91.3	1844.4	1701.2	139.0	3.2	1843.0	100	312.1	65.7	29.2	0.3	95.2	31
Snakehead	537.9	26.4	1.6	7.0	35.0	368.5	131.3	15.5	3.7	150.5	41	534.9	23.3	25.5	150.6	199.4	37
Grass carp	93.2	11.5	4.7		16.2	603.1	516.1	14.5	3.0	533.6	88	12.5	1.1	0.8		1.9	15
Goldfish	209.8	27.4	5.4	1.9	34.7	108.7	69.8	13.5	1.0	84.3	78	157.4	18.5	21.0	11.6	51.1	32
River perch																	
Asp	17.9	0.4		0.3	0.7	16.6	11.8	3.6	0.1	15.5	93	14.3	2.2	2.1	0.1	4.4	31
Small fry	104.8	11.2	0.1	3.5	14.8	143.8	105.5	9.1	3.9	118.5	82	23.2	1.9	5.8	2.1	9.8	42
Total	4209.0	455.3	35.7	66.7	557.7	4365.0	3430.1	322.3	114.5	3867.0	89	1678.0	170.2	144.6	206.5	521.3	31

*I - Karakalpakstan; II - Mejdurechye; III - Sarbas Bay; IV - Muinak Bay; V - total catches in reservoirs II-IV; VI - total catches in reservoirs II-IV in % from the total catches in Karakalpakstan.

** The information on catches in 1992 is not complete.

Table 3. Fish fauna of the lower Amu-Dar'ya river

Species	River Amu-Dar'ya	Mejdurechye reservoir	Lake Sarbas	Lake Muinak
1	2	3	4	5
I. Family Acipenseridae				
1. *Acipenser nudiventris* (Lovetzky) - bastard sturgeon (ship)	∂	-	-	-
2. *Pseudoscaphirhynchus kaufmanni* (Bogd.)* - big Amudar shovelnose	∂	∂	-	-
II. Family Esocidae				
3. *Esox lucius* (L.) - pike	+	+	+	+
III. Family Cyprinidae				
4. *Rutilus rutilus aralensis* (Berg)* - Aral roach	+	+	+	+
5. *Leuciscus idus oxianus* (Keys.)*- Turkestan ide (orfe)	∂	∂	∂	∂
6. *Aspius aspius iblioides** - Aral asp	+	+	+	+
7. *Scardinius erythrophtalmus* (L.) - rudd, redeye	+	+	+	+
8. *Ctenopharingodon idella* (Valenciennes)† - grass carp	+	+	+	+
9. *Mylopharingodon piceus* (Richardson)† - black carp	∂	∂	+?	-
10. *Pseudorasbora parva* (Schlegel)† - stone moroco	+	+	+	+
11. *Barbus brachcephalus* (Kessler) - Aral barbel	∂	∂	∂	-
12. *B. capito conocephalus* (Kessler) - Turkestan barbel	∂	∂	-	-
13. *Chalcalburnus chalcoides aralensis* (Berg) - Aral shemaya	+	+	-	-
14. *Alburnoides taeniatus* (Kessler) - striped [syrdar] bystranka	+	+	+	+
15. *A. bipunctatus eichwaldi* (Filippi) - eastern bystranka	+	+	+	+
16. *Abramis brama orientalis* (Berg) - eastern bream	+	+	+	+
17. *A. sapa aralensis* (Tiapkin)* - Aral white-eye	∂	∂	+?	+?
18. *Capoetobrama kuschakewitschi* (Kessler)* - ostroluchka	+	+	+	+
19. *Parabramis pekinensis* (Basilewsky)† - white amur bream	+	+	+	-
20. *Hemiculter leucisculus* (Basilewsky)† - sawbelly	+	+	+	+
21. *Pelecus cultratus* (L.) - sabrefish, razorfish	+	+	+	+
22. *Pseudoperilampus (Rhodeus) ocellatus* (Kner)† - eyed bitterling	+	-	-	∂
23. *Carassius auratus gibelio* (Bloch) - goldfish	+	+	+	+
24. *Cyprinus carpio aralensis* (Spitshakov)* - Aral carp	+	+	+	∂
25. *Hypophthalmichthys molitrix* (Valenciennes)† - silver carp	+	+	+	+
26. *Aristhichthys nobilis* (Richardson)† - spotted silver carp	+	+	+	+
27. *Aspiolucius esocinus* (Kessler)* - pike-asp	+	-	-	-
IV. Family Cobitidae				
28. *N. amudarjensis* (Rass)* - Bukhar loach	∂	-	-	-
29. *N. oxianus* (Kessler)* - Amudar stone loach	+	+?	-	-
30. *Sabanejevia aurata aralensis** - Aral stone loach	+	+?	+?	-
V. Family Siluridae				
31. *Silurus glanis* (L.) - catfish	+	+	+	+
VI. Family Channa				
32. *Channa (Ophiocephalus) argus warpachowskii* (Berg)† - snakehead	+	+	+	+
VII. Family Percidae				
33. *Perca fluviatilis* (L.) - river perch	+	∂	∂	∂
34. *Stizostedion lucioperca* (L.) - sander, pike-perch	+	+	+	+
VIII. Family Gasterosteidae				
35. *Pungitius platigaster aralensis** - Aral stickleback	+	+	-	-
IX. Family Gobiidae				
36. *Rhinogobius similis* (Gill)† - Amur goby	+	+	+	+

Notations:
* – endemic; † – acclimatisants; ∂ – rare species;
- – species absent; + – living species; +? – necessary to confirm availability of species;

Table 4. The biology indices of fundamental commercial fish (data from scientific-research catches)

Species of fishes	Water-body*	Length of fish, cm		Mass, kg		Age composition of catches, %						
		limits	average	limits	average	0+	1+	2+	3+	4+	5+	6+
Carp	I	27.0-48.2	36.3	0.40-1.93	0.90			5.6	33.3	44.3	11.2	5.6
	II	27.8-61.7	38.8	0.41-3.62	1.17			7.4	62.9	25.9	3.8	
	III	24.6-42.0	31.1	0.26-1.30	0.60	14.3		5.0	15.0	75.0		
Silver carp	I	23.0-60.9	42.8	0.15-3.00	1.20		10.8	78.4	8.1	2.7		
	II	41.5-46.2	44.1	1.10-1.55	1.33			85.7	14.3			
	III	26.5-41.2	35.4	0.30-1.00	0.70		33.3	66.7				
Grass carp	I	55.8-77.0	61.8	2.90-6.73	4.20			89.9	7.3	2.8		
	III	55.8-77.0	61.8	2.90-6.73	4.20			89.9	7.3	2.8		
Goldfish	I	14.8-29.0	20.4	0.10-0.65	0.30			7.3	36.3	38.2	16.4	1.8
	II	21.4-28.6	24.6	0.21-0.55	0.38				30.0	45.0	25.0	
	III	17.6-28.2	24.9	0.13-0.64	0.40				27.6	20.7	48.3	3.4
Sander	I	20.8-59.1	40.7	0.10-2.93	0.70	5.9	47.1	17.6	11.8	11.8	2.9	2.9
	II	27.8-55.0	47.8	0.21-1.78	1.22		11.1			33.3	55.5	
	III	22.1-58.5	43.8	1.12-2.20	1.10		2.6	5.3	5.3	36.8	34.2	15.8
Snakehead	I	24.0-75.0	50.9	0.20-4.40	1.70		2.0	28.1	40.0	25.2	4.0	0.7
	II	53.0-66.0	54.5	1.44-3.22	3.20					66.7	33.3	
	III	26.0-61.0	38.3	0.12-2.21	0.60	14.3	54.3	8.6	14.3	8.5		
Pike	I	37.6-51.7	44.4	0.41-1.20	0.80				33.3	66.7		
	II	40.0-60.5	48.3	0.55-1.55	0.93				50.0	50.0		
	III	35.2-67.7	50.8	0.37-2.7	1.40			33.5	33.5	33.0		
Catfish	I	28.0-91.0	51.7	0.20-5.80	1.50							

* I - Mejdurechye reservoir, II - Sarbas Bay, III - Muinak Bay.

Table 5. Growth rate of fish in waterbodies of lower reaches of Amu-Dar'ya

Waterbody	l_1	l_2	l_3	l_4	l_5	l_6	n
Carp							
Mejdurechye reservoir	10.7	20.8	30.6	35.0	37.5	40.1	18
Sarbas Bay	10.8	22.4	32.5	39.7	53.8		27
Muinak Bay	9.2	17.4	24.8	30.1	39.9		21
Sander							
Mejdurechye reservoir	18.5	27.0	33.9	42.0	46.4	52.0	19
Sarbas Bay	17.7	27.8	37.2	44.9	52.6		5
Muinak Bay	16.5	27.8	36.7	41.1	48.7	53.0	31
Pike							
Mejdurechye reservoir	15.1	27.5	35.8	45.4			14
Sarbas Bay	14.5	30.3	39.7	50.6			14
Muinak Bay	15.7	29.8	39.8	52.1	65.5		12

Table 6. Growth rate of silver carp *Hypophthalmichthys molitrix*

Year	l_1	l_2	l_3	l_4	l_5	l_6	l_7	n	Research
Amur near Elabuga 1947	9.4	25.1	36.1	44.2	49.8				Sysoeva T.K., 1958
Dautkul reservoir 1984	19.6	36.8	44.9	56.8	66.4	68.2	72.3	8	Zholdasova I.M., and Guseva L.N., 1987
Mejdurechye reservoir Schegekul lake 1988	18.0	31.8	41.8	50.6	62.3			69	Present authors
Koksu lake 1988	22.6	33.5	44.3	53.7	59.9			22	
Mejdurechye reservoir 1993-1995	24.2	39.1	46.7	58.3				46	Present authors
Sarbas Bay 1993-1995	27.9	40.1	46.2					11	Present authors
Muinak Bay 1993-1995	23.98	36.8	31.7					8	Present authors

Table 7. Growth rate of grass carp *Ctenopharingodon idella*

Year	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	n
Amur near Elabuga 1950	7.0	15.0	22.2	29.2	35.5	40.0	43.2	45.0	77
Dautkul reservoir 1985	14.8	27.8	36.8	44.4	52.5				17
Mejdurechye reservoir 1993-1995	20.3	46.2	60.8	66.08	71.9	78.0			116
Muinak Bay 1993-1995	20.7	41.0	49.7	58.4	65.9				2

Table 8. Growth rate of snakehead *Channa argus warpachowskii*

Year	l_1	l_2	l_3	l_4	l_5	l_6	l_7	n	Research
River Amur near Bolon 1946-1949	23.2	36.2	44.9	53.9	58.5	64.5		16	Kulichenko N.I., 1958
River Amur near Elabuga 1945	22.3	36.8	46.5	56.4	61.9	66.7	71.0	50	Kulichenko N.I., 1958
Mejdurechye reservoir									
1993	14.6	25.6	37.8	45.5	53.8			8	Present authors
1994	21.3	36.4	46.7	52.9	47.8			18	
1995	20.8	35.1	46.1	52.2	53.8			3	
Sarbas Bay 1994-1995	23.5	37.2	47.1	57.0	63.4			3	Present authors
Muinak Bay									
1993	17.2	27.1	32.0	50.5				10	Present authors
1995	17.9	31.7	43.3	50.4	59.5	71.1		15	

Figure 1. Aral Sea fish population

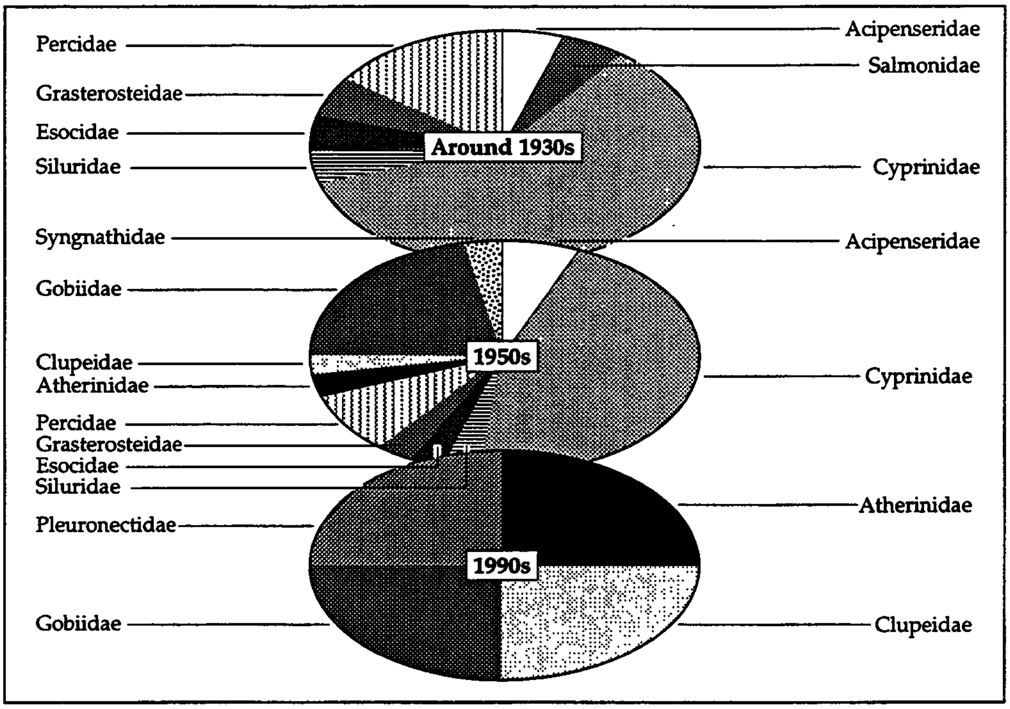


Figure 2. Fishing industry in the Aral Sea

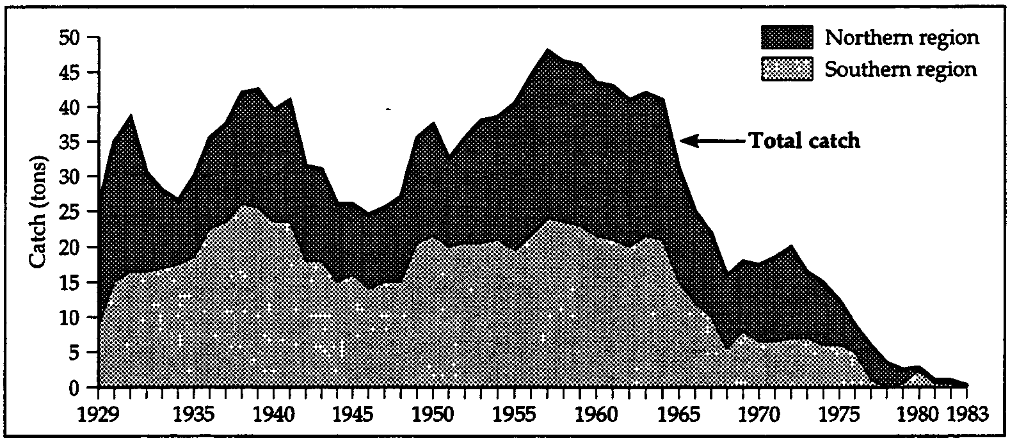
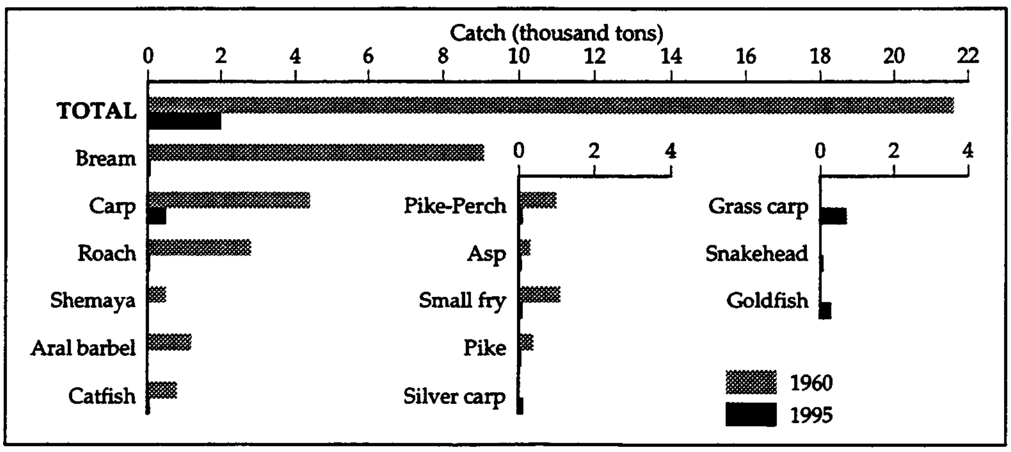


Figure 3. Fishery dynamics, 1960 and 1995



WATER AND SWAMP BIRD POPULATION AS A COMPONENT OF BIODIVERSITY OF THE ECOSYSTEMS IN THE AMU-DAR'YA AND ADJACENT LAKES

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Introduction

The intensive economic (or rather anti-economic) activity within the Aral Basin and, in particular, in the Amu-Dar'ya valley has led, as we know, to the transformation of the natural ecosystems and their components. The worst deterioration occurred in the hydromorphic ecosystems of the Amu-Dar'ya delta. Its faunistic structure is still changing, and the spatial redistribution of animals, including birds, and the reduction in their numbers is continuing.

While monitoring the biological diversity of the Amu-Dar'ya valley, primary attention should be paid to the study of the hydrophylous ornithocomplexes, because these serve as state indicators of the water and swamp ecosystems. The biological diversities of the ecosystems are classified as alpha, beta and gamma levels (Whittaker, 1960, 1965). Hence, the authors surveyed the water bodies (alpha level), not only in the delta (beta level) but also in the entire plain portion of the Amu-Dar'ya, assessing it at the integrated gamma level.

The present work is based on the field investigations conducted from 1994 to 1995 in the lower reaches of the Amu-Dar'ya river, as well as between 1985 and 1989 in the middle Amu-Dar'ya and from 1984 to 1990 in the Sarykamysh lake. The main target was the study of the actual state of hydrophylous ornithocomplexes: their space distribution, composition, structure and seasonal aspects. The first results concern the pattern of the biotopic conditions of water bodies, the distribution and number of water fowl and some other water and swamp birds.

The avifauna of the Amu-Dar'ya river and adjacent lands covers over 300 species and sub-species (Rustamov 1945, Ametov 1981) of which water and swamp birds groups form: Podicipediformes - 5 species (2 recorded by the authors), Pelecaniformes - 4 (3), Ciconiiformes - 12 (4), Phoenicopteriformes - 1 (1), Anseriformes - 22 (22), Gruiformes - 9 (2), Charadriiformes - 44 including Godwits - 30 (9) and Gulls - 14 (8).

Routes, data and techniques

Field surveys of water bodies, physiognomic characteristics and bird counting, were performed from an aeroplane (AN 2) at 50-100 m height, from a boat, as well as from the shore. Work was conducted throughout the following water bodies and at the following dates:

- In the Middle Amu-Dar'ya between the Mukry settlement and Tuyamuyun hydro-electric station, from the shore, in May, June and July 1986; aerial survey in December 1985, February and December 1986, February and April 1987, February 1988 and February, April, May and June 1989; in the Tailak, Turanguldua, Ainakul and Soltandag lakes, from a boat, in December-February 1987-89.
- At the Sarykamysh lake, the surveys were carried out at the research stations in April-June 1984-90: absolute nest counting on the islands and observations of the

nesting life of the water and swamp birds, counts over the lake from a motor boat (4-5 times during a season) and those from the shore, every 5 days following the permanent route (91 km long).

- In the lower Amu-Dar'ya in July and December 1985-90 and November-December 1994-95: selecting aerial survey along the Der'yalyk and Mal'yab collectors, Sarykamysh, Goikyrlan and Kernai lakes, as well as along the river bed between Tuyamuyun reservoir and Nukus - Dashkhovuz towns.

- In the Amu-Dar'ya delta in November 1995, the aerial survey was conducted with synchronous counting of birds following the route Dashkhovuz-Nukus-Dautkul-Karateren-Zhiltyrbas-Dumalak-Muinak-Adzhibai-Sudoch'e-Kernai-Dashkhovuz.

Thus, all valleys of the Amu-Dar'ya from the Afghanistan border to the Aral Sea (1,770 km) were observed, including large, medium and the majority of small water bodies on its right and left banks and delta. As a result of these field trips and aerial surveys, large-scale topographic and space photos of 53 water and swamp bird habitats were recorded, covering over 8,000 km^2. A register and bird location scheme map were prepared, characterizing the studied groups of birds on migration or at nesting and hibernation places (Fig 1).

Throughout the work, over 100 flight hours were spent and 630,000 birds belonging to 51 species were recorded. As a count unit, one individual was taken and, as a calculation unit, the average of individuals per sq. km. The average width of the Amu-Dar'ya river channel between Mukry and Tuyamuyun was assumed to be 2 km. The aquatic areas of the other water bodies were obtained from bibliographical sources although, mostly, they were determined on the spot by the authors themselves.

For data storage and processing, the respective packages of the 'Windows-95' Programme were used.

Habitat characteristics

The middle Amu-Dar'ya valley, in addition to its own flood plain, comprises a vast network of irrigation and drainage canals. The fairway is highly unstable, the channel is rich in temporary and permanent islands of various sizes. Temporary islands are flat, silted-sandy, without vegetation or supporting rare shoots. Their biotopical conditions are beneficial for nesting of Little and Common Terns (*Sterna albifrons, S. hirundo*), Black-winged Stilts (*Himantopus, himantopus*) but due to the ephemeral character of these islands, the nests appear and soon perish. The permanent islands are larger, they can rise 1-2 m above the water surface and are of permanent topography. The main part of their area is covered by grass and shrubs, with a mixture of the ancient and recent riparian communities (tugais). Such islands serve as nesting places (in addition to the above-mentioned birds) to White-tailed Lapwings (*Vanellochettusia leucura*), as well as Collared Pratincoles (*Glareola pratincola*), and Gray Herons (*Ardea cinerea*) though only on the territories close to backwaters and oxbow lakes or irrigation canals with clean water on their shore plots, suited to the growth of the small non-food fish (trophic factor). The combination of such conditions is not available on every flood plain, so Little and Common Terns, Gray Herons are dispersed, building no large flocks. As some Godwits and Sandwich Terns (*Sterna sandvicens*) are not constrained by the above-mentioned factors, almost all irrigated agricultural land is suitable for them, being residents of the flood plain.

Lakes and reservoirs may be classified into four main groups:

1. **The flood plain lakes** (for instance Ainakul), having been filled by flood waters. As a rule, such lakes are not large, with a jagged shore line, covered by tugais

(mainly *Tamarix*). These lakes can serve as nesting places for some Godwit species, especially on small islands.

2. **The delta lakes**. The recent Amu-Dar'ya delta includes the alluvial deltaic plain up to north of the Takhiatash cape, being limited on the left-bank by the south-eastern cliffs (chink) of Usturt, and on the right-bank by the north-western ridge of the Kyzylkums. The seasonal changes of the water regime of the delta lakes are related to water supplied by the drainage system, rather than being fed by river water, as the Spring-Summer floods are followed by the fall one. Because of the contraction of Aral Sea, the delta area diminished from 3,000 m^2 in 1960 to 2,100 m^2 in 1970 and 700 m^2 in 1990. In 1980, only 14 lakes remained of the initial 36 surveyed in 1960 (Lukashevich and Ametov, 1990), as also recorded by us (Fig.2). Both the continuing sea shore line retreat and the reduction of water discharge entering the delta have led to the further desiccation of its lakes. Those still existing (for instance, Zhiltyrbas or Dumalak) are extremely unstable, nothing but small remnant water bodies with strongly jagged shore lines, covered by 'rogos' or reed belts, 800 m in width. The biotopic conditions and food availability on such lakes are suitable for Godwits e.g. Green Sandpipers (*Tringa ochropus*), Great Cormorants (*Phalacrocorax carbo*), Mallards (*Anas platyrhynchos*) and some other species.

3. **Reservoirs**. Some of these are built in the river channel (e.g. Tuyamuyun) and others in flooded river valleys (Soltansandzhar or Zeid). The reservoirs serve not only for river flow regulation but also as filtration lakes. They are filled up in Autumn-Winter and discharged in Spring-Summer, hence the water levels and, consequently, the shore lines are not fixed. Biotopic conditions of the Tuyamuyun and Soltansandzhar reservoirs can potentially allow nesting of Pelicans (*Pelicanus*), Great White (*Egretta alba*) and Gray Lag Herons, Great Cormorants, Common Terns, some Gulls (*Larus*) and Godwits. These reservoirs are of significant importance for birds during their migration and hibernation.

4. **Lakes and flood lands** appear in the basins or other natural depressions, as a result of the collection and drainage waters (e.g. Dengizgul, Soltandag, Kattashor). Their shore lines can be rather jagged, then sloping. Bays and coves containing small islands are, as a rule, covered with reed belts of different widths (from 5 m to 200 m or more) and broken by expanses of open sandy shores. The biotopic and, especially, trophic conditions are suitable for nesting of certain species of Terns, Gulls, Godwits as well as Great Cormorants, Gray, White and Great Herons. Nevertheless, the nesting is limited by the water level variations, which do not correspond to the breeding cycle of the water birds, so that their clutches often perish. With a rise in the water level, Gulls, Terns and Godwits occupy some spits, turning into the islands later on. On shallow lakes and flood lands, Heron and Cormorant flocks can occupy the saksaul *Haloxylon* spp. and candym *Calligonum* spp. shrub tops.

The same group of water bodies includes the Sarykamysh lake, which is one of the large water bodies in Middle Asia (2,900 km^2), into which the drainage waters arrive through the Der'yalyk collector, running from the lower reaches of the Amu-Dar'ya since 1962. Due to favourable ecological conditions, the Sarykamysh has an increasing importance for water and swamp birds owing to the contraction of the Southern Aral and soil deterioration. Suffice it to say that the number of water and bird species attained 84 (8 resident, 18 migratory-nesting, 6 migratory-wintering, 49 migratory and 3 occasional) (Rustamov 1948, Velikanov and Khokhlov 1979).

Results and discussion

The Middle Amu-Dar'ya. The number of birds seen along the flood plain or on the flood plain lakes during Spring-Summer (nesting) differs substantially from that observed in Winter (Table 1). For example, in the nesting season the average number of water and swamp birds is 5.6 individuals per km^2 (0.6% of the total), compared to 1,030 (99.4%) on the lakes, which is 180 times more. For the Winter period, those indices are equal to 692 (24%) and 2,191 (76%), respectively, the difference being 3.2 times only. In Winter, the number of birds increases, due to the arrival of wintering waterfowl, mainly Ducks (*Anas*) and Coots (*Fulica*).

During the nesting seasons, the most frequent are Gulls - 818 individuals per km^2 (78.9%), much exceeding Herons - 97 (9.3%), Cormorants - 76 (7.3%), Ducks - 24 (2.3%) and Coots - 22 (2.1%). The total number is much higher than on the flood plain. In Winter the most numerous are Ducks and Geese - 1,728 (59.9%) and Coots - 702 (24.3%), followed by Cormorants together with Pelicans - 199 (6.9%), Herons - 153 (5.3%) and Gulls - 101 (3.5%). In Winter, as well as in Spring, the number of birds on the flood plain is less than on the lakes and reservoirs.

In the Spring-Winter period, the maximal density of water and swamp bird population was observed on the Shorkuduk (839 individuals per km^2) and Kizylburun (57) lakes, mainly composed of Gulls, with a density approaching 745 and 28 respectively. On the Tailak and Turangulduz lakes, the density was similar (23-24). The same is true for the Kelif lake system, as well as for the Soltandag lake and the Mekhedzhan channel entering it (from 10 to 17). On the remaining water bodies, the density of birds in the period indicated was lower (Table 1).

In winter, the highest density of birds was observed at the Dengiskul lake (716 individuals per km^2), the Mekhedzhan channel (378) and the Amu-Dar'ya flood plain between Kerki and Karabekavul villages (294). On the Tailak-Turangulduz lakes as well as on the flood lands to the west of Chardzhev town and on Kattashor lakes, the bird density was within the limits of 150-200 individuals per km^2. On the flood plain between Mukry and Kerki, between Karabekavul-Chardzhev and Seidi on the Shorkuduk, Kizylburun and Ainakul lakes, these indices are lower, about 100-150 individuals per km^2. The bird population density on the remaining water bodies is much lower.

We pass to the description of the birds nesting and wintering on the Middle Amu-Dar'ya water bodies. On the Shorkuduk lake, Great Cormorants, Gray and Great White herons nest by a general flock on the spots of the slightly flooded (*Saksaul*) community (the inter-shrub distances varying from 1 to 10 m) from 200 to 800 m in width, stretching as long as 2 km. The Common Tern flocks are distributed through two large and a few small islands. The population of Herring Gulls (*Larus argentatus*), Slender-billed Gulls (*Larus geneo*) and Sandwich Terns (*Sterne sandvicensis*) - on a single island, the former two species nested as one unevenly merged flock around 300 m in diameter, while the nests of Sandwich Terns are scattered throughout the entire island.

On the Soltandag lake almost all flocks are concentrated on the 2 x 3 km. bay, located in its south-western zone. Most of the Great Cormorant nests were found in the shrubs of slightly flooded *Saksaul* communities. The nests of Gray Lag Herons - in *Tamarix* shrubs and reeds on the small sandy islands, 3-4 m in diameter, dispersed throughout the bay. Little and Common Terns nest around the periphery of the same small islands, forming no large flocks.

On the Kyzylburun lake, the small nest sites belonging to Little Terns were seen on two islands, 50 and 100 m in diameter, respectively, being separated as the water level rises. On the adjacent Ainakul lake, on one of its islands, Collared Pratincoles together with White-tailed Lapwings nest as a general flock.

 On Kattashor lakes, the nesting places of Little and Common Terns and Collared

Pranticoles form a flock on one of the islands, the formers' nests being rare, whereas those of the latter are comparatively dense (up to 3 m from each other). Gray Lag Herons prefer nesting here, likewise as on other islands covered by dense reeds.

The appearance of almost inaccessible lakes, such as Soltandag, Kyzylburun, Kattashor created favourable conditions for nesting of manifold hydrophylous ornithocomplexes, in particular of Cormorants, Herons, Gulls, Terns and some Godwits. Their nesting places on the water bodies indicated are, however, of an ephemeral character, except for the nesting on the slightly flooded shrubs, and are mainly influenced by the water level fluctuation of the lakes.

Winter is mainly frost-free (a belt with mild Winters) in the Middle Amu-Dar'ya. In the flood plain, the stagnant river waters and flooded fields freeze only at night, when water birds gather on the lakes. During the day-time the birds, usually ducks, fly out on the heated fields, free of ice cover on sufficiently large surfaces. When short frosts occur, they most often affect the river channel. On the flood plain, lakes and water reservoirs, the diversity of species is richer in such periods: Coot, Mallard, Greater-winged Teal (*Anas crecca*), Red-crested Pochard (*Netta rufina*) and, beside these, on the reservoirs, Tufted Duck (*Aythya fuligula*) and Great Cormorant are common.

The Delta Lakes. As mentioned above, these lakes were surveyed by the authors in November-December 1994-95. We had no opportunity to carry out Spring counts (due to lack of means); therefore, the distribution and number of some representatives of the water and swamp birds during the nesting season was assessed, using the data obtained in 1987-90 (Table 2).

The delta hydrophylous ornithocomplexes depend on the succession of the water and swamp habitats and dynamic of the hydromorphic ecosystems, as a whole. In this connection, one should bear in mind the potential displacement of both the nesting places and distributed-through-flocks nesting bird accumulations, not only in the delta but also over the entire Southern Aral region, including the Sarykamysh lake (Zaletaev, 1989).

Winter is cold, in the belt of the lower Amu-Dar'ya, with negative temperatures and ice cover on the water bodies. Therefore the delta lakes, being the resting and feeding places, are of importance for waterfowl and other water and swamp birds mainly when they are on fall migration.

The results of our counts in 1994-96 and data of the State Committee for Nature Conservation of the Karakalpakstan Republic for 1992-94 (the authors acknowledge the kind assistance of Dr. R. Reimov in obtaining these data), show that in the Autumn, the delta water bodies support an average of 23,500 Ducks, Coots and other waterfowl (Table 3). One could think that their number is under-estimated, but it should be taken into consideration that these are the indices characterizing the long-term average level of the bird abundancy, confined to the migration season, composed of the bird numbers from the variable 'migration surges'. During some short time mass migration in some years, the waterfowl was numbered by hundreds of thousands of individuals.

As should be anticipated, the maximal number falls on Ducks (42.2% of total), mainly composed of Mallards, Green-winged Teal and Garganey (*Anas querquedula*), Red-crested Pochard and Common Pochard, and Tufted Duck, as well as Coot (32.0%). Low abundance indices of Gulls do not reflect the real situation, because they were ignored (by the 'Nature Conservation Service' of Karakalpakstan) or underestimated almost on every water body. In the Autumn, Herring Gull and Slender-billed Gull is likely to dominate among the Gulls.

The best lakes for migratory birds, confirmed by the number of birds they support, are: Sudoch'e, Mezhdurechenskoye as well as Zhiltyrbas.

Sarykamysh Lake. The water and swamp bird population here in the Spring/Summer period is composed of 32 species with an average general density of over 800 individuals per km^2 (Table 4 and 5), of which 19 species are nesting (over 500 individuals per km^2) and 13 are migratory (around 300). The most common species are considered to be Great Cormorant and Coot, though dominating in April only, due to the arrival of migratory birds, and they are rare in May-June. Less common are the Slender-billed Gull and Gull-billed Tern (*Gelochelidon nilotica*). Common birds are also Red-crested Pochard, Herring Gull, Common Tern, Tufted Duck, Common Pochard, as well as both Pelican species and Great Black-headed Gull (*Larus ichthyaetus*). Other species occur rarely.

The fluctuations of bird numbers are explained by natural redistribution of birds in seach for food and nesting places. Therefore, the recordings of exact numbers of birds from the shore over such a vast water body is a difficult task. The data obtained reflects the bird numbers in the southern Sarykamysh only (Table 4) which could not be extrapolated for the whole lake because of biotopic differences between the southern, eastern and northern parts of the lake. On the contrary, the bird flock and nest counts within it gave almost exact results, especially for 1986-89 (Table 5).

Great Cormorant is the most common bird (61% of nests of all species) which starts nesting earlier than other birds and forms both monospecies and merged flocks. In the latter case, the nest number is always higher as compared with that of other species. The flocks are seen on sandy islands directly on the ground or in the slightly flooded shrubs and reed stands. The flock can number from several tens to two thousand nests. Both Dalmatian and Common Pelicans, *Pelicanus crispus* and *P. onocrotalus* usually nest together with Great Cormorant, though they can form separate flocks. The Dalmatian Pelican flock can hold from 2 to 77 nests. The Common Pelican inhabitants contained as many as 2, 36 and 100 nests.

Great Cormorant was formerly common on the lake also, which was not the case of Pelicans, in particular Common Pelicans (Velikanov and Khokhlov, 1979). The underestimation of the quantity of Great Cormorants in June 1983 was apparently due to the incomplete survey of the lake (Eminov et al., 1987).

The decline in numbers of Dalmatian Pelican and Great Cormorant in 1988 (the Common Pelican was not nesting at all in this year) was caused by the sharp rise of the lake water level during the Winter of 1987-88 (about 60 cm). This, combined with wind activity, led to the disappearance of islands in the south and western parts of the lake. On the other hand, in the northern-western part of the Sarykamysh, the flooding of large islands resulted in the formation of smaller islands and an increase of the shoals area, which created new nesting opportunities complementing the lost ones. In the following year (1989) the number of birds increased, especially of the Common Pelican.

The Slender-billed Gull, Gull-billed Tern and Least Tern predominate among Gulls.

In one case, the merged flock of Slender-billed Gull and Gull-billed Tern was found in the middle of comparatively large islands of about one hectare. 800 nests were recorded of the Slender-billed Gull, while on the edges, up to 1,000 nests belonging to the Gull-billed Tern. In another case, in the centre of the large Gull-billed Tern flock, 14 nests belonging to the Slender-billed Gull were found. The flock pattern of the former is more distinct: in the south-eastern part of the Sarykamysh, 2 or 3 flocks, each with nests numbering from a few hundred to a few thousand were built annually. Common Tern, against Gull-billed Tern, in the different parts of the water body, forms merged small flocks, composed of only a few tens of nests.

The Herring Gull, by small groups or separate pairs, usually inhabits the flocks of Great Cormorant, but sometimes forms large monospecific flocks of up to 100 nests.

The Caspian Tern (*Hydroprogne caspia)* is a rare species in the Sarykamysh. In 1985, only one monospecific flock composed of 16 nests was found. In 1986, two inhabitants (of 3 and 5 nests) in the flock made up of Slender-billed Gull and Herring Gull together with Great Black-headed Gull; in 1988, one more flock on the high gravel island in the central portion of the lake was found.

In 1986-89, the Great Black-headed Gull settled only on a single island located close to the south-western lakeshore, where its flocks numbered from 80 to 100 nests each. Herring Gull, Great Cormorant and Dalmatian Pelican were also seen there. In 1990, the Great Black-headed Gull flocks, each containing few nests, appeared on the islands in the central and north-western parts of the Sarykamysh.

Little Tern usually forms merged flocks, together with White-tailed Lapwing (*Vanellochettusia leucura)* and Black-winged Stilt, on the islands inaccessible to predators. The number of Little Tern nests in such habitats approaches hundreds, that of White-tailed Lapwing and Black-winged Stilt - a few tens.

In the flocks of both Tern and Godwits, some Ducks build nests; these are: Mallard, Gray Duck (*Anas strepera*), Red-crested Pochard, sometimes Sheld Duck (*Tadorna tadorna*). The number of these species during the nesting season is not high - up to 200 nests on the average. Interestingly, Ducks do not create true flock patterns but, together with other species, they form specific flocks, thus manifesting nesting parasitism. In 1990, the Mute Swan also started nesting in the Sarykamysh - 15 nesting pairs were seen there.

The Great-crested Grebe (*Podiceps cristatus*) nests in small flocks by few pairs in the slightly flooded *Saksaul* shrubs surrounded by reeds. During 1984-86, this bird occurred very rarely and nested in single pairs. In the successive years, especially in 1989, the species number increased, each flock then holding up to 80 nests.

The Gray Lag Heron does not form large flocks. It is seen in rare groups of 2-10 pairs, or as single birds in the same *Saksaul* shrubs, surrounded by reeds. Few nests were found in the Great Cormorant flock.

The Ibis is a rare species. Only 3 flocks were found, with 17 nests in 1985 (in the Great Cormorant flock), 5 in 1988 and 3 in 1989.

Most of the flocks comprising water and swamp birds were observed in the same places during 1-2 nesting seasons. Flooding and eroding of islands forces the birds to build their nests on other islands, or spits. For example, in 1989 as compared with 1984-88, substantial displacement of nesting inhabitants of not only Great Cormorants and Pelicans but also other flocked birds occurred - from the southern segment of the lake to its southern-western parts. The number of nesting Cormorants rose from 400 to 1,300. The birds' requirements in food should also be taken into account. Aerial survey in November 1995 revealed that the majority of lakes in the south and south-western sections of the Sarykamysh disappeared, because of flooding and erosion. This had an impact on the displacement of the nesting places of water- and swamp birds belonging to the Sarykamysh population.

The expected stabilization of the lake would result in the increase of salinity of its water which, in turn, would create conditions for the nesting of Flamingo (*Phoenicopterus roseus*).

In Winter, the state of the bird population is determined by cold frosts and respective temperatures. However, in spite of the negative temperatures, this water body is not always covered by ice, probably due to the very high salinity of the water. For example, solid ice cover was observed there from January to March 1984, from December 1984 to March 1985, in February 1988, and from December 1993 to February 1994. During the rest of the cold period, only belts of 10-15 m wide (though sometimes up to 100 m) were covered by ice near the shores. Depending on that, water- and some other birds stay there, not only for their migration, or in the beginning of the Winter (end October - end November) but also later on. Usually towards the end of November or in December, most of the birds (up to 70-75%), forced by the cold weather, fly as far as the middle Amu-Dar'ya region and possibly further southwards to the South-Eastern Caspian Sea or the belt of the Karakum canal. The remaining birds, mostly Swans (*Cygnus*), are seen up to the end of the winter and even at the ice cover, if the unfrozen patches of water in the middle are still open. The birds then attempt to reside not on the open water but in bays and coves along the periphery of the lake, especially in its southern half. In the years with no ice cover, the number of birds may either decline or rise.

Lastly, the full list of aerial counts is presented below (V. Shubenkin also participated). On 23 December 1994 and 25 November 1995 were recorded respectively:

Coots - 25,600 and 6,120 individuals; Red-crested Pochards - 0 and 8,400; Common Pochards - 90 and 4,900; Mallards - 160 and 3,250; Greater Scauts (*Aythyamarila*) and Tufted Ducks - 2,120 and 18; Great Cormorants - 400 and 33; Swans (mostly Mute Swans) - 77 and 212; Smews - 0 and 670; Teals (mainly Green-winged Teals) - 0 and 680; Gray Lag Geese - 1 and 4; Sheld Ducks - 2 and 0; Black-headed Gulls - 5 and 4; Gray Lag Herons - 0 and 13; Great White Herons - 0 and 12. On the first date 25% were surveyed and on the second date - 75% of the aquatic area were surveyed.

Conclusions

The preliminary results showed the present state of the water and swamp birds, their composition and also spatial/temporal structure on the water bodies, local lake systems and the Amu-Dar'ya valley. The appearance of many accumulation water bodies instead of flood plain waters and lakes has changed the existence and integrity of the territorial groups of the bird population. The bird population changes depend upon the succession pattern of the hydromorphic ecosystems, developing on the background of anthropogenic processes which impact differently on each ecosystem. The breach in the functional integrity of the ecological structure of the water- and swamp bird population and, hence, of the hydromorphic ecosystem as a whole appears through a series of hydrolotical and hydrobiological factors. The survey, enriched by new bibliographical data, will allow the ecologico-economical appreciation of the hunting-at-large-fowl, needed for monitoring the biological resources of the Amu-Dar'ya region, as well as to elaborate the measures for conservation and rational use of their diversity in Karakalpakstan, Khoresm and Bukhra velayats (administrative districts) of Uzbekistan and in the Dashkhovuz and Lebap velayats of Turkmenistan.

References

a) In Russian

1. Ametov, M., 1981: 'Birds of the Karakalpak and their Protection'. Nukus: 137 p.
2. Velikanov, V.P. & Khokhlov, A.N., 1979: 'On Ornithofauna and Peculiarities of Fowl and Nearby Water Birds of the Sarykamysh Lake'. Trudi Kizylchalskogo zapovednika. Baku 1:236-240.
3. Zaletaev, V.S., 1989. 'Displacement of Nesting Places and Concentration of Pelecaniformes in the southern Aral Region as a Response to Both Desertification and the Appearance of Accumulation Water Bodies'. Vsesouyznoe sovechshanie po problemam kadastra i ucheota zhivotnogo mira. Ufa 3:90-92.
4. Lukashevich, P.B., 1990. 'Impact of Water Factor on the Structure and Functioning of the Hydrophylous Ornithocomplexes in the Amu-Dar'ya Delta'. Moscow: 14 p.
5. Lukashevich, P.B. & Ametov, M.B., 1990. 'Pelicans in the Lower Reaches of the Amu-Dar'ya'. In: Materialy 3 respublikanskoi konferentsii Tashkent: 51-53.
6. Rustamov, A.K., 1945. 'Biocoenotic Groupings and Geographical Spread of Birds of the Amu-Dar'ya Flood Plain'. Izvestiya Turkmenskogo filiala Akademii nauk SSSR.2: 65-72.
7. Rustamov, A.K., 1948. 'On the Modern Physiognomy of the Sarykamysh Basin Avifauna'. Dokladi Akademii nauk SSSR 60/8: 1449-1451.
8. Eminov,A.E., Saparmuradov,D.S. and Kozlov, A.N., 1987. 'On Ornithofauna of Some Islands of the Sarykamysh Lake'. Izvestiya Akademii nauk Turkmenskoy SSSR 2: 17-21.

b) In English

9. Whittaker, R.H., 1960. 'Vegetation of the Siskitou Mountains, Oregon and California'. Ecol. Monogr. 30:279-338.
10. Whittaker, R.H., 1965. 'Dominance and Diversity in Land Plant Communities'. Science 147: 250-260.

Table 1. Number of water and swamp birds in (a) Spring-Summer and (b) Winter

Orders and Families		Pelecaniformes		Ciconiiformes		Anseriformes		Rallidae		Laridae		Total		
Name of Water Body (See Fig. 1)	Seasons	1	2	1	2	1	2	1	2	1	2	1	2	%
1. Flood plain from Mukry to Kerki	a	1	0.002	2	0.4	6	0.3	0	0	2	0.4	11	1.1	0.1
	b	3	0.5	2	0.4	7	106.0	0	0	3	0.1	15	107.0	3.7
2. From Kerki to Karabekavul	a	1	0.02	3	0.3	4	0.4	0	0	5	0.5	13	1.2	0.1
	b	2	0.9	2	0.4	10	293.0	1	0.05	2	0.1	17	294.4	10.2
3. Karabekavul to Chardzhev	a	2	0.1	2	0.1	5	0.4	0	0	4	0.1	13	0.7	0.07
	b	3	2.1	3	0.6	10	98.0	0	0	2	0.3	18	101.0	3.5
4. From Chardzhev to Seidi	a	1	0.008	3	0.2	4	0.2	0	0	3	0.4	11	0.8	0.08
	b	1	0.1	2	0.4	8	119.0	0	0	1	0.1	12	119.6	4.1
5. From Seidi to Darganata	a	3	0.1	3	0.3	4	0.05	1	0.003	3	0.2	14	0.6	0.06
	b	3	0.1	2	0.1	10	5.2	0	0	3	0.01	18	5.4	0.2
6. From Darganata to Tuyamuyun reservoir	a	4	0.7	2	0.1	5	0.2	0	0	4	0.2	15	1.2	0.1
	b	1	0.4	2	0.1	6	8.8	0	0	2	0.04	11	9.3	0.3
7. From Gazochak to Nukus	a	–	–	–	–	–	–	–	–	–	–	–	–	–
	b	0	0	2	0.4	2	55.0	0	0	1	0.02	5	55.4	–
Total for within flood plain	a	4	0.9	3	1.4	9	1.5	1	0.003	5	1.8	22	5.6	0.5
	b	4	4.1	3	2.4	18	685.0	1	0.05	4	0.7	30	692.2	24.0
9. Zeid reservoir	a	–	–	–	–	–	–	–	–	–	–	–	–	–
	b	1	2.1	2	0.8	6	36.0	1	30.0	0	0	10	68.9	2.4
10-11. Keliffs lakes	a	3	0.2	3	2.1	7	1.7	2	18.8	5	9.9	21	33.8	3.25
	b	6	10.7	5	1.8	22	216.0	1	65.8	3	1.3	39	295.6	10.2
14. Dengizgul lake	a	–	–	–	–	–	–	–	–	–	–	–	–	–
	b	3	2.6	2	0.3	12	123.0	1	289.0	2	0.9	20	415.8	14.4
15. Shorkuduk lake	a	1	40.0	2	84.0	0	0	0	0	4	745.0	7	869.0	83.9
	b	1	0.1	0	0	4	63.0	1	60.0	0	0	6	123.1	4.3
17. Tailak & Turangulduz lakes	a	0	0	0	0	0	0	0	0	1	24.0	1	24.0	2.3
	b	0	0	2	8.8	6	43.0	1	90.0	2	41.0	11	182.8	6.3

Orders & Families		Pelecaniformes		Ciconiiformes		Anseriformes		Rallidae		Laridae		Total		
Name of Water Body (See Fig. 1)	Seasons	1	2	1	2	1	2	1	2	1	2	1	2	%
18. Kizylburun lake	a	1	25.5	2	4.0	0	0	0	0	3	27.7	6	57.2	5.5
	b	2	16.2	1	3.3	10	60.0	1	44.0	2	3.5	16	127.0	4.4
19. Soltandag lake	a	4	3.9	2	4.2	5	0.9	2	2.9	4	3.6	17	15.5	1.5
	b	3	14.4	2	3.9	10	9.3	1	13.4	3	1.9	19	42.9	1.5
20. Mekhedzhan canal	a	0	0	0	0	1	16.7	0	0	1	0.2	2	16.9	1.6
	b	3	59.0	2	68.0	6	195.0	1	55.0	1	0.9	13	377.9	13.1
21. Ainakul lake	a	–	–	–	–	–	–	–	–	–	–	–	–	–
	b	0	0	2	14.9	4	75.0	1	5.0	1	25.0	7	119.9	4.2
23. Flood areas west of Chardzev	a	–	–	–	–	–	–	–	–	–	–	–	–	–
	b	3	15.3	2	43.8	6	102.0	1	15.4	2	19.2	14	195.7	6.8
24. Romanguldogadzhik lake	a	–	–	–	–	–	–	–	–	–	–	–	–	–
	b	3	59.3	2	0.4	5	18.0	1	6.0	1	0.4	12	84.1	2.9
25. Kattashor lake	a	1	1.2	3	0.8	4	2.3	0	0	3	3.5	11	78.0	7.5
	b	3	15.5	3	4.8	10	98.0	1	28.0	4	5.9	21	152.2	5.3
35. Soltandzhar reservoir	a	3	2.0	3	0.03	4	0.1	0	0	4	0.4	14	2.5	0.2
	b	2	0.1	2	0.003	9	5.1	1	0.1	2	0.1	16	5.4	0.2
44. Kernai lake	a	3	2.0	2	0.5	0	0	0	0	2	1.5	7	4.0	0.4
	b	–	–	–	–	–	–	–	–	–	–	–	–	–
Total for lakes and reservoirs	a	4	74.8	4	95.6	8	22.7	3	21.7	6	815.8	25	1030.6	99.5
	b	4	195.3	4	150.8	17	1043.0	1	702.0	4	100.1	30	2191.3	76.0
Total for all water bodies	**a**	**4**	**75.7**	**5**	**97.0**	**20**	**24.2**	**3**	**21.7**	**7**	**817.6**	**39**	**1036.2**	**100.0**
	b	**6**	**199.4**	**5**	**153.8**	**22**	**1728.0**	**1**	**702.0**	**4**	**100.8**	**38**	**2883.5**	**100.0**

Note: 1. - Number of species
2. - bird individuals per km^2

Table 2. Maximal number of some birds of the Amu-Dar'ya river delta lakes in the nesting season (R.V. Lukashevich, 1990)

Species	Lake systems				Total
	Suchoche	Karadzhar	Toguzture	Koksu	
Egretta alba	160	160	400	-	720
Platalea leucorodia	280	240	480	-	1,000
Plegadis falcinellus	500	1,800	500	-	2,800
Cygnus olor	140	20	80	540	780

Table 3. Number of water and swamp birds by species on delta lakes in Autumn

Lakes (See fig.2)	Years	Groups of Species							Total
		Coot	Ducks	Geese	Swans	Cormo-rants	Herons	Gulls	
1	2	3	4	5	6	7	8	9	10
1. Kernai	1994	700	70	–	2	13	–	50	835
	1995	1,600	17,400	–	5	1,000	2	27	20,034
2. Dautkul	1993	600	800	16	–	260	29	?	1,705
	1994	5,400	7,200	144	–	1,890	270	?	14,904
	1995	370	30,230	–	–	17	2	50	30,669
3. Sudoche	1992	41,600	29,500	9,360	?	12,650	3,100	?	96,210
	1993	36,860	27,388	8,333	?	13,060	2,800	?	88,441
	1994	7,900	3,880	866	77	2,430	–	?14	15,147
	1995	430	965	180	38	4	2		1,633
4. Mezdurechenskie	1992	2,980	16,250	105	?	3,980	2,150	?	25,465
(Shage & Zakirkul)	1993	30,600	15,950	86	?	4,070	1,700	?	52,406
	1994	12,600	12,290	869	124	13,480	–	?	39,363
5. Adzhibai	1995	–	–	–	–	–	2	–	2
6. Muinakskie	1992	3,300	11,779	1,957	?	480	?	?	17,516
	1993	800	850	13	6	60	39	?	1,768
	1995	3	100	–	–	–	–	7	110
7. Sarbas	1995	140	4,200	–	–	1	–	8	4,349
8. Dumalak	1994	2,160	3,160	72	24	144	118	?	5,678
9. Abbas	1995	–	–	–	–	–	10	–	10
10. Zhiltyrbas	1992	11,980	27,500	350	–	2,700	8,350	?	50,880
	1993	12,780	28,200	284	–	2,270	8,744	?	52,278
	1995	20	93	–	55	–	–	–	168
11. Koksu	1995	40	110	9	38	2	180	34	413
12. Karateren	1994	560	162	–	–	30	–	65	817
	1995	3	285	–	–	4	–	4	296
Average:			**9,933**	**1,509**	**41**	**2,788**	**1,719**	**29**	**23,559**
%:		**32.0**	**42.2**	**6.4**	**0.2**	**11.8**	**7.3**	**0.1**	**100**

Table 4. Number of water and swamp birds in the Southern Sarykamysh in April-June

Species	Number of bird individuals/sq. km						
	1984	1985	1986	1987	1988	Average	%
Nesting:							
Fulica atra	5.0	397.8	1006.0	520.0	322.9	450.3+/-162.9	57.0
Netta rufina	10.8	108.5	11.0	21.0	0.3	32.1+/-19.1	4.1
Larus genei	-	12.3	16.2	16.0	6.2	10.1+/-3.4	1.3
Sterna albifrons	-	4.0	4.6	18.7	3.4	6.1+/-3.7	0.8
Gelochelidon nilotica	-	7.7	5.7	6.3	5.3	5.0+/-0.5	0.6
Himantopus himantopus	2.1	5.3	7.2	3.7	1.3	3.9+/-1.1	0.5
Podiceps cristatus	0.5	0.5	1.8	1.4	12.1	3.3+/-2.2	0.4
Anas platyrhynchos	0.04	0.7	1.4	4.2	6.4	2.5+/-1.2	0.3
Vanellochettusia leucura	0.8	1.1	1.4	5.5	1.7	2.1+/-0.2	0.3
Tadorna tadorna	0.7	2.4	2.1	2.4	2.0	1.9+/-0.3	0.2
Plegadis falcinellus	0.3	1.4	0.7	0.4	3.6	1.3+/-0.6	0.1
Sterna hirundo	-	0.5	1.7	1.9	1.1	1.0+/-0.3	0.1
Ardea cinerea	0.5	0.5	1.0	0.9	0.9	0.8+/-0.1	0.1
Larus argentatus	-	0.7	0.2	0.7	1.9	0.7+/-0.5	0.1
Charadrius alexandrinus	1.2	0.9	0.5	0.7	0.2	0.6+/-0.2	0.1
total	24.1	544.7	1062.0	604.5	378.6	522.1+/-13.0	66.0
Migratory:							
Phalaropus lobatus	3.7	16.4	2.8	639.6	6.4	133.8+/-126.5	16.9
Aythya fuligula	3.2	0.7	10.4	106.5	182.7	60.7+/-36.3	7.7
Aythya ferina	3.7	6.4	36.7	190.6	11.7	49.8+/-35.7	6.3
Tringa glareola	1.1	7.9	6.6	8.9	2.4	5.4+/-1.5	0.7
Tringa ochropus	3.2	6.3	2.0	7.1	2.2	4.1+/-1.1	0.5
Mergus albellus	-	1.6	0.5	4.5	5.3	2.4+/-1.1	0.3
Bucephala clangula	1.2	3.6	0.7	3.2	1.4	2.0+/-0.6	0.2
Tringa totanus	3.3	0.6	3.7	0.7	0.7	1.8+/-0.7	0.2
Tringa stagnatilis	0.3	3.7	0.4	0.09	0.6	1.0+/-0.2	0.1
Anas crecca	0.2	0.6	1.6	0.8	1.0	0.8+/-0.2	0.09
Anas clypeata	0.1	0.5	0.6	0.3	0.5	0.4+/-0.09	0.07
Egretta alba	0.1	0.4	0.5	0.7	0.3	0.4+/-0.1	0.06
Ardea purpurea	0.09	0.4	0.2	0.4	0.5	0.3+/-0.08	0.05
total	20.2	49.1	66.6	963.4	215.6	273.9+/-15.7	34.0
Total	**44.3**	**593.8**	**1128.6**	**1567.9**	**594.2**	**796.0+/-14.3**	**100.0**

Table 5. Number of living nests of flocked birds on Sarykamysh lake through species

Years	1984	1985	1986	1987	1988	1989	Average:	
Species							**No.**	**%**
Phalacrocorax carbo	3600	2900	3500	4886	2005	3157	3341	61.0
Larus genei	14	-	800	-	700	4000	919	16.8
Gelochelidon nilotica	240	400	1000	100	1000	1170	652	12.0
Larus argentatus	70	100	180	303	354	200	201	3.8
Pelecanus crispus	48	175	87	215	100	142	128	2.4
Pelecanus onocrotalus	-	36	2	105	-	457	100	1.9
Sterna hirundo	-	-	-	-	150	190	57	1.1
Hydroprogne caspia	-	16	8	1	45	128	33	0.7
Plegadis falcinellus	-	17	-	-	5	3	4	0.1
Total	**3972**	**3644**	**5657**	**5700**	**4469**	**9547**	**5498**	**100.0**

Figure 1. Water/swamp bird habitats in the belt influenced by the Amu-Dar'ya river

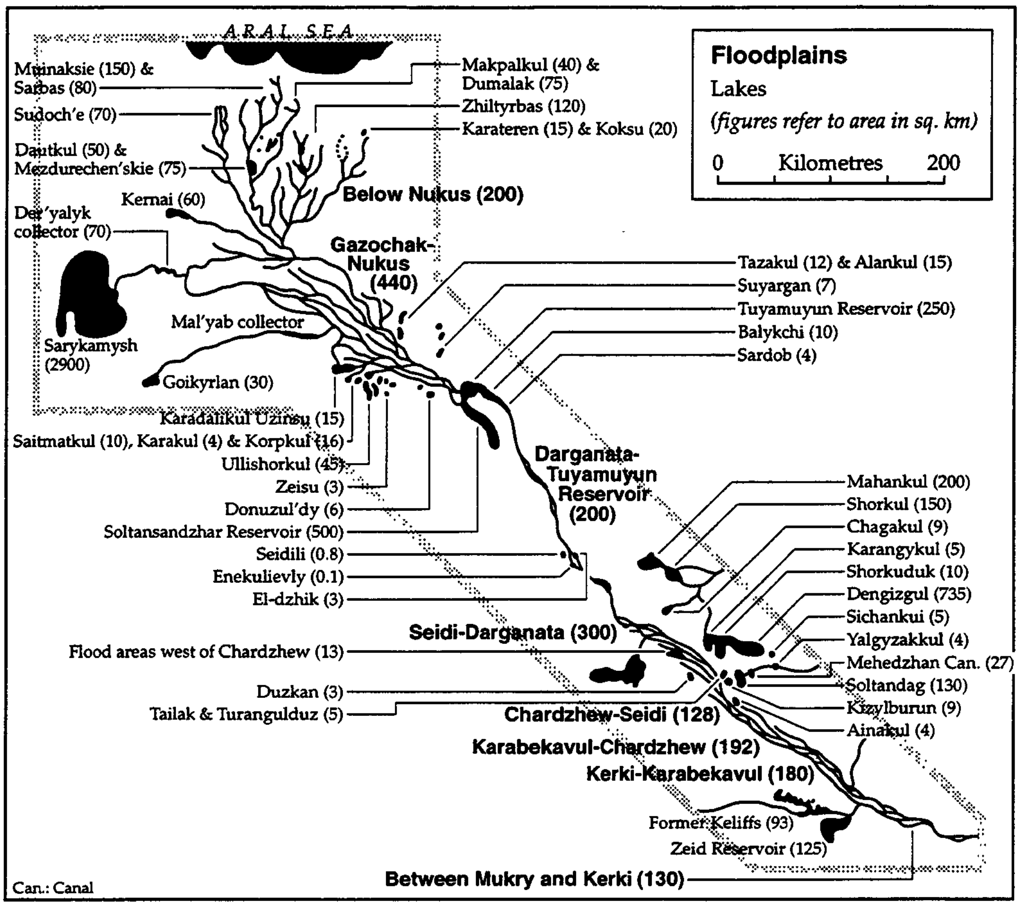
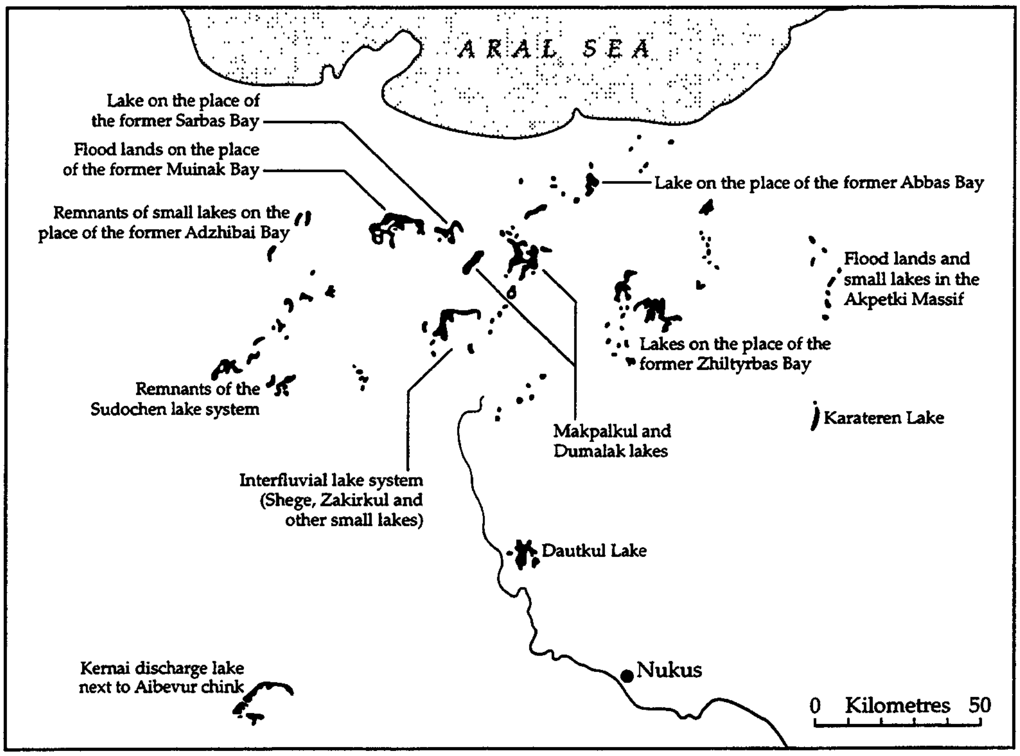


Figure 2. The state of lakes and flood lands in the Amu-Dar'ya delta around Summer 1995



ECOLOGY OF WILD MAMMALS AND PARASITES AND THEIR ROLE IN CARRYING INFECTIONS IN THE ARAL SEA AREA

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Changes occurring in the ecosystem of the Aral Sea Basin in the second half of the 20th century have attained global scale and have disrupted many years' dynamic balance in nature (Glazovsky, 1990; Reimov, 1992; Reimov, Konstantinova, 1992). As a consequence of anthropogenic impacts, the Aral Sea continues to shrink, with continuing desertification of the Amu-Dar'ya and Syr-Dar'ya deltas. Extremely dangerous diseases may now expand in Central Asia, due to the invasion of the vast desert area around the Aral Sea by rodents and other desert species of animals - carriers of infections. Therefore, the assessment of the role of mammals and their parasites in the desert landscape of the Aral Sea area is of great theoretical and practical significance.

The main objectives of our investigations have been:

- study of relief and landscape changes in the Southern Aral Sea area, and the distribution of wild mammals in various biotopes of the dried territory of the region;
- comparative analyses of theriopopulation, definition of number, extent and participation of wild mammals and their parasites in epizootologic processes on the investigated area;
- classification of the dried area of the Southern Aral Sea in terms of potential epizootic threat;
- large-scale cartography of spreading and abundance of infection disease carriers in the region.

Region of investigation: changes of relief and landscape of the Southern Aral Sea area under the impact of anthropogenic desertification

The landscape complex of the Southern Aral Sea comprises sandy (north-western Kyzylkum and Zaunguz Karakum) and gypseous deserts (Southern Ust-Jurt) adjacent to the Aral Sea, valleys (Khorezm oasis) and deltas of the Amu-Dar'ya, adjacent to the Turan lowland area. The specific nature complexes of the region (oasis, sandy and gypseous deserts, tugai and reed thickets, reservoirs, desiccated sea bed) have their typical landscape, vegetation and fauna, in accordance with the type of relief, climate, hydrothermic regime, soils, communities of organisms.

The Aral Sea used to be the largest hydrographic system, the most important climate regulator, located at the junction of the vast deserts of Karakum, Kyzylkum and the Ust-Jurt plateau. Under anthropogenic impact and the use of the Amu-Dar'ya and Syr-Dar'ya waters for irrigation, the Sea is shrinking and an unstable, saline wasteland is formed in its place, dispersed by the wind. The Amu-Dar'ya and Syr-Dar'ya deltas, the inter-oasis and peripheral lakes of Khorezm oasis and Kzyl-Orda region, have all been greatly transformed. In the 1930s, 146 big lakes existed in the Amu-Dar'ya delta, with a total area of 600 km^2; in the 1950-60s, they were reduced to

300 km². Tugai thickets, which offered habitat to many animal species, extended along the Amu-Dar'ya and its channels, down to the Sea, over a total area of about 650,000 hectares. Lake-marsh forms of reed occupied over 1,200,000 ha.

The area of tugai-influenced landscapes has decreased by more than 10 times; only relics remain from the real Tugai forests. In the Amu-Dar'ya delta, all the bays dried out, the area of the preserved lakes being reduced to 12-15 thousand hectares. Table 1 shows the change of the surface area of land and watered lots of the Amu-Dar'ya for the last 30 years. The geosystems which developed on the dry sea bed and former sand bays, over an area of 30,000 km², consist of fine sands and various saline soils, with almost no vegetation. Thus, the increasing anthropogenic transformation has considerably changed the ecological conditions of animal habitat, and disrupted the natural balance and biodiversity of the fauna (Reimov, 1985, 1992).

Investigation methods and material

Common methods of ecological field experiments were used in the investigations (Novikov, 1953; Reimov, 1972). The population density of rodents and other small mammals was based on route-colony stock-registration of inhabited holes of rodents, 'trap sites' and 'trap per day' (USSR Academy of Sciences Moscow, 1958, 1971). Material on ectoparasites of rodents (fleas, mites) were collected by methods applied by antiplague organizations (Serjanov, 1965).

Territory-biotope distribution, numbers of mammals on the dry territory of the Aral Sea, in oasis and adjacent deserts were elaborated. Large-scale maps of rodent settlements and population structures were prepared. Material was collected on stationary lots of the Amu-Dar'ya delta and dry Sea bed, in the Spring-Summer-Autumn periods of 1993-95. Stationary research was conducted in various environmental lots (in the Amu-Dar'ya delta, on the dry bottom of the former Ajibay-Jyltyrbas bay, in the Karabayly-Akbetkey archipelago and dry part of the Aral Sea), located in the transition zone between the desertifying part of the Amu-Dar'ya delta and the dry Sea bed (Reimov and Seitnazarov, 1994).

On the basis of lithology and phytocenoses, we can distinguish in the region four biotopes (Table 2).

Research results and analysis

The theriopopulation of the Southern Aral Sea area and its significance as vectors of infective diseases

65 mammal species, related to 6 groups, 16 families, 44 genera, have been recorded in the region investigated (Reimov, 1972, 1985). The centre of this region is the habitation area for 34 species (51.6%), the northern and northwestern border for 30 species (31.4%) and the southern and southwestern border for the rest of the species.

Almost half of the theriofauna (47.9%) of the southern Aral Sea area are animals of the desert faunistic complex, 27.7% of species are widely spread in the zones of semi-deserts and dry steppes, and the rest are species of intra-zonal biotopes.

Table 3 shows the distribution of mammals in different environments of the Southern Aral Sea area. In recent years, owing to the radical changes of nature biocomplexes of the region, theriofauna composition has lost 6 species out of the remaining 59 (Table 4).

Not all species take part in the epizootologic process. The most significant species are dominant, numerous and mobile, having close inter-population contacts and are sensitive to different diseases. Such species at the centres of plague infection in

Kyzylkums are *Rhombomys opimus* and *Meriones merdianus, Citellus fulvus, Spermophilopsis leptodactylus,* in Ustiurt - *Rhombomys opimus* and *Meriones erythrourus,* and *Citellus pygmaeus.* In the oases and the Amu-Dar'ya delta, humidity-loving species are significant - *Meriones tamariscinus, Nesokia indica* and some species of jerboa (*Jaculus*) and also *Mus musculus, Cricetulus migratorius* etc., living in ecotones (sands-oasis) and in residental areas.

Despite the wide spreading and large numbers of some species of domestic and wild animals, their epizootic significance is limited. As these rare and less numerous species can not be considered as distributors of various dangerous infections, we turned our attention to study the density and parasitofauna of rodent species, which are extremely important in spreading dangerous infections.

Abundance and reproduction of landscape species of rodents

During the 3 years of stationary observations, we established that many ecological processes on the dried territories southwards of the Aral Sea shore, correspond to recorded parameters of abiotic and biotic factors of adjacent landscape-geographical lots of sandy and gypseous deserts. So, reproduction dynamics of numbers of rodents on the above-mentioned environmentally different places in general are taking place normally. Here, obviously general changes in weather conditions, vegetation communities and other vital factors seem to be important.

In the last 3 years, populations of *Rhombomys opimus* and *Meriones meridianus* in the Karakalpakstan part of Kyzylkum have been in a phase of deep depression. In October 1990 their average number was 5.0 animals per 1 hectares, habitation index of colonies being 63.8, in 1994 these indices were 2.1 and 46.9%, respectively. The cold period of 1993-94 was extremely unfavourable for desert rodents and their ectoparasites. Winter arrived early (by the end of October), and was long and cold (snow started on November 12-15 and lasted to late March). This affected negatively the physiological state, activity and food-supply of animals. The Winter mortality rate of many rodents species was two or three times higher than in many previous years. Aggravation of their general physiological state and fatness influenced their sexual potency to some extent and the initial phases of their reproduction were delayed.

Rhombomys opimus is widely spread in the deserts of Kyzylkum, Karakum and Ustiurt. Fairly abundant on the oasis fringes and island sands, and in some places of the dried sea bottom, the animals reach the desertified areas of the oasis and Amu-Dar'ya delta, increasing the frequency of contacts with sinanthropous animal species. Over 15-20% of the Amu-Dar'ya delta area and the dried part of the sea bed are occupied by island sands and sandy areas, stabilized by vegetation to different extents: plump soils and salines, covered by scarce bushes of *Salsola* and *Tamarix.* Here, settlements of *Meriones* are found, with a colony density of 1.0-2.0 in the centre and up to 1.8-2.5 per hectares at the fringes.

The number of *Rhombomys opimus* on the vast territories of the Kyzylkum autonomous plague seat was comparatively low by the Autumn of 1992: on an average 1.88 animals per 1 hectare, the *Rhombomys opimus* reached 65-80%, so the population density in the following Spring was only 1.0-1.2 animals per 1 hectares, with an habitation rate of 15-30%. On the territory of Ustiurt, from Autumn 1992 to Spring 1993, the natural mortality of *Rhombomys opimus* was 41.7% on the plains, 63.6% in areas of *Haloxylon* growth. On the first lot, from Autumn to Spring, the number changed with an average of 2.4 to 1.4 animals per 1 hectare, habitation rate of the colonies being 50.4% and 61.5%, respectively. Thus, in general, the number of *Rhombomys opimus* on all investigated places in Spring 1993 was not very high, but stayed at the same level as in 1992. On the dried bed of the former Ajibay Bay and Tokmak-Ata island (Muinak), no animals were caught and residential colonies of this species were not ascertained.

In 1993-94, the weather conditions in Winter and Spring were extremely unfavourable. In the sands of north-western Kyzylkums, the number of animals per hectare decreased from 3.1 in Spring 1993, to 0.8 in Spring 1994; on the southern Ustiurt, from 1.7 to 0.6 specimens, respectively. On inter-oasis sands and the dried sea bed, the number of specimens/hectares varied between 2.1 in Autumn 1993 and 0.9 in Spring 1994.

Variations of live-stock of *Rhombomys opimus* from Autumn 1994 to Spring 1995 were again within the range of data for many years (1950-90) (Table 5).

In 1993, the reproduction intensity of *Rhombomys opimus* in the investigated area was at a higher level than in many previous years. The average number of embryos per female was 6.6, with an average 31.4% of pregnant animals. In the Kyzylkum desert of the Pre-Aral Sea area, in the Autumn of 1993, the average number of animals per hectare increased 3.6 times (between 1.5 and 5.6 times), in Western Kyzylkum up to 4.0 (2.2-5.6) times, in the outskirts of sands of Nukus up to 2.1 (1.0-4.5) times, the habitation rate of colonies being 38.4-60.0%. The number of *Rhombomys opimus* on the territory of stationary investigation from Spring to Autumn increased from 0.8-1.7 to 2.1-3.7, on the average.

In consequence of the protracted Spring in 1994-95, reproduction started 10-15 days later, but the reproduction rate was higher and lasted longer (to mid October). All the wintered individuals and a considerable number of females from the first hatch (up to 65%), took part in the reproduction. The maximum peak of pregnancy - 74.3% was recorded in the second and the third decade of April; in May, the number of pregnant individuals averaging 68.0-56.3-32.5%, and in June - 15.4-9.1-17.6%, respectively. Further on, at the beginning of July, 17.9% of females were pregnant in late August - 15.8%, and decreased to mid October (from 7.1 to 0.2%). The first young animals appeared on the surface by early May, representing 34.3% of the population, and 68.3% by late May-June. One wintered female hatched 3.25 times on average, with a total number of 20.2 young animals by the end of the season. The course and character of reproduction of *Rhombomys opimus* were similar, in general, on the island, sandy areas of the oasis and the Amu-Dar'ya delta and on the Ustiurt. *Rhombomys opimus* strives to realize its potential reproductive abilities everywhere (Table 6).

Owing to the intensive and prolonged reproduction, the number of *Rhombomys opimus* sharply increased in Autumn 1995: in Kyzylkum it averaged - 2.2-3.5 animals per hectare, on Ustiurt - 2.3-3.2; in islands sands - 2.1-2.5; on the dried sea bed - 1.6-2.0. The habitation rate of colonies varied from 25.0% to 65%, depending on the state of biotopes.

The common species composition of fleas, typical of this type, was detected in *Rhombomys opimus* and in their holes. The index of abundance of fleas in the fur of *Rhombomys opimus* varied from 0.5 to 6.0.

Meriones meridianus is spread unevenly over the oases and the Amu-Dar'ya delta, and its number is not high. In Ustiurt, the number of this species in Autumn was at the level of the previous years (1991-93) and varied in the average range of 2.0-3.5% (Table 7).

34 species of fleas were found on *Meriones meridianus* (Romanovsky et al., 1957), in oases - 13 (Asenov, 1968).

Meriones erythrourus (lybicus) is spread in Ustiurt and North-western Kyzylkums, while in oases and the Amu-Dar'ya delta this species was almost not found. It started to settle on the dried Aral Sea bottom, but its number is not high. We have detected this species on the sandy land, covered by *Haloxylon* and *Tamarix* at the foot of the Ustiurt plateau (cape Uzyn Kayr) and on the dried bed of former Ajibay Bay. The number and course of reproduction of this *Meriones* in 1993-95 is shown in Table 7.

Meriones tamariscinus is widely spread in the valley and the Amu-Dar'ya delta, and its number is very high. In the deserts of Kyzylkum and Ustiurt this species is not ascertained. By number, it averaged 5-6% of rodents caught (sometimes up to 16%-20%) in Spring 1993, and two or three times more in Autumn. Variations in number of this species are shown in Table 7, similar to data for many previous years (Reimov, 1987).

This *Meriones* has 29 species of fleas and 4 species of ticks (Serjanov, 1965; Asenov, 1968).

Mus musculus is widely spread in the fauna of the Aral Sea region. It lives here both in residential areas and natural plots (Table 8). It dominates in tugais and reed thickets, wastelands covered by herbs, and on crop fields (Reimov, 1987). In nature, it reproduces from March to December, and sometimes even in Winter. Its reproduction intensity in 1993-95 is shown in Table 9.

On *Mus musculus*, 14 species of fleas were found, 4 species of ticks and 1 species of Cestodes (Serjanov, 1965; Davlatov, 1967; Asenov, 1968; Reimov, 1987).

Nesokia indica is widely spread in the oases and delta. In terms of number, it dominated over other rodents. It lives only in wetland biotopes, in reed thickets and shrubs, bank tugays, on the banks of collectors and canals. In the samples, the number of *Nesokia indica* was not high, only in some places were there 2-3 animals per 1 hectare.

Fleas were not found on the 27 inspected rats.

Besides the mentioned species of rodents, in the sampling sites 19 species of mammals were also recorded, their number usually not being high.

Parasites of rodents

In order to find out biocenotic links and to explain the epizootic process of plague and other extremely dangerous infections, the ectoparasitofauna of *Meriones, Rhombomys opimus* and other species of mammals was studied.

98 species of fleas, related to 10 genera, are specific parasites of *Meriones*. They are unevenly distributed within the borders of their host area (mostly rodents). Most species of fleas (69) belong to the genus *Xenopsylla*, 36 species of which were encountered in the samples, and 19 of them are distributed only in the desert part of the Palearctic.

Among the mammals studied (over 200 thousand), relating to 35 species (4 species of *Meriones*, Suslic - 3; Gerbil (*Jaculus*) - 13; *Mus* and alike - 3; field mice - 3; insect-eating species - 3; small predators - 5), only 10 take part in epizootic process (of plague).

Rhombomys opimus is the main carrier of plague in the focus, with no comparison in number and expansion among other desert rodents. On this species there are 27 species of fleas and 8 species of ticks.

According to bibliographical data, there are about 30 species of ticks in rodents and in their holes. We may suppose that rodents (*Rhombomys, Meriones*) also take part in the circulation of ricketsiosis, spirochetosis, fever and some arboviruses, associated with ticks. 17 species of helmints are ascertained among *Rhombomys opimus*.

Rhombomys opimus has more than 10 zoonoseous infections, including an extremely dangerous one - the plague (see Figure 1). In the investigated area, natural infections of skin leishmaniasis exist. Skin analysis of seasonal changes showed that the level of infection usually increases in the second half of June, and reaches its maximum in August - September (i.e. in the period of the highest number of mosquitoes - *Phletomus papatasi, Ph. alexandri, Ph. caucasicus, Ph. andrejevi, Ph. mongolensis, Ph. sergenti, Ph. smirnovi, Sergentonyis arpaklensis, S. grecovi*). Total contamination by skin leishmaniasis of *Rhombomys opimus* varies by years within the range of 60-85%.

Differentiation of the Southern Aral Sea area in respect to its potential hazard of infections caused by ectoparasites

On the dried sea bed and the Amu-Dar'ya delta, specific biotopes with domination of xerophile and halophile vegetation communities appeared. They are related to traversed reliefs of sandy and saline deserts. Favourable conditions are created here for large populations of psammophyle rodents and other animals. Analyses of species spectrum of carriers, their population density and of biocenotic links, back the idea of potential forms of plague and a number of other extremely dangerous infections (such as cholera, Siberian ulcer, brucellosis, leishmaniasis, etc.).

Fauna on the dried sea bed is formed by the spreading of species, inhabiting the adjacent regions - north western Kyzylkums, the Amu-Dar'ya delta and the Ustiurt (Reimov, 1994). Investigations of the dried sea bed (over a distance of 100 kilometers from South to North, and 120 kilometers from West to East), and also of former shallow water regions at the edge of adjacent lots of desert (Kyzylkum and Ustiurt) show a significant increase of the number and change in the distribution of wild mammals and arthropod ectoparasites in 1993-95. Nevertheless, the number of rodents on stationary lots in comparison with sandy deserts was low (Tables 2, 7).

The following general pattern of fauna formation on the landscapes of the dried sea bed could be observed: mesophyle species of small mammals, related to wetlands, settle at the early developmental stage (2-5 years). Then, with increasing desertification and evolution of desert vegetation communities, psammophyle species began to prevail. On the dried bed of the former bay and in the environs of Uchsay - Kyzylkayr, *Rhombomys opimus* colonies could not be assessed. Here, trapping of *Meriones meridianus* varied from 3% to 5%; *M. tamariscinus* 1-2%; *M. erythrourus* 3-4%; *Mus musculus* 2-5%. The number of *Meriones* considerably increased when approaching the eastern edge of Ustiurt.

On stations in Erjan-Atau and Akbetkey environs, the number of rodents was also not high. Density of colonies of *Rhombomys opimus* - main carrier of plague - usually increased from West to East. The settling of *Rhombomys opimus* and other rodents significantly decreased with the distance from the former sea shore, northwards into the dried zone.

Thus, the newly created vast areas of sandy and saline deserts on the dried Aral Sea bed offer favourable conditions for the development of desert biocenoses, generating new potential seats of extremely dangerous infections. Many years' research on the theriopopulation and their parasitofauna in the South Aral Sea area has confirmed the increasing importance of anthropogenic factors in the dynamics of abundance and species composition of animals in this region. Further shrinking of the Aral Sea will have significant consequences on the transformation of nature and landscape desertification. The expansion of deserts widens the area where psammophyle rodents will multiply, thus increasing the hazard of human contacts with disease carriers, which may lead to an epidemic state in the region.

The proposed zooepizootic regionalization of the Southern Aral Sea area takes into account earlier reports and materials, including the ones which were compiled by the authors in recent years. Doing this, attention was given to the landscape-geographical features of distribution and number of desert rodents (mainly *Meriones, Citellus*), biocenotic links and structure of populations of mammal species and their parasites, as well as to the character of epizootics, possible places of implantation of the plague and its microseats.

By considering the evironmental and biocenotic characteristics, the species spectrum of carriers and other indices, the following natural epizootic lots could be ascertained in the north-western Kyzylkum and on the Southern Ustiurt: ancient Akchadarya Delta, western Kyzylkum, Nukus sands, highland of Beltau, north western (pre-Aral) sands, North-Ustiurt plains, central plains, south plains-saline and Eastern preplateau lot.

The natural-epizootic lots of north-western Kyzylkum and the Southern Ustiurt are described in detail in the authors' previous works (Reimov, 1985, 1987, 1994; Kenjebayev et al. 1987, 1990). The newly created desert areas in the Amu-Dar'ya delta and the dried Aral Sea bed are described here briefly:

- The eastern landscape is mostly sandy, covered by desert vegetation. The area covers about 360-400 thousand hectares, comprising all former islands and channels of Akbetkey archipelago, located in the south-western part of the Aral Sea. Flora and fauna are completely identical with north-western Kyzylkums; they are characterized by dense settlements of psammophyle rodents, with a medium level of ectoparasites. The epizootic past was not studied. The high numbers of rodents and ectoparasites could also encourage the spreading of infections into neighboring lots. Peripheral lots are intensively used for pastures. There are almost no residential areas.

- Pre-delta marginal-saline lot. It has the shape of an elongated strip of 20-35 kilometres, from the mouth of the Amu-Dar'ya up to Beltau highland and occupies a vast territory between the zone of irrigated agriculture and former sea shore (area - 200-250 thousand hectares). It is characterized by the presence of many species of carriers (wild mammals), typical for Kyzylkum and the theriofauna of the lower Amu-Dar'ya region. The main carrier's (*Meriones*) settlement density is low, but in some places high in number and frequent contacts with sinanthropic species are likely, as the settlements are close to residential areas. Epizootics were registered on the lot in 1948 and in 1956. The epizootic index is not high - 0.07, and the epidemic potential and economic significance are low.

- The western pre-Ustiurt occupies part of the Aral Sea between the mouth of Amu-Dar'ya and the edge of the Ustiurt. It consists mainly of sandy-saline plains, covered by shrubs and herbs. Included here are also the pre-hill highlands (Tokpak-Ata-Uchsay) and the dried bed of the former Ajibay bay. Fauna formation is low. The number of small rodent species is not high (trapping - 2-8%). Problems of parasitic diseases are not anticipated within the next 5-7 years.

- Several large collector canals of the drainage network (KS-1, 3, 4, 5 and Ustiurt collector and Raushan) end within the boundaries of the three above described regions, filling numerous depressions and creating shallow lakes. The remains of the Amu-Dar'ya also flow there. From the upper parts of the oases, together with sand, silt and wastes, a large amount of infection germs and agrochemical residuals enter into this area. The microorganisms then arrive into the small, warm-water reservoirs, where they accumulate in great numbers. As these reservoirs are intensively used for hunting, fishing and drinking water for cattle, they can become a source of infection for people.

- The central - dry sea bed or dunes. Includes the former sea bed, dried out in the last 20-30 years, from Kyzylkum cape in the west, to the Kokdarya mouth, etc., Uyali in the east and from former bays in the south up to the cut in the north (about 1-1.5 million hectares). At present, this is a vast sandy-saline valley, with dunelike sands and depressions. The area expands each year, and the flora and fauna are at the initial stage of formation at the marginal strips of the dried area, not more than 20-30 kilometres deep. Settlements of *Rhombomys opimus* are still rare. The number of secondary species of small rodents is less than 4-5 per 1 hectare. Hence, epizootics are not predicted here for the next 5-10 years.

- Siberian ulcer is becoming a real threat in the dried parts of the sea and delta, with centres observed many times in the northern regions of the Republic (Muinak, Kungrad, Chimbay and Takhtakupir). The cattle of these regions are now concentrated and pastured in the zones of lakes with channel outfalls. Reed for fodder is prepared here, and muskrats and fish are caught in the delta reservoirs.

Conclusion

Conditions are enhanced for the existence of desert rodents by the shrinking of the Aral Sea, its bays and delta lake system. Their number significantly increases on the newly created sandy areas. This concerns also the activity of the carriers of extremely dangerous infections. *Rhombomys opimus* with its specific fleas of genus *Xenopsylla* is mainly responsible for the spreading of the plague in the Souuth Aral Sea area. *Meriones meridianus, M. tamariscinus* and *Critellus* are secondary carriers. The possibility of contacts of humans with desert rodents is increasing. Also the epidemiologic significance of *Mus musculus,* which is a carrier of tularemia, has to be observed.

Analyses of the landscape in the region, the biocenotic links, the character of parasitic distribution, the number of carriers, enabled the study of the heterogenity of infections and their origin in the different parts of the country. Large-scale cartography of spreading and numbers of carriers of infectious diseases in the Southern Aral Sea area, is the basis of prediction for each ecological-epizootic region and for proposing measures on prophylactics and controls in the investigated area.

References

Reimov, A. 1972. Ecological and Morphophysiological Analysis of Mammals in the South Aral region. Nukus, pp. 53-61.

Reimov, A. 1985. Mammals of the South Aral Region (ecology, protection and use). Uzbek Academy of Sciences, Tashkent, pp. 18-26.

Reimov, A. 1987. Rodents of the South Aral Region. Uzbek Academy of Sciences, Tashkent, pp.60-63.

Reimov, A.; Seitnazarov, C. 1994. Distribution and Quantity of Mammals in the Amu-Dar'ya Delta. Karakalpakstan Branch of Uzbek Academy of Sciences, Nukus, pp. 36-41.

'For a complete list of the publications cited in this chapter, which exist in Russian only, readers are invited to write directly to Dr Reimov at the Karakalpak Branch of the Academy of Sciences in Uzbekistan'.

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Table 1. Changes of correlations of areas of dry and water lots of the Amu-Dar'ya delta over a period of 30 years

Part of delta	Total area (km^2)	Land		Reservoirs and waterbodies with reed		Swamps	
		1960-1965	1990-1995	1960-1965	1990-1995	1960-1965	1990-1995
Western	3028	30.5*	61.0	29.0	18.5	40.5	20.5
Central	1036	32.4	64.8	21.0	10.3	45.8	24.9
Eastern	2020	46.3	63.2	19.5	9.7	34.2	17.1
Southern (interoasis)	1016	68.6	84.3	16.2	8.1	15.2	7.6
Total	7100	40.8	81.6	23.4	10.7	35.8	7.7

Table 2. Number of species of mammals and correlation of groups in main biotopes on stationary lots (I-IV - number of biotopes; #Spec - number of species)

		Eastern (Akbetkey)				Central (Erjanatau)				Western (Ajibay)					
		I		III		II		IV		III		IV		II	
Order	Family	#Spec	%	#Spec	%	#Spec	%	#Spec	%	#Spec	%	#Spec	%	#Spec	%
Insectivora	Erinacidae	1	6.66	–	–	1	6.25	1	7.69	1	8.33	1	7.14	1	5.88
Lagomorpha	Leporidae	1	6.66	1	10.00	1	6.25	1	7.69	1	8.33	1	7.14	1	5.88
Rodentia	Sciuridae	1	6.66	–	–	1	6.25	–	–	–	–	–	–	1	5.88
	Dipodidae	2	13.32	–	–	2	12.50	2	15.38	2	16.6	2	14.28	1	5.88
	Muridae	–	–	1	10.00	2	12.50	2	15.38	–	–	1	7.14	1	5.88
	Cricetidae	3	19.98	3	30.00	3	18.75	3	23.07	4	33.3	3	21.42	5	29.41
Carnivora	Canidae	2	13.32	2	20.00	3	18.75	1	7.69	2	16.6	1	7.14	2	11.76
	Mustelidae	3	19.98	2	20.00	3	18.75	1	7.69	2	16.6	1	7.14	3	17.65
	Felidae	1	6.66	–	–	–	–	1	7.69	9	8.33	1	7.14	1	5.88
Artiodactyla	Suidae	–	–	–	–	–	–	1	7.69	-	–	1	7.14	–	–
	Bovidae	1	6.66	1	10.00	–	–	–	–	–	–	1	7.14	–	–
Total		15	100	10	100	16	100	13	100	12	100	14	100	17	100

Table 3. Distribution of mammals by nature complexes and biotopes of the Southern Aral Sea area

Landscape-geographical lots	Number of species	Numerous (%)	Ordinary (%)	Rare (%)
Valleys and deltas of Amu-Dar'ya	45	22.30	57.70	20.00
Tugai thickets	28	22.00	50.00	28.60
Reed thickets	16	31.25	31.25	38.50
Agricultural areas (oasis)	31	6.50	54.80	38.70
Island sands & outskirts of oasis	30	16.60	43.40	40.00
Highlands	27	0.00	33.30	66.70
Plump saline deserts	23	4.30	47.80	47.80
Constructions	4	0.00	75.00	25.00
Sandy deserts of Kyzylkum	41	14.80	65.85	19.80
Dunes and slightly fixed sands	25	0.00	28.00	72.00
Fixed hilly sands	38	13.10	47.40	39.50
Loamy plainland and salines	31	3.20	54.80	41.90
Outskirts of artesian	27	7.40	51.80	40.70
Constructions	5	20.00	60.00	20.00
Gypseous deserts of Ust Jurt	41	12.20	60.40	27.40
Clayey plainlands (plateau)	35	11.45	51.45	37.10
Sands and shrubs of...	29	6.90	37.90	55.20
Salines and takyrs	19	0.00	26.30	73.70
Chinks and edges, bluffs	34	8.80	58.80	32.40
Constructions	3	0.00	66.65	33.50
Ancient Sarykamysh delta	33	24.20	51.50	24.20
Deserts with dense soils	29	10.30	65.50	24.10
Half fixed hilly sands	23	13.00	43.50	43.50
Salines and takyrs	9	0.00	22.20	77.80
Tugays-shrubs	26	11.50	57.70	30.80
Edges of plateau and highlands	27	3.70	48.15	48.15
Constructions	5	40.00	20.00	40.00
Dried Aral Sea bed	3	8.70	47.80	43.50
Half fixed sandy deserts	17	11.80	47.10	41.10
Saline plainlands	14	7.10	50.00	42.90

Table 4. Changes of mammals fauna composition of the Southern Aral Sea area in the conditions of degradation of environment

	1960-1965				1990-1995				
Names of groups	Number of species	Numerous (%)	Ordinary (%)	Rare (%)	Number of species	Numerous (%)	Ordinary (%)	Rare (%)	Vanished (%)
Insectivora	4	25	50	25	4	25	25	50	0
Chiroptera	12	33	16.6	50	10	20	20	60	16.6
Lagomorpha	1	100	0	0	1	0	100	0	0
Rodentia	27	51.8	22.2	18.5	27	37	25.9	37	0
Carnivora	16	37.5	31.2	31.2	14	28.6	28.6	43	12.5
Artiodactyla	5	40	40	20	3	0	66.6	33	40
Total	65	43.1	26.1	27.7	59	28.8	28.8	42	9.2

Table 5. Number of *Rhombomys opimus* in various landscapes (per colony)

Landscape-geographical lots	1950-1990		1993		1994		1995	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
North-western Kyzylkum	1.8	3.4	1.2	3.7	0.8	3.0	1.4	3.1
South Ust Jurt	1.2	2.0	1.2	2.3	0.9	2.0	1.0	2.6
Interoasis sands	1	2.3	1.2	2.5	0.6	2.1	0.8	2.2
Dried bed of bays and the sea	0	0	1.2	3.6	0.8	2.7	1.0	3.1

Table 6. Intensity of reproduction of *Rhombomys opimus, Meriones meridianus, M. tamariscinus* and *M. erythrourus* in 1993-95

Name of species	Indices	1993	1994	1995
R. opimus	Share of pregnant females in April-June (%)	21 - 65	30 - 70	33 - 69
	Number of embryos per 1 female	6.0 - 7.1	6.0 - 7.5	6.3 - 7.3
M. tamariscinus	Share of pregnant females in April-June (%)	26 - 38.8	24 - 38	27 - 37.5
	Number of embryos per 1 female	5.1 - 5.9	5.0 - 5.8	4.9 - 5.7
M. meridianus	Share of pregnant females in April-June (%)	22 - 38	25 - 98.1	24.5 - 41.5
	Number of embryos per 1 female	5.0 - 6.0	4.5 - 6.0	4.7 - 6.1
M. erythrourus	Share of pregnant females in April-June (%)	25 - 66	27 - 65	30 - 64
	Number of embryos per 1 female	4.3 - 6.7	4.7 - 6.2	4.2 - 7.0

Table 7. Number of *Meriones* (% of trapped animals) in various landscapes

Species	Landscape-geographical lots	1993		1994		1995	
		Spring	Autumn	Spring	Autumn	Spring	Autumn
Meriones meridianus	North-western Kyzylkum	2.6	5.3	2.8	5.7	2.7	6.1
	Southern Ust Jurt	2.5	7.2	1.8	5.8	2.6	6.2
	Interoasis sands (Amu-Dar'ya delta)	2.9	6.0	2.5	6.9	2.8	6.3
	The dried bed of the Sea and bays	2.7	7.0	1.8	4.9	2.5	6.8
Meriones erythrourus	North-western Kyzylkum	2.9	6.2	0.8	4.5	1.4	4.5
	Southern Ust Jurt	5.2	6.8	2.5	5.4	2.6	5.3
	The dried bed of the Sea and bays	0.8	3.2	0.6	2.9	1.1	4.0
Meriones tamariscinus	Outskirts of oasis and edge of sands	2.8	5.0	1.6	3.1	1.7	3.9
	Amu-Darya delta	1.8	7.5	1.3	7.6	1.6	8.2
	The dried bed of the Sea and bays	0.8	2.6	0.5	3.6	0.7	4.2

Table 8. Number of *Mus musculus* in natural and sinanthropic conditions of habitat

Region of study	Residental areas		Natural conditions	
	% trapped	% of inhabited nest	% trapped	% of inhabited nest
Oasis and valleys	5.2 (1.5-19.5)	9.5-23.1	3.7 (0.5-8.0)	80.0-15.0
Deltas of rivers	5.5 (0.5-20.0)	12.5-26.6	4.6 (1.0-7.6)	8.0-12.5
Dried sea bed			3.2 (2.0-5.8)	
Sandy deserts (Kyzylkum)	4.1 (1.0-22.5)	15.5-21.3	0.3 (0.1-2.5)	
Gypseous deserts	7.5 (0.5-18.5)	15.0-31.9	0.2 (0.1-2.0)	

Table 9. Reproduction of *Mus musculus* and *Nesokia indica* in 1993-95

Species	Indices	1993		1994		1995	
		Populations					
		Residential	Natural	Residential	Natural	Residential	Natural
Mus musculus	Pregnant females (%)	30.3-66.0	35.0-60.0	38.0-50.0	30.0-48.0	28.0-56.0	30.0-45.0
	Embryos per female	6.2-6.8	5.9-6.2	6.0-7.0	6.2-7.2	5.6-6.5	6.3-6.8
Nesokia indica	Pregnant females (%)	35.0-55.0	30.0-62.5	24.5-56.0	35.0-60.0	30.0-50.5	40.0-58.5
	Embryos per female	5.0-5.5	5.1-5.4	4.9-5.7	5.0-5.8	5.0-5.4	5.1-5.5

Figure 1a. Quantity of animals with infections

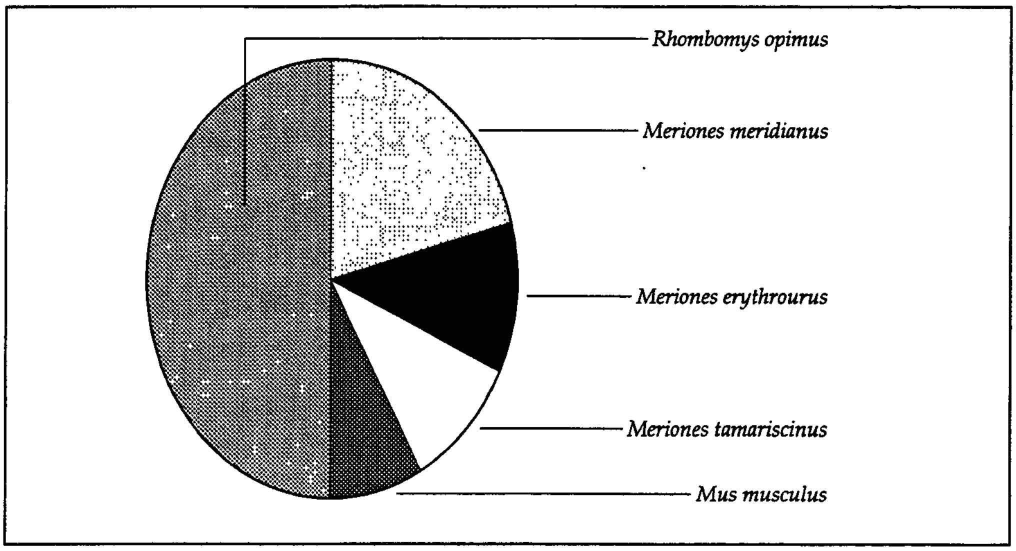
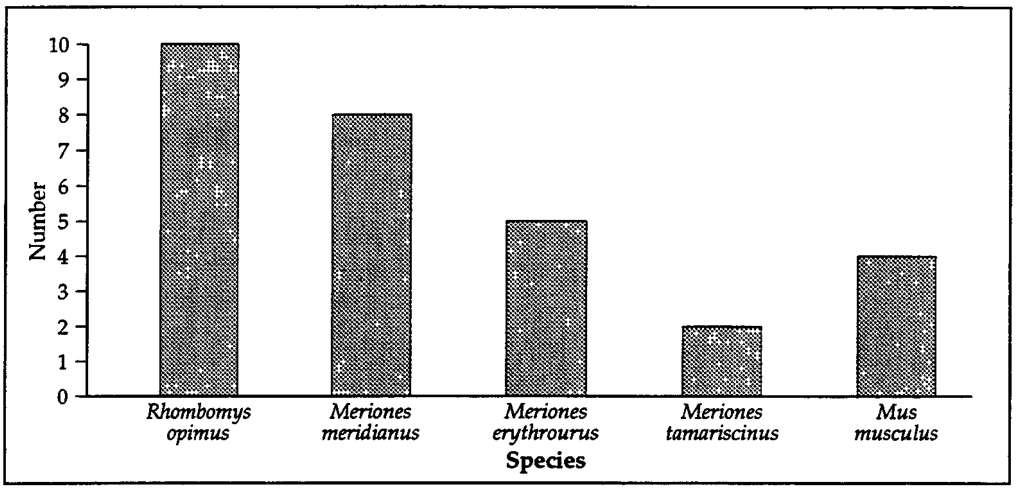


Figure 1b. Quantity of animals with infections



AQUATIC INVERTEBRATES AS INTERMEDIATE HOSTS OF PARASITES

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Introduction

Parasites play an important role in both the natural ecosystems and the productivity of domestic animals. Many parasites of fish, birds and mammals have complicated life cycles, certain stages of which take place in aquatic invertebrates. The intermediate hosts of these parasites are in most cases Cyclopidae and Gastropoda: Cyclopidae are intermediate hosts of parasitic cestode and nematodes of fish, waterfowls and mammals, as well as of *Dracunculus medinensis*, a pathogenic agent affecting humans and animals which was, till recently, abundant in Central Asia; Gastropoda are intermediate hosts of the trematodes – parasites of birds and mammals, and of pathogenic agents of such diseases as fascioliasis and orientobilharziasis, which are widely spread over the southern regions of the Aral Sea basin.

While the parasites of vertebrates inhabiting the Aral Sea basin have been explored fairly well (Sultanov, 1963; Osmanov, 1971; Azimov, 1986), this is not so for parasites of aquatic invertebrates, nor the invertebrates themselves. Too little is known about the aquatic Gastropoda and Cyclopidae of the region, their spatial distribution, seasonal development and rate of infections by helminths. The present research partly fills this gap, contributing thus to more effective control of parasitic diseases of humans and animals, as well as to the protection of nature in the region.

Material and methods

From 1993 to 1995, the material was sampled in Muinak, Kungrad, Bazatau and Nukus Districts of Karakalpakstan, during seasonal field trips in May, July and September. Zooplankton samples from other regions (generously provided by S. Embergenov, S. Kazakhbayev and I. Getz), were also used in order to ascertain the species composition of Cyclopidae in Karakalpakstan.

From various water bodies (Lakes Shegekul, Sudoch'ye, Karateren, Karakul, Muinak Bay, Sarbas, etc., as well as from ponds, ditches, canals, rice fields and fish ponds), the cyclopoids were collected using a conical plankton net with 100µm mesh and fixed in 4% formaldehyde. The cyclopoids were then examined in the laboratory by microscope. Infected cyclopoids were dissected and the helminths were separated from them. A total of 160 planktonic samples was processed and 1,770 cyclopoids were examined. The molluscs were sampled in the shoals of the same water bodies as above. Altogether a total of 3,465 molluscs was collected and examined. The molluscs – either alive or fixed in 70% alcohol – were examined for infection by helminths. For that purpose, the molluscs were dissected and studied under microscope. To study their biology, the molluscs were kept in an aquarium, in laboratory conditions.

The infection rate of cattle was determined by examining 650 animals and 1,500 samples of their faeces.

Cyclopidae as intermediate hosts of helminths

Species composition of Cyclopidae in the southern Aral region

The Cyclopidae fauna of the southern Aral region has been described by Akatova (1950), Aripov and Mukhamediev (1978), Allaniyazova (1980), and Kazakhbayev (1988). These authors recorded 21 Cyclopidae species: *Apocyclops dengizicus* (Lepeschkin); *Acantocyclops vernalis* (Fischer); *Cryptocyclops bicolor* (Sars); *Cyclops strenuus* (Fischer); *C. vicinus* (Uljanin); *Diacyclops bicuspidatus* (Claus); *D. bisetosus* (Rehb.); *Ectocyclops phaleratus* (Koch); *Eucyclops macrurus* (Sars); *E. macruroides* (Lill.); *E. serrulatus* (Fisch.); *Macrocyclops albidus* (Jur.); *M. fuscus* (Jur.); *Megacyclops viridis* (Jur.); *Mesocyclops leuckarti* (Claus); *Microcyclops viridis karvei* (Kief. & Moor.); *M. varicans* (Sars); *Paracyclops fimbriatus* (Fisch.); *Thermocyclops crassus* (Fisch.); *T. dybowski* (Lande); *T. oithonoides* (Sars). Unfortunately, their determinations were not accompanied by figures or descriptions, and were also considerably outdated.

The present work was the first in-depth study of Cyclopidae in Karakalpakstan (mainly planktonic and weed forms). Twenty-nine species were recorded (Table 1). 13 species of these are new to the fauna of the southern Aral Sea region, 11 species are new to the fauna of Karakalpakstan and 7 species are new to the fauna of Central Asia.

5 species recorded by the above mentioned authors, have not been detected in our study (*C. strenuus, A. vernalis, E. macruroides, M. fuscus, T. oithonoides*). Two of these (*C. strenuus, A. vernalis*) were never found in our long-term investigations in Uzbekistan: apparently, these two species were confused with *C. furcifer* and *A. robustus*. More likely is the presence of *T. oithonoides* in the southern Aral but, again, misidentification of the closely related *T. taihokuensis* cannot be excluded. The species *M. fuscus*, which is usually identified in southern regions of Uzbekistan, should probably be added to our list.

The Cyclopidae fauna of Karakalpakstan is formed of three major bio-geographic components: *C. bicolor, C. furcifer, C. vicinus, H. rotundipes, E. macruroides* and *M. leuckarti* belong to the northern Palaearctis species; *C. linjanticus, H. spinifer, M. aequatorialis, M. ogunnus, M. aspericornis, M. ruttneri, M. karvei, T. vermifer, T. taihokuensis* are elements of subtropics and tropic fauna; *A. dengizicus, A. robustus, D. bisetosus, D. bicuspidatus, E. phaleratus, E. serrulatus, M. viridis, M. albidus, M. varicans, P. fimbriatus, T. crassus, T. dybowski*, are cosmopolite species.

Tropic species such as *C. linjanticus, H. spinifer, M. aequatorialis, M. aspericornis*, have been recorded only in the Summer months. On the contrary, *P. fimbriatus, C. vicinus, C. furcifer*, which are of more northern origin, were recorded only in Spring and Autumn. However, some tropical species, such as *M. ogunnus, M. ruttneri* and *T. vermifer*, were recorded in the Summer months, September and October.

Infection of Cyclopidae by helminth larvae

Infection of Cyclopidae by helminth larvae was recorded in 10 of the 33 water bodies which were studied (Table 2). In general, infections are more frequent and have a higher rate in Autumn than in Summer and Spring. A somewhat higher level of infection was recorded in the dry year 1995 than in the wet year 1994. An increase of density of fish and water fowls appears to result in higher infection rates of both cyclopidae and vertebrates.

The following cyclopoid species were recorded as intermediate hosts of helminths (in order of decreasing frequency of infection):

A. robustus, T. vermifer, M. albidus, T. crassus, T. dybowski, C. vicinus, E. serrulatus. The percentage of infected cyclopoids was comparatively low (Table 2), but touched all species in the water bodies.

Larvae of 6 cestode species were found in the cyclopoids. The highest level of infection was by the larvae of a fish parasite, *Bothriocephalus acheilognati* (Yamaguty). This parasite was not earlier recorded in Central Asia, but was in the 1960s accidentally introduced with some Chinese fish species, such as *Hypophtalmichtys molitrix, H. nobilis, Ctenopharyngodon idella*, etc.

In 22 cases, infection of cyclopoids by larvae of water fowl helminths was recorded - *Diorchis inflata* (Rud.), *D. ransosni* (Schultz), *Cyclorhida omalacris* (Wedl), *Fimbraria fasiolaris* (Pallas), *Confluaria capillarioides* (Fuhrmann) (Table 3). Definitive hosts of these are pheasants, ducks, sandpipers.

No infection of the cyclopoids by nematoda has yet been recorded.

Molluscs as intermediate hosts of helminths

Gastropods are intermediate hosts of a number of trematode species and they are the most important vectors of such hazardous parasites of wild and domestic animals as schistosomatides. As larvae, they parasitize in the aquatic gastropods; and at the adult stage, in the blood of mammals. Previous studies have shown that cattle in the southern Aral region are mostly infected by *Orientobilharzia turkestanica* (Skrjabin) (Azimov, 1986). In Uzbekistan, these trematodes have been recorded in the animals of Karakalpakstan, Khorezm, Bukhara, Syr-Darya, Dzhizak and Tashkent regions. Foci of infection were also found in Afghanistan, Azerbaijan, China, India, Kyrgyzstan, Turkmenistan, and other Asian states.

Definitive hosts are cattle, sheep, goats, camels, horses, donkeys, pigs, cats and rats. Intermediate hosts are freshwater molluscs of the genus *Lymnaea*: *L. auricularia, L. tenera, L. peregra, L. gedroziana* and *L. luteola*. For instance, in southern Kazakstan, the intermediate hosts of *O. turkestanica* are *L. auricularia* and *L. peregra* (Uvaliyeva, Lavrov, 1981).

The fauna of aquatic Gastropoda in the southern Aral is poorly explored. In literature, reference is made to the presence of *Lymnaea auricularia, L. stagnalis, Planorbis planorbis, Bithynia caerulans, Caspiohydrobia kazakhstanica* (Arystanov, 1986). In the water bodies of Karakalpakstan, we have recorded the following 11 species of Gastropoda: *Anisus spirorbis, A. septemgyratus, Gyraulus albus, G. ehrenbergi, Lymnaea auricularia, L. corvus, L. stagnalis, L.truncatula, Physa acuta, Ph. fontinalis*, and *Planorbis planorbis*.

The most widespread species are *Physa acuta, Ph. fontinalis, Planorbis planorbis, Lymnaea auricularia*, and *L. stagnalis*. All recorded gastropods inhabit less than 1 metre deep, in shallow water bodies. We failed to record *Caspiohydrobia kazakhstanica*, which has been mentioned by Arystanov (1986). This mollusc, which used to inhabit the Aral Sea, apparently disappeared because of the increased salinity of the water.

The abundance of molluscs varies significantly, depending upon the type of water body and mollusc species. Most abundant are molluscs in the Muinak Bay, Dautkul, Lake system Toguz-Tora, and Mashankul. So, the number of *L. auricularia* found in Lake Dautkul was 12-23 per m^2, and in the Kevusar canal 3-8 per m^2. The abundance of this species apparently declined in the last years, as previous investigations recorded much higher numbers - up to 100-200 per m^2 (Azimov, 1986; Arystanov, 1986). Arystanov (1986) also noted the decrease of molluscs in the southern Aral. In 1994, the abundance of *Physa* spp. ranged between 44-123 per m^2 in the shoals of Muinak Bay. However, in the dry year of 1995, the gastropod abundance was significantly lower than in the wet year of 1994. So, the number recorded in Muinak Bay decreased several times, and reached only 7-19 per m^2 in 1995.

Infection by trematode larvae was recorded for four species: *L. auricularia, L. stagnalis, Physa fontinalis* and *Gyraulus albus* (Table 4). Most infected were the *L. auricularia*, as already noted by other authors (Arystanov, 1986). The biology of this mollusc was, therefore, thoroughly studied.

L. auricularia is a hermaphroditic egg-laying species. The number of eggs in each laying ranges between 6 to 40 and more. The eggs are oval, with a length of 0.72-0.74 mm, and are attached to plants, and shells of other molluscs. The embryonal development lasts 27-28 days at 10-12°C, and 7-8 days at 30°C. After hatching, the length of shell is 0.84-0.86 mm and the young molluscs develop intensively: in 25-33 days, they reach a shell length of 13-16 mm and begin to lay eggs of their own. It is a phytophagous species. In northern Uzbekistan, it was noted that this species produces 3 generations (Azimov, 1986).

The molluscs are more active in the warm season of the year (from May to September), when the water temperature is usually over 20°C. In October, the number of active molluscs sharply drops, they go down into the bottom silt and spend the Winter in a state of diapause.

L. auricularia was mainly infected by larvae of *Orientobilharzia turkestanica*, and to a lesser degree, larvae of *Fasciola gigantica*. The level of infection of molluscs by larvae of *O. turkestanica* depends on the type of water body, ranging between 0.5% and 53.0%. Infection was recorded in almost all water bodies where *L. auricularia* was present. The highest level of infection was found in the Togus-Tore lake system.

Certain regularities could be found in the seasonal variations of molluscs being infected by cercaria of *O. turkestanica*. No infected molluscs were found in May, and the highest level was recorded in July. The infection level of molluscs considerably dropped in August, staying below 5% in September. A similar pattern of infection of molluscs was observed in the north-eastern parts of Uzbekistan. According to Azimov [1986], adult cercaria had already been detected in molluscs in May, the rate of infection growing till July and decreasing by the fall. With the average not exceeding 2%, the level of infection was significantly lower in north-eastern Uzbekistan than in the Aral Sea region.

The periodicity of shedding cercaria from the molluscs was investigated in the laboratory. From a mollusc in Lake Dautkul 7,435 cercaria shed in a day, out of which 4,235 between 08 h and 12 h, 110 from 13 h to 16 h, and 2,990 from 17 h to 20 h. No shedding of cercaria was recorded at night. The number of maritae in infected mammals can reach hundreds of thousands. Female *O. turkestanica*, on becoming mature, move towards the smallest veins close to the intestine walls and lay immature eggs in the lumen. While moving along the tissues, the eggs mature and then, entirely mature and mobile, they penetrate the walls and are released together with the faeces (Azimov, 1986).

The level of infection of another species, *L. stagnalis*, was relatively low (Table 4). Arystanov (1986) already reported about the infection of this species by *Trichobilharzia*, as well as by other trematodes (*Echinostomum revolutum, Opisthogliphe ranae*). The infection of *Gyraulus albus* by the trematodes *Gastrocila* sp. and *Physa fontinalis*, as well as trematodes of unclear systematic position (Bilharziellidae gen.sp.) was first recorded in the southern Aral region.

Infection of mammals by trematode *O. turkestanica*

The Aral Sea region is among the territories in Central Asia most acutely infected by orientobilharziasis. The infection is noted in almost all species of domestic animals and in a number of wild ones. Particularly cattle is most affected by this disease. The rate of infection, recorded in 1995, in different districts of Karakalpakstan, varied in a range from 75% to 100%, for adult animals. The infection rate of young animals was much lower (approximately twice as low).

The data obtained show a considerable increase in the number of cattle infected by *O. turkestanica*, over the last few years (Table 5). Namely, in the 1980s, about 46.5% of the cattle in Karakalpakstan were infected (Azimov, 1986). Thus, the epizootic situation caused by orientobilharziasis was considerably aggravated in this region. The reason is the degrading ecological situation of the Aral Sea, in the first place due to the building of vast irrigation networks and the unwise use of water resources for irrigated agriculture. As a result, optimum conditions were created for the spreading and breeding of molluscs, which are the intermediate hosts of the parasites. The anthropogenic factor contributed to the spreading of the parasites in all stages of their growth.

The seasonal variation of the infection of mammals is different from that of the hosts, the molluscs. While the peak of infection of the molluscs is in July-August, the peak of cattle infection occurs in the Autumn-Winter period (Table 6). The infection intensity (the number of parasites in the host organism) culminates in the same period, for both adult and young animals.

Prospects of control of orientobilharziasis in cattle

In the regions studied, the main definitive hosts of the parasites are cattle, and cattle contribute most to the infection of molluscs by trematodes. This warrants the following steps for the control of orientobilharziasis in the Aral Sea basin:

- diagnosis of orientobilharziasis in cattle;
- chemotherapy (anti-helminthic treatment) of cattle;
- control of the abundance of mollusc populations, as intermediate hosts of *Orientobilharzia turkestanica* (destruction of the molluscs' biotopes, drainage of swampy marshes and pastures, application of molluscocides;
- rotation of pasture and in-door cattle breeding.

References

Azimov D.A., 1986. Trematody - зфкфышен яршмщетшлр ш срудщмулф. Tashkent, Fan. 128 pp. [The Trematodes - parasites of animals and humans].

Azimov D.A. & S.Dadayev S., 1977. Ыгешсртну ишщдщпшсруылшу кшеьн уьшыышш еыуклфкшо екуьфещв. - Doklady Akademii Nauk Usbek SSR. N 5. p. 67-69. [Diurnal biorhythms of trematoda cercaria emission].

Akatova N.A., 1950. Materialy k izucheniyu planktona nizovjev Amudarii. - Trudy Zoologichesk. Instituta Akad. Nauk SSSR. V. 9. N 1. p. 79-89. [Materials of the study on plankton in the lower reaches of the River Amu-Dar'ya].

Allaniyazova T., 1980. Зкщьуяргещсртну лрщяофумф еыуыещв кши ш мщвтшлр зешеы м тшящмшфлр Фьгвфкшшю , ШтЖ Зфкфяшен кши ш мщвтшлр иуызщямщтщсртшлр тшящмоум Фьгвфкшш. Tashkent, Fan. p. 128-144. [Intermediate hosts of cestodes of fishes and waterfowl in the lower reaches of the River Amu-Dar'ya].

Aripov D. & Mukhamediev A.M., 1978. Ьфеукшфдн л пшвкщишщдщпшсруылщн лрфкфлеукшыешлу щяук тшяшмшум Фьгвфкшш. - Sbornik Nauchnikh Trudov Tashkentskogo Gosudar. Universiteta. V. 232. p. 9-19. [Materials to hydrobiological characterization of the lakes in the lower reaches of the River Amu-Dar'ya].

Arystanov E., 1986. Афгтф зфкеутше ш дшсрштщл екуьфещв ьщддгылщм вуден Фьгвфкшш ш огпф Фкфдылщпщ ьщкЎф. Tashkent, Fan. 160 pp. [The fauna of partenits and larvae of trematoda of mollusks in the delta of the River Amu-Dar'ya and the Aral Sea].

Kazakhbayev S., 1988. Ыщмкуьуттщу ыщыещнфтшу яшщздфтлещтф щяукфЫгвщсроу. - In: Ыекгсегкф ыщщиыруыем пшвкщишщтещм м тшящмофлр Фьгвфкшш. Tashkent, Fan. p. 29-37. [Present state of the zooplankton of the Lake Sudochje].

Mirabdullayev I.M., 1996. The genus Mesocyclops (Crustacea, Copepoda) in Uzbekistan (Central Asia). - Intern. Rev. gesamt. Hydrobiol.

Osmanov S.O., 1971. Зфкфяшен кши Гяиулшыефтф. Tashkent, Fan. 532 pp. [Parasites of the fishes of Uzbekistan].

Sultanov M.A., 1963. Пудьштен вщьфыртшлр ш щлрщетшсрЎу,зкщьныдщмшлр зешеы Гяиулшыефтф. Tashkent, Fan. 244 pp. [Helminths of domestic and game birds of Uzbekistan].

Uvalieva K.K. & Lavrov L.I., 1981. Улщдщпшсруылфнф лрфкфлеукшыешлф ш кфызкувудутшу зкгвщмшлщм огпф ш огпщ,мщыещлф Лфяфлрыефтф, зкщьуяргещсртнлр лршяофум Щкшутещишдрфкяшф егклуыефтшлф (Skrjabin, 1913). - In: Зфкфяшен, лщьзштутен мшвтшлр ш тфяуьтнлр ишщеыутщящм Лфяфлрыефтф. Alma-Ata, Nauka. p. 112-122. [Ecology and distribution of Lymnaea, intermediate hosts of Orientobilharzia turkestanica, in southern and south-eastern Kazakstan].

Table 1. Occurrence of Cyclopidae species in the waterbodies in Karakalpakstan

	Pools and ditches	Muinakski Zaliv	Lake Sarbas	Lake Shegekul	Lake Karazhar	Lake Syrlitas	Lake Ayazkul	Lake Sudochye	Lake Akchakul	Lake Karatereng	Lake Batakul	Lake Ashikul	Lake Dautkul	River Amu-Dar'ya	Muinak Fishery Farm
Cyclopidae	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1. *Apocyclops dengizicus* (Lepesch.)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. *Acanthocyclops robustus* (Sars)**	+	+	+	+	-	-	-	-	-	+	+	-	+	-	+
3. *Cryptocyclops bicolor* (Sars)	+	+	+	-	-	+	-	-	-	-	-	-	-	-	+
4. *C. linjanticus* Kiefer**	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. *Cyclops furcifer* Claus**	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6. *C. vicinus* Uljanin	-	+	+	+	-	-	-	-	-	+	-	-	-	-	+
7. *Diacyclops bisetosus* (Rehberg)	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
8. *D. bicuspidatus odessana* (Claus)	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-
9. *Ectocyclops phaleratus* (Koch)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
10. *Eucyclops macruroides* (Lilljeborg)	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
11. *E. serrulatus* (Fischer)	+	+	+	-	+	+	-	-	-	-	-	-	-	+	+
12. *Halicyclops rotundipes* Kiefer	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
13. *H. spinifer* Kiefer**	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
14. *Macrocyclops albidus* (Jurine)	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+
15. *Megacyclops viridis* (Jurine)	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16. *Mesocyclops aequatorialis* Kiefer*	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
17. *M. aspericornis* (Daday)*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
18. *M. ogunnus* Onabamir*	-	+	-	+	-	-	-	+	+	+	-	+	-	+	-
19. *M. leuckarti* (Claus)	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
20. *M. ruttneri* Kiefer** -	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+
21. *Microcyclops karvei* Kiefer et Moor.	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22. *M. rubellus* (Lilljeborg)	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+
23. *M. varicans pachyspina* Lindberg**	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+
24. *Paracyclops fimbriatus* (Fischer)	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
25. *Thermocyclops crassus* (Fischer)	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-
26. *T. dybowskii* (Lande)	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+
27. *T. rylovi* (Smirnov)	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-
28. *T. tihokuensis* Harada*	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+
29. *T. vermifer* Lindberg**	+	-	-	-	-	-	-	-	+	+	-	-	-	-	-

* - species new to Karakalpakstan;

** - species new to Central Asia.

Table 2. Infection (%) of the cyclopoids by the larvae of trematodes in waterbodies of Karakalpakstan

Waterbodies	1994			1995	
	May	July	Sept.	Aug.	Sept.
1. Lake Sarbas	-	2.6	5.7	6.4	6.0
2. Lake Muinaksky Zaliv	-	6.8	-	-	5.0
3. Lake Shegekul	-	-	2.5	-	7.5
4. Canal Kevusar	1.4	3.6	-	-	-
5. Ponds of the Muinak Fishery Farm	-	2.5	5.0	-	8.8
6. Ponds of the Nukus Fishery Farm	-	-	-	-	9.0
7. Ditch near Muinak	1.8	2.2	4.5	-	5.0
8. Ditch near Shagyrlik	-	-	3.6	3.6	4.8
9. Lake Zhansyz	3.5	3.0	4.0	-	-
10. Lake Syrlitas	-	3.9	4.0	3.4	6.2
Monthly mean infection level	2.2	3.5	4.1	4.4	6.2

Table 3. Infections of Cyclopidae species by larvae of various trematoda species (numbers are the cases of infection)

Cyclopidae	Trematoda					
	Botriocephalus achilognathi	*Diorchis inflata inflata*	*Diorchis ransoni ransoni*	*Cyclorhyda omala*	*Fimbraria fašiolaris*	*Confluaria capillarioides*
Acanthocyclops robustus	3	-	1	2	2	1
Thermocyclops vermifer	4	1	-	-	1	1
T. crassus	-	2	1	1	1	-
T. dybowskii	1	1	-	-	1	1
Macrocyclops albidus	-	-	1	2	2	-
Cyclops vicinus	2	2	-	-	-	-
Eucyclops serrulatus	1	-	-	-	-	-

Table 4. List of the molluscs in the waterbodies of Northern Karakalpakstan

Molluscs	Specimens studied, numbers	Specimens infected by helminths	Helminth species
1. *Lymnaea corvus*	159	-	-
2. *L. auricularia*	1005	250 (24.8%)	*O.turkestanica*, *F. gigantica*
3. *L. truncatula*	250	-	-
4. *L. stagnalis*	256	3 (1.1%)	*Trichobilharzia* sp.
5. *Planorbis planorbis*	175	-	-
6. *Anisus spirorbis*	107	-	-
7. *A. septemgyratus*	67	-	-
8. *Gyraulus albus*	260	6 (2.3%)	*Gastrocila* sp.
9. *G. ehrenbergi*	42	-	-
10. *Physa acuta*	1025	-	-
11. *P. fontinalis*	124	1 (0.8%)	

Bilharziellidae gen.sp.

Table 5. Infection of cattle by Orientobilharzia in districts of Karakalpakstan

Districts under study	Number of cattle studied	Infected cattle	
		Number	%
Kegeily	105	105	100
Chimbai	100	90	90
Muinak	100	80	80
Kungrad	105	90	86
Turtkul	100	75	75

Table 6. Infection of cattle by populations of maritae of Orientobilharzia in the Aral Sea basin

Season	Individuals studied	Infected		Infection intensity, thousand individuals
		Individuals	%	
Adult animals				
Spring	100	65	65	25
Summer	100	70	70	35
Autumn	100	90	90	105
Winter	100	90	90	110
Calves (less than 1 year old)				
Spring	50	-	-	-
Summer	50	15	30	3
Autumn	50	25	50	15
Winter	50	25	50	20

PERSISTENT PESTICIDES AND HEAVY METALS IN THE ECOLOGY OF WATER ECOSYSTEMS OF THE SYR-DAR'YA RIVER BASIN IN KAZAKSTAN

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Introduction

The well-known catastrophic changes of the Aral Sea (such as degradation of land, salt and sandy erosion, and so on) could be mitigated by large-scale reclamation measures. However, one visible problem will persist even after future ecological improvements, and indeed is set to increase, if the economic situation in the countries of the Syr-Dar'ya and Amu-Dar'ya basins were to remain unaltered. The issue is one of pollution of runoff, which brings water to the Aral Sea with practically insoluble compounds of heavy metals and chlorine organic pesticides. It is necessary to add the pollution of groundwater during the uranic extraction, when about 15-20 metals (including cadmium) are transferred to soluble state, but with only the uranium being absorbed. Their accumulation and movement in the various ecosystem components are practically unknown and can be assessed only through changes of flora and fauna in the respective biocoenoses. The impact of these chemical pollutants was well demonstrated on the example of human populations only. For example, medical records about high contents of chlorine organic pesticides in mothers' milk and consequent infant mortality in the Aral Sea region were published in 1970-79, but were overshadowed by other "global" problems. The only information on animals related to the mass elimination of industrial fish species and the consequences in the Chardara Reservoir.

Methods and collected material

Specimens for assessing chlorine organic pesticides (COP) and heavy metals (HM) in the Syr-Dar'ya water system were sampled in Spring-Summer and Autumn, 1993-1995, in 29 permanent sites: in the Syr-Dar'ya (from the border with Uzbekistan), drainage channels, Keles River, Boz-Su River, Chardara Reservoir, environs of Kzyl-Orda and Kazalinsk and Kamyshlybash lake system (Figs. 1 and 2). In total, 1,960 analyses on COP content and 2,060 analyses on HM content were carried out. Pollutants were collected by usual methods: zoobenthos was collected by Petersen bottom-scooper, zooplankton by small-mesh nets (trawls) and near-bottom organisms by trawling and also by washing them off plants. Samples of macrophytes and sediments were taken at the same time and at the same locations. For fishing, nets were used with mesh size from 50 to 180 mm. Water, which was needed for HM examinations, was fixed with a 5% solution of HNO_3 and HCl acids (and by N-hexane for pesticide examinations). The remaining quantities of toxicants were separated by extraction when analysing the consequences of pollution. The body length, weight, age and sex of collected fishes were examined in the course of these investigations.

Fish specimens were dissected to assess separate organs (brain, liver, gonads, various muscles and visceral fat). Each sample was weighed, then reduced, placed in glass chemical jars, fixed by N-hexane and extracted. The same procedure was applied to COP examination of zooplankton, benthos, plants and sediments (previously damp sample weight had been determined). After the extraction was repeated three times, the method of H_2SO_4 clearance was used. The samples on HM were then fixed in

3-5 ml concentrate HNO_3, in laboratory conditions. Later on they were evaporated to (with HCl added) 7 ml control volume. Such preparations were dissolved by heating to about 150°C in mixture with 5 ml of concentrated HNO_3 in special hermetic reactors under high pressure conditions. After that, the specimens were moved to chemical glass jars (30 ml volume), closed with a nylon cover, marked and sent to the spectrophotometer. The remaining pesticide quantities in water and biota were determined in a gas-liquid chromatograph "Chrome 5" with an electron detector, HM, by atomic absorption on spectrophotometer AAS-1N (Zeiss-Jena, Germany).

Investigation results: Chardara Reservoir and Syr-Dar'ya

The toxicological study conducted in 1993 showed that different places of the Syr-Dar'ya River, Chardara Reservoir and Kamyshlybash Lake differ in the level of pollution, as well as the presence of HCCH isomers, metabolite DDT and HM. Water analyses from different basin points detected the presence of isomers HCCH, DDT-DDE, Cu, Cd, Pb and Hg. So, in rivers flowing to Chardara, the COPs were from 130 to 360 ng/l in water (with HCCH predominance). Their concentration was 120 ng/l in the middle part of reservoirs. At the same time, the COP concentration near the dam stations dropped below 20 ng/l. The same decrease of COP concentration was recorded at the middle part of the Syr-Dar'ya river-bed - 80-300 ng/l.

Observations showed that the main quantity of COP was brought into the middle basin from Uzbekistan by the rivers: Syr-Dar'ya (890-940 ng/l), Keles (50-80 ng/l) and by water from collectors "Western" and "Northern" (150-250 ng/l). The entrance of chlorine-organic substances from the collectors "Eastern" and "Toksambay" was slightly lower (120-200 ng/l).

The concentration and distribution of HM (Pb, Cd, Cu and Zn) was similar, with some variations, as those of COP pollution. So, in the upper part of Chardara Reservoir, the concentration of Cu was 1.3-1.8 μg/l, Cd - 2.23-4.90 μg/l, Pb - 2.74-11.90 μg/l, Zn - 5.30-17.75 μg/l. The HM concentration in the water near the dam and 100-150 km further downstream decreased, but increased again in the lower reach of the Syr-Dar'ya. Near Kazalinsk City, the water concentration of Zn was near to 44.0 μg/l, Cu - 70.0 μg/l, Cd - 5.3 μg/l and Pb - 21.5 μg/l. The HM concentration in the stagnant water of the Kamyshlybash lakes was very high: Zn - 115.5-209.0 μg/l, Cu - 171.7-350.0 μg/l, Cd - 17.0-23.8 μg/l, Pb - 94.2-107.7 μg/l.

The large quantity of pesticides and HM found in the water at different locations of the Syr-Dar'ya and Chardara shows that many agricultural farms in the region use these COP and industrial companies dispose technical water, rich in HM salts and other reagents. From the fishery and agricultural points of view, the COP level must be below 50 ng/l. But the actual COP concentrations influence the water ecosystem of both river and reservoir, causing a decrease of their productivity and fish reproduction and contribute to the bad ecological-toxic situation in nearest zones of the Syr-Dar'ya River basin.

The toxicants in the water enter into the biological cycle present in sediments, macrophytes, hydrobionts subject to transformation along the trophic chain. The highest concentrations of HCCH (2 μg/kg), DDT (8 μg/kg) in Chardara were found in grey sludge sediments. In the Syr-Dar'ya near Kazalinsk City these concentrations were even higher (from 10 to 14 μg/kg). At the same time, the Zn concentration in sludge stations changed in the range of 23-38 μg/kg, Cu - 10-19 μg/kg, Cd - 1.0-1.5 μg/kg, Pb - 8-10 μg/kg. Sediments with very strong HM concentrations were found in the zone of the collector drains discharging water into the Chardara Reservoir. For instance, very high concentrations of Pb and Cd were found near the Chardara Dam. This shows how important the bottom sludge of the deep-water part is in the deactivation processes. Water plants are among the main accumulants of COP and HM, extracting them from water and sediments. In *Phragmites* samples taken from different places of the river, the COP contents were in the range of 2.3-3.9 μg/kg, and DDT - 1.6-3.2 μg/kg. In the tissues of *Potamogeton perfoliatus*, concentrations were recorded of HCCH - 2.4-3.1 μg/kg and DDT - 1.05-3.5 μg/kg of damp weight. Concentrations of Zn - 9.3-28.0 mg/kg, Cu - 3.1-6.6 mg/kg, Cd - 0.1-0.48 mg/kg and Pb - 0.22-0.48 mg/kg were found in plants close to the water (*Phragmites*, *Scirpus* and *Typha*).

The data show that invertebrates also accumulate all types of pollutants of the aquatic environment. The most numerous planktophagous species (base of fish feeding), such as Cladocera (*Daphnia mongolianum, Moina micrura*) extract from the water from 0.75 to 1.25 μg/kg of COP and 3.05-5.6 μg/kg of DDT. In bodies of the representative near bottom organism - *Mysis* sp., concentrations of COP were found in the range of, 2.54-3.25 μg/kg, and of DDT - 3.60-4.67 μg/kg. Palaemonidae are very good accumulators of pollutants: concentrations of HCCH in their bodies were around 30.0 μg/kg and of DDT - around 36.0 μg/kg of damp mass. In Cladocera, HM contents were in the range of: Zn - 8-10 mg/kg, Cu - 1.2-1.8 mg/kg, Cd - 0.63-0.68 mg/kg, Pb - 0.90-3.36 mg/kg. In the bodies of *Mysis* sp., HM concentrations were in the range: Zn - 7.1-8.1 mg/kg, Cu - 2.2-5.1 mg/kg, Cd - 0.54-0.68 mg/kg, Pb - 0.96-4.40 mg/kg of damp mass. In Decapoda samples, concentrations were found of Zn - 10.6-25.4 mg/kg, Cu 4.6-7.8 mg/kg, Cd 0.96-1.74, Pb 2.-4.3 mg/kg, of damp mass.

Analyses of organs and tissues of different fish species collected in the Syr-Dar'ya and Chardara showed rather high concentrations of COP and HM. The high pesticide concentrations in gonads, fat and other tissues of *Aabramis brama orientalis, Pelecus cultratus* and *Lucioperca lucioperca* (from 256 to 416 μg/kg) were over the permissible level for human food products (200 μg/kg), thus representing a danger for people. Of the heavy metals, it was mainly Zn that was detected in samples of muscle, liver, gills and roes, in concentrations around 66.9 mg/kg. Cu accumulates mainly in liver, while Pb and Cd do so in gills. Cd concentrations twice the permissible limit (0.2 mg/kg) were recorded everywhere. The increased pollutant concentrations in fat, brain, liver and gonad products, in particular during high summer water temperature, can be detrimental to fish in the investigated water bodies, especially at advanced stages of fish development.

Study of the toxicological situation in the Syr-Dar'ya basin in 1994 and 1995 confirmed the heavy pollution by COP and HM. In the Chardara, the hexachlorane contents in the water near Cape White Stone varied in the range of 90-150 ng/l, DDT (in trace quantity) - 60 ng/l. HCCH in the range of 20-30 ng/l and DDT - 60-80 ng/l was detected in the zone near Rybstane and Cape Krepost'. Their indexes were higher in the Syr-Dar'ya river-bed and near Uturly Island: HCCH - 140-160 ng/l, DDT - 80-90 ng/l. Water in the central part of the reservoir contained up to HCCH - 80 ng/l and DDT - 75 ng/l. In comparison with the previous year, some increase of general HCCH contents in Chardara water was recorded (Fig. 3). HM contents in water varied in the range: Zn - 2.2-9.26 μg/l, Cu - 1.35-6.55 μg/l, Cd - 1.59-4.40, Pb - 9.61-18.28 μg/l. The highest HM concentrations were observed in the central stations in the last research period. The HM indexes in stations along the northern reservoir coast were lower. Even lower HM contents were found in the region of the dam, proving thus the purifying capacity of the reservoir. High contents of Pb in the reservoir water was recorded in comparison with the previous study period, with an increase from 10.9 μg/l to 18.28 μg/l., showing that the irrigation channels and small rivers of the upper part of the Syr-Dar'ya basin were heavily polluted by HM. The main toxicants were Pb and Cd. In the reservoir, in the 1994 vegetation period, the average HM concentrations were: Zn - 4.66 μg/l, Cu - 3.73 μg/l, Cd - 2.43 μg/l and Pb - 14.3 μg/l.

The reservoir bottom continued to be polluted. COP contents in sludge deposits were ten to a hundred times higher than in the water (the same as in 1993). The highest HCCH concentration (2.6-3.9 μg/kg) was recorded in the black and grey sludge near Uturly Island, near Cape White Stone and near the dam; the highest concentration of DDT (5.2-9.6 μg/kg) was observed near the inflow of the Syr-Dar'ya into the reservoir, in the central part of the reservoir and near Rybstane.

Sand sediments usually contain a minimum quantity of pollutants (HCCH 0.26-1.2 μg/kg; DDT 0.60-1.4 μg/kg). As compared to 1993, a large increase in COP concentration was registered in 1994 at the reservoir bottom (Fig. 4). This proves that the reservoir water is being purified by the deposition of sediment particles. At the same time, according to data on sludge pollution in the Chardara Reservoir, serious danger exists in some reservoir parts, because many benthos organisms have high COP concentrations. Analyses of HM in bottom deposits showed a mosaic pattern of distribution. In comparison with the preceding period, the Zn contents was lower (8.4-11.7 mg/kg in 1994, 23.3-38.5 mg/kg in 1993). The Cu concentrations in sludge were the same (15.9-23.7 mg/kg), the Cd index increased on average to 0.5-0.7 mg/kg, and Pb - to 10-12 mg/kg of damp mass. Highest concentrations of Pb and Cd were found in sediments at the middle part of the reservoir and near collector inflows. Pb and Cd predominated in sediments near the dam, which shows the decontaminating capability of the sludge. The high concentrations of Pb and Cd in reservoir sludge originate from toxic contamination by industrial waters in Uzbekistan. Water plants are important factors of water de-contamination, as confirmed by the investigations in 1995. The most active COP absorbers are *Polygonum amphibium* and *Potamogeton filiferus:* the concentrations of HCCH in a plant body were from 10.7 to 15.1 μg/kg and of DDT - 12.5 till 18.4 μg/kg.

Ceratophyllum demersum contained up to 11.9 μg/kg of HCCH and 2.8 μg/kg of DDT. Hexan chlorane concentrations in *Phragmites* tissue were 3.9 μg/kg and of DDT - 2.8 μg/kg, Zn - 2.04 mg/kg, Cu - 2.45 mg/kg, Pb - 18.5 mg/kg and Cd - 1.97 mg/kg. The concentrations of Zn and Cd in *Polygonum amphibium* were two times higher, than in *Phragmites*; at the same time Pb predominate in samples of *Phragmites* and *Scirpus*. The maximum pollutant indexes again were for water macrophytes (*Potamogeton* and *Myriophyllum*). They are good absorbers in Chardara: as they accumulate Zn, the reduction of Zn concentrations in water and sediments in 1994 was probably connected with intensive growth of macrophytes. Thus, the data confirm the presence of COP and HM in water plants in great quantities, proving that the water plants reduce the pollutant content of the water.

As shown above, the pollutants in water surroundings enter into fluxes of matter and penetrate into the organisms of invertebrates and fish. The analysed samples showed that zooplankton and benthos from different reservoir parts accumulated toxins on the same level as in 1993. The sum of HCCH isomers in Chironomid larvae varied in the range of 12.0-26.5 μg/kg, with DDT metabolites at 5.33-22.6 μg/kg; the bodies of the imago stage contain COP at 30.4-32.0 μg/kg. Their role is therefore important in bringing toxic substances to the land. Molluscs (*Anodonta* sp.) should be mentioned among the invertebrates, as these accumulate hexachloran (20.2-28.4 μg/kg) and DDT (5.71-19.4 μg/kg). The accumulation in Decapoda, Odonata and Coleoptera larvae is also great (COP - 14.52-16.20 μg/kg). Invertebrates concentrate large quantities of COP from the water and bottom, promote the reservoir self-clearing and at the same time they create a hazard in the food chain, up to the fishes, at the end of the chain. COP arrive into fish tissues from the skin cover and gills or on trophic ways. In the first case, they are more toxic. Observations for toxin contents in organs and tissues of different fish species showed that the majority of them contain DDT, HCCH and HM (Table 1).

Research in 1994 showed that Chardara fishes accumulated pollutants in the same quantities as in 1993. High concentrations of Pb and Cd in muscles and livers (more than 2-4 times the health standards) were discovered. These toxicants (see Fig 5-6) are dangerous for fish as well as for the people who eat them.

The migration of pollutants with different transformation indexes was determined on the example of selected trophic chains. Data 1993-1994 are represented in Figures 4 and 5. These diagrams show that all COP and HM indexes were much higher than the indexes of 1993. The indexes of Pb in water, macrophytes, zoobenthos and fishes, the COP indexes in water, sediments and fishes were highly increased. This confirms that the input of COP into the reservoir through the main transport ways (waste water, groundwater, precipitiation) not only continued, but even increased in 1994.

The COP and HM penetration and especially their accumulation in animal tissues are dangerous for the reservoir fauna, because these pollutants exert a great and chronic influence, which can impact the population of the hydrobionta, as well as the ecosystems in general.

Kamyshlybash Lake

As regards water quantity and quality, the Kamyshlybash Lake system, which has become very important for the region after the shrinkage of the Aral Sea, mainly depends upon the Syr-Dar'ya water regime. Investigation of the toxicological situation in Kamyshlybash Lake water in summer and autumn 1994-1995 showed the presence of α-, β- and γ- isomers of DDT and its metabolites; their concentrations exceeded the health standards (Table 2). The residual concentration of COP in the Syr-Dar'ya delta was 0.15-0.29 μg/l. The pollutants came with the river water to Kamyshlybash Lake system and spread over the whole water body. The lake water often became mixed because of strong and rapid storms (wind velocity was sometimes 30-35 m/sec), so that the pesticides were carried large distances, depending on the wind direction. According to Table 2, the highest concentrations of pesticides in the Summer of 1994 were located in the central, north-western and south-eastern parts of Kamyshlybash Lake; lower pollutant concentrations were found in southern, north-eastern and south-western parts of the lake. These indexes were considerably higher in the autumn (mainly 0.40-0.60 μg/l). In the river delta, the COP concentration was 0.20-0.28 μg/l in autumn. In May-June 1995, the concentration of chlorine organic pesticides in the lake increased over the whole lake system (see Fig. 7).

It is well known that DDT and HCCH are very dangerous toxicants, and according to health standards, their concentration in water should not exceed 0.05 μg/l (by former USSR and USA standards); DDT is dangerous for fishes, molluscs and crustaceans at the level of 1 μg/l. Thus, toxicants in these concentrations in Kamyshlybash can influence the life cycles of hydrobiota and the quality of water bodies in the Syr-Dar'ya delta lakes.

Tables 3 and 4 contain data on HM pollution (Zn, Cu, Pb, Cd and Hg) in the water at various locations in Summer 1994-1995.

The HM contents in the lake water has a mosaic pattern, with the predominance of Pb and Cu. The highest concentrations of HM were: Zn - 209.0 μg/l, Cu - 617.0 μg/l, Pb - 130.0 μg/l, Cd - 23 μg/l and Hg - 1.29 μg/l. The north-eastern part of the lake was most polluted by HM. The HM indexes increased in the 1995 vegetation period, in comparison with 1994. The HM concentrations in river delta water were lower than in the lake water. The HM concentrations were higher than the permissible concentrations by fishery standards for Zn - 4 times, Cu - 10 times, Cd - 5 times and Pb - 4 times.

The indexes show that HM pollutants definitely influence the water ecosystem and the sanitary toxicological situation for hydrobionts and people.

The general pollution level shows toxicant accumulation at the end of the trophic chain (sediments, plants, zooplankton, benthos and fishes). The maximum accumulation of DDT and HCCH in Kamyshlybash sediments in 1994 is observed in the south-western, north-western and central parts of lake, where the lake bottom mainly consists of black and grey sludge deposits (largely dominated by DDT - see Table 5). A lower concentration of toxicants was observed in sludge with sand in southern, eastern and south-western parts of the lake.

In May-June 1995 the toxicant concentration level in sludge deposits was rather the same as in 1994 (see Fig. 8).

In all the regions studied, uneven distribution of α-, β- and γ- HCCH isomers and predominance of DDT-DDE in the sediments were observed. The highest pollutant concentrations (from 50.4 to 70.8 μg COP per kg damp mass) were found in bottom sediments of the river delta.

The bottom deposits and macrophytes are the main toxicant absorbers in the Kamyshlybash Lake. The highest HM concentrations were found in bottom deposits of black and grey sludge. These deposits contained up to 10.5 mg/kg of Zn, Cu - 6.49 mg/kg, Pb - 9.7 mg/kg and Cd - 1.14 mg/kg (see Tables 6 and 7). Metal concentrations in the Syr-Dar'ya bottom sludge were higher than in the lake bottom sludge.

Pb (up to 15.2 mg/kg of damp black sludge mass) predominated in the samples. The data show that the bottom sludge of Kamyshlybash Lake plays a great role in water decontamination, especially as regards to DDT and Pb. Well-known property of COP is their easy accumulation by plant and animal organisms. Whereas COP do not damage the plant tissues, they accumulate in the plant organisms which use them as additional organic material. On the contrary, in animal bodies the accumulated COP damage the most sensitive organs.

The level of accumulation of pesticides according to data from Summer and Autumn 1994-1995 is different in different plant species. In samples taken from different parts of the lake, the COP content in the plant tissue of *Potamogeton filiformis* varied in the range from 0.36 to 183.1 μg/kg of damp mass, for *Potamogeton perfoliatus* - from 8.5 to 139.6 μg/kg, for *Myriophyllum* sp - from 38.3 to 73.8 μg/kg, for *Scirpus* sp. - from 3.60 to 156.1 μg/kg and for *Charra* from 13.3 to 15.7 μg/kg. This dispersion of pollutant contents in high water plants is closely connected with the composition of sediments where the plants grow. The highest COP concentrations were found in plants grown in grey and black sludge deposits, the lowest on sludge sands. Submerged macrophytes actively accumulate HM from the water (see Table 8).

Good accumulators are *Potamogeton, Myriophyllum* and *Charra*. So, Zn was discovered up to 12.7 mg/kg, Cu - 10.0 mg/kg, Pb - 11.0 mg/kg of damp plant mass. The plants near the water and along the coast contained HM in lower concentrations.

It has been known for a long time that plankton and benthos invertebrates are not independent in osmotic position: their semipermeable membranes and permeable part of integument allow the water with toxicants to penetrate into animal bodies and accumulate in great quantity. The data confirm that the invertebrates as well as macrophytes extract the pesticides from the water. So the most abundant planktonphagous species, which represent the food base of fish (Decapoda), extract COP from the water 9.9 - 364.0 μg/kg of damp mass. Water Crustaceans accumulate HM in the following concentrations: Zn - 4.5 mg/kg, Cu - 1.6 mg/kg, Cd - 0.9 mg/kg and Pb - 6.4 mg/kg of damp mass. The total concentration of chlorine organic pesticides with DDT predomination attains in *Mytilus*, which is the representative of near bottom population, up to 12.73 to 121.32 μg/kg of damp mass. Some representatives of benthos organisms also extract pollutants. So, HCCH concentration in Mysidaceae is up to 37.84 μg/kg and DDT - 166.38 μg/kg of damp mass. Amphibia show good pollutant extracting potential. The HCCH concentration in young lake frogs (*Rana ridibunda*) was 42.2 μg/kg and DDT - 121 μg/kg. Adult frog specimens have other indexes: 36-60 and 110-272 μg/kg, respectively. HM indexes were the following: Zn - 7.4 mg/kg, Cu - 2.0 mg/kg, Cd - 1.5 mg/kg, Pb - 5.6 mg/kg. The extracting of COP from water by invertebrates must be understood not only as a factor of water area self-purification, but also as a threat of pollutant transfer by transformation across the food chain, towards fishes, birds and etc. The benthos representatives of Kamyshlybash Lake (*Lymneae stagnalis*, larvae of Chironomidae, *Mytilus*, etc.) had the following HM concentrations: Zn - 7.1 mg/kg, Cu - 1.6 mg/kg, Cd - 1.5 mg/kg and Pb - 25.4 mg/kg. The Pb concentrations were high in all samples of benthos organisms.

Analyses (1994-1995) have shown great concentrations of pollutants in fish organs and tissues of different species in the Kamyshlybash Lake system, with an increasing tendency from year to year (Tables 9 and 10). When COP are absorbed by fish organisms, they persist for a long time and act as neuronal toxicants. Thus, high concentrations of pollutants in fat, brain and liver of *Cyprinus carpio, Silurus glanis, Esox lucius, Scardinius erythrophthalmus, Perca fluviatilis, Rutilus rutilus aralensis*, together with high water temperatures in summer, can perniciously affect fish, especially in early stages of onthogenetic fish development. A potential threat to all hydrobiota of the Syr-Dar'ya delta, the toxins act actively already in concentration of 1-2 μg/l. The research results on HM accumulation are presented in Table 11.

Long-term observations have confirmed that the dispersion of COP in fishes is not connected with age and physiological characteristics, but with the fatness of the body. Gradually accumulated in fat body parts, the toxicants become a serious danger for the fish, because fat entry and fat mobilisation are realised only through the liver, which accumulates toxins during the fat transformation process. High concentration of toxicants in visceral fat can lead to their high concentrations in the liver during periods of intensive fat use (thaws in winter, breeding time, poor alimentation, change of pH and O_2, etc.). Such reasons resulted in high fish mortality in the Chardara Reservoir, at breeding time in Spring.

Toxic ecological monitoring of the Kamyshlybash Lake system shows continuing pollution of the water by chlorine organic pesticides and heavy metals. Toxicants were found in most samples of water, sediments, water plants and animals. Though many toxicant indexes are not above the health standards, the accumulation of pollutants can lead to poisoning and sometimes to the death of animals. Table 12 gives general information on pollution in 1994-1995, whilst the main trophic paths of pollutant migration and transfer indexes from one trophic link to other are shown on Fig. 7. The cycle of COP movement in Chardara and Kamyshlybash is illustrated by Fig. 9: the pollutants (which arrive via waste water, atmosphere, groundwater) migrate in the water bodies and transform into isomers and metabolites. The intensity of toxicant isomerisation depends mainly on energetic conditions (presence of oxygen, pH, temperature, illumination, etc.). The subsequent circulation of pesticides is connected with the ecological relationships between the biocoenosis components.

Phytoplankton and micro-organisms in water are eaten by zooplankton, the latter by planktophagic fishes, which were then eaten by fishes of prey. At the bottom, pollutants accumulate in sludge, macrophytes and benthos organisms, which again are eaten by benthophagic fishes. Predators accumulate pollutants for their whole life.

The pollutants thus arrive into the final link of the trophic chain - the predator fish species. Further transfer of the pollutants occurs through birds, water mammals and people, who use fish and fish products.

The transfer of persistent pesticides from lower to higher links in the trophic chain is accompanied by increasing pollutant concentration. The longer the trophic chain, the higher are the pollutant concentrations. This is the reason for biological increase of concentrations, from minimum values, to dangerous levels (0.1 mg per 1 kg of damp weight).

Conclusions

First of all, it must be considered that the years 1994 and 1995 were rather exceptional, because of very high precipitation. Consequent to the melting of low-mountain snow in Spring, the main water storage of the Kazakstan part of the Syr-Dar'ya basin - the Chardara Reservoir - was overfilled by May (over 2 metres) and about 300 000 m^3 of water had to be evacuated into the Aydarkul reservoir. This caused a certain extent of general and local habitat pollution from chlorine organic pesticides and heavy metals, as can be seen when comparing the newly obtained data with those of the previous years. These were unfavourable circumstances for the Project, which had to provide the base measures to preserve the Aral Sea, by better economy of use of irrigation water. From the general point of view, this situation has confirmed the need for a project which would aim at preserving the Aral Sea water level by better economy of irrigation water, as the dam at Kzyl-Orda could not cope with such an increased quantity of water - it would just be destroyed.

In spite of the increased inflow into the Chardara Reservoir in Spring 1994-1995, high concentrations of COP and HM were observed in different local habitats and their components. The COP concentrations (with strong prevalence of HCCH isomers) fluctuated from 130 to 360 ng/l in the streams, which enter the reservoir. Their concentration in water was 120 ng/l in the middle part of lake. At observation points near outlets through the dam, the concentration of COP decreased to 20 ng/l. Approximately the same and even lower concentrations were observed in the middle part of the Syr-Dar'ya river channel, i.e. up to the inflow of collector drains of the irrigation systems. In autumn, pollution by COP reached 250-400 ng/l, downstream from Kazalinsk, below the inflow of collector-drainage water into the Syr-Dar'ya. Consequently, COP concentrations in the delta lakes (Kamyshlybash system) approached the levels of the Chardara Reservoir lake (80-120 ng/l).

Concentrations and distribution of HM in the aquatic environment (lead, cadmium, copper, zinc) were similar to those of COP pollution, with some variations. In the upper part of Chardara Reservoir lake, the concentration of lead was 2.74-11.9 µg/l, copper - 1.3-8.5 µg/l, cadmium - 2.23-4.9 µg/l, zinc - 5.3-17.75 µg/l. Near the water exit from the reservoir and 100-150 km further downstream, the HM concentrations decreased in the Syr-Dar'ya. Below Kazalinsk, the concentration of Zn in water was approximately 44.0 µg/l, Cu - 70 µg/l, Pb - 21.5 µg/l. It can be seen that some amount of HM was washed out from Chardara reservoir, while in the stagnant water of the Kamyshlybash lake system, the HM concentrations reached their highest values: Zn 115.5-209 µg/l, Cu - 171.7-350 µg/l, Cd - 17-23 µg/l, Pb - 94.2-107.6 µg/l.

It is a natural process that the COP and HM enter into biotic and abiotic circulation and accumulation in the different water systems of the Syr-Dar'ya. For instance, the amount of pollutants accumulated in the bottom sediments increase proportionally with the content of organic deposits.

Aquatic plants accumulate pollutants equally as bottom sediments and hence, the level of pollution of these biotopes depends on the abundance of macrophytes and their susceptibility to contamination by pollutants. These two components, as well as water, are the primary cause of pollutant accumulation in aquatic organisms.

 According to preliminary data, the most vulnerable to contamination by COP and

HM are benthophages (Natantia, Mollusca) and plankton filterers (Cladocera). For instance, in Chardar lake, Natantia contained 30.0 µg/kg of HCCH, 36.3 µg/kg of DDT, 25.4 mg/kg of zinc, 7.8 mg/kg of copper. 1.75 mg/kg of cadmium, 4.3 mg/kg of lead. Concentration of HCCH in Cladocera reached 2.0 µg/kg., of DDT - 5.6 µg/kg, zinc - 10.0 mg/kg, copper - 2.0 mg/kg, cadmium - 0.8 mg/kg, lead - 3.4 mg/kg. Chironomidae showed the same level of contamination.

Phytophagic and planktophagic fishes are heavily contaminated by COP and HM. For example, concentration of pesticides in *Cyprinus carpio, Pelecus cultratus, Abramis* varied from 210.0 to 256.0 µ/kg and in some cases (reproductive products) reached 416 µ/kg. Contamination of predatory fish (*Stizostedion, Aspius aspius*, etc.) is close to these levels, with minor differences. However, considerable variations were observed of COP and HM concentrations in different organs and tissues of various fish species. While pesticides mainly accumulate in fat tissues, reproductive organs and brains of fish, heavy metals concentrate in their gills, liver or muscle tissues, depending on the species.

In contrast to invertebrates in the delta lakes, contamination by COP and HM of fish was considerably lower, although even there, the concentrations of pollutants, especially of Cd, were 2-4 times higher than the sanitary standards.

Thus, even in the extraordinary water-abundant years, the investigations noted heavy contamination by pollutants of all hydrocoenosis components in different parts of the Syr-Dar'ya.

Research conducted in the upper (in Kazakstan) and lower parts of the Syr-Dar'ya indicated high COP and HM concentrations in plants, caused by polluted water *(Phragmites, Typha*, etc.), showing also that all analysed animal species in these habitats contained COP and HM. The largest quantity of these was found in heterobionts - Chironomidae. Pollutant concentrations showed great differences in Orthoptera: Acridoidea have several times higher concentrations than Tettigonioidea. Soil invertebrates (Lumbricidae, Grillotalpidae) were less contaminated. Tenebrionidae and *Scolopendra* had an intermediate position. Arachnida were considerably contaminated. Pollutant concentrations 2-5 times higher than the sanitary standards were found in several species of birds. Analyses have proved that fish with different feeding and phenological activities had approximately equal content of COP, accumulated mainly in fat tissues, reproductive organs and brain, whereas HM concentrated in the gills, liver or muscle tissues, depending on fish species.

Table 1. Contents of chlorine-organic pesticides in fish organs and tissues in Chardara Reservoir (Spring 1993, 1994)

Fish species	Specimen number	HCCH αβσ µg/kg damp mass					DDT+ DDE µg/kg damp mass				
		Brain	Liver	Fat	Gonads	Muscle	Brain	Liver	Fat	Gonads	Muscle
1993											
Cyprinus carpio	5	traces	4.17	8.37	2.4	10.84	31.3	65.0	112	11.2	15.2
Pelecus cultratus	12	34.8	29.1	3.9	38.0	8.2	traces	98.7	7.9	250.2	26.6
Carassius auratus gibelio	10	24.5	2.3	traces	4.0	2.2	58.6	13.7	traces	10.6	4.5
1994											
Cyprinus carpio	8	12.3	36.6	12.4	4.5	56.8	36.3	46.7	93.2	9.2	10.4
Pelecus cultratus	10	traces	31.9	48.0	26.6	7.1	traces	90.6	128	111	16.5
Carassius auratus gibelio	11	20.5	29.9	10.4	4.5	56.8	37.5	100	32.2	19.3	56.1

Table 2. Contents of chlorine organic pesticides in Kamyshlybash Lake water (Summer 1994)

Regions	Pesticides (average contents in µg/l)	
	HCCH isomers	DDT metabolites
South-West, station 5	0.18	0.20
North-West, station 1	0.16	1.09
Centre, station 6	0.26	0.30
North-East, station 7	0.15	0.18
East, station 8	0.26	0.18
South-East, station 9	0.58	0.36
South, station 10	0.11	0.10

Table 3. Heavy metal content in the Kamyshlybash Lake water (Summer 1995)

	Ingredients in µg/l			
	Zn	Cu	Pb	Cd
Water, station 1	116.16	422.26	87.08	13.03
Water, station 3	108.41	370.76	108.85	13.02
Water, station 5	123.90	391.36	92.52	13.34
Water, station 6	116.17	391.36	81.63	13.34
Water, station 7	112.27	617.94	97.96	12.07
Water, station 8	108.41	308.97	130.61	13.03
Water, station 9	100.67	216.28	81.63	10.49
Water, station 10	108.41	164.78	87.08	14.35
Tokay Lake water	112.29	216.28	92.52	5.72
Akshatau Lake water	100.67	278.07	92.52	9.53
Dzhanay Lake water	127.77	257.47	97.96	4.45
Shomishkol' Lake water	96.80	267.77	81.63	7.31
Raimkol' Lake water	162.62	370.08	92.52	10.49
Kataykol' Lake water	116.16	226.58	136.06	14.62
Karakol' Lake water	135.52	370.76	114.29	8.90
Ashikol' Lake water	154.88	401.66	119.73	15.57

Table 4. Heavy metal content in the water of Sar-Dar'ya River delta and Kamyshlybash Lake in 1994

	Ingredients in µg/l				
	Zn	Cu	Pb	Cd	Hg
Syr-Dar'ya River, Kazalinsk Water Collector	44.01	70.09	5.29	21.54	0.79
Kamyshlybash, western part	121.03	239.50	23.81	107.68	0.17
Kamyshlybash, centre	209.05	350.49	18.52	107.68	0.05
Kamyshlybash, east	115.03	171.74	12.04	94.22	1.29

Table 5. Chlorine-organic pesticide content in sludge of Kamyshlybash Lake (Summer 1994)

Regions	Pesticides (average in µg/kg)	
	Sum of HCCH isomers	Sum of DDT metabolites
South-West, station 5	3.8	190.9
North-West, station 1	4.6	151.5
Centre, station 6	8.1	153.8
North-East, station 7	3.2	50.7
East, station 8	15.0	36.2
South-East, station 9	4.6	29.4
South, station 10	11.5	20.3

Table 6. Heavy metal content in the sediments of Kamyshlybash Lake and Syr-Dar'ya River (Spring 1994)

	Ingredients in mg/kg			
	Zn	Cu	Pb	Cd
Sediments, station 1	2.419	4.312	0.917	1.852
Sediments, station 2	5.347	3.317	0.917	9.259
Sediments, station 3	5.601	3.317	0.859	6.944
Sediments, station 4	5.474	3.483	0.802	8.729
Sediments, station 5	8.529	3.317	1.146	6.018
Sediments, station 6	8.784	3.980	0.974	9.723
Sediments, station 7	8.529	3.649	1.203	7.840
Sediments, station 8	8.784	4.644	0.859	8.333
Sediments, Syr-Dar'ya, station 1	11.330	10.282	1.490	15.277
Sediments, Syr-Dar'ya, station 2	11.830	9.951	1.375	13.888

Table 7. Heavy metal content in the sediments of Kamyshlybash Lake (Summer 1995)

	Ingredients in mg/kg			
	Zn	Cu	Pb	Cd
Sediments, station 1	8.13	6.49	5.71	0.20
Sediments, station 2	7.59	6.49	4.57	0.20
Sediments, station 3	9.49	7.21	4.57	0.29
Sediments, station 4	6.51	6.49	5.71	0.16
Sediments, station 5	5.42	5.05	3.43	0.20
Sediments, station 6	10.57	7.21	8.56	0.20

Table 8. Heavy metal content in the macrophytes in Kamyshlybash Lake (Summer 1995)

	Ingredients in mg/kg			
	Zn	Cu	Pb	Cd
Potamogeton perfoliatus, st.6	7.05	5.05	4.19	0.31
Potamogeton perfoliatus, st. 7	3.79	4.33	5.71	traces
Potamogeton perfoliatus, st.8	5.69	5.05	4.19	0.18
Potamogeton perfoliatus, st.9	4.07	5.05	4.95	0.25
Potamogeton perfoliatus, st.10	6.23	5.77	3.05	0.16
Potamogeton filiformis, st. 1	4.61	4.33	4.19	0.20
Potamogeton filiformis, st. 3	12.73	10.09	8.76	0.46
Potamogeton filiformis, st. 7	1.42	0.56	3.43	0.18
Potamogeton filiformis, st. 9	7.59	3.60	4.95	0.18
Potamogeton filiformis, st. 10	8.94	5.77	6.48	0.31
Scirpus sp., st. 1	5.42	0.39	2.29	traces
Scirpus sp., st. 3	3.25	4.33	4.54	0.09
Scirpus sp., st. 5	8.13	3.60	3.81	0.08
Myriophyllum sp., st. 5	1.63	0.90	5.71	0.20
Myriophyllum sp., st. 7	3.52	6.48	3.05	traces
Myriophyllum sp., st. 9	2.44	7.21	4.19	0.25
Filamentous alga, st.3	3.79	6.49	3.05	0.22

Table 9. HCCH content in organs and tissues of fish in Kamyshlybash Lake in summer 1994-1995

Fish species	Specimen number	HCCH (α,β,γ) μg/kg of damp weight			
		Muscles	Fat	Liver	Brain
Cyprinus carpio	4	19.9	12.8	16.9	5.2
	3	*16.5*	*36.3*	*49.0*	*16.6*
Silurus glanis	4	10.4	15.4	6.8	20.4
	6	*19.6*	*14.0*	*17.9*	*21.7*
Esox lucius	3	13.7	16.4	6.3	30.4
	4	*23.8*	*18.7*	*18.6*	*48.2*
Scardinius erythrophthalmus	5	–	–	–	–
	6	*11.0*	*21.8*	*14.4*	*11.2*
Perca fluviatilis	4	25.9	22.0	44.5	15.6
	–	–	–	–	–
Rutilus rutilus aralensis	7	10.4	18.7	13.8	14.7
	4	–	–	–	–

* Upper values - 1994, *Lower values - 1995.*

Table 10. DDT content in organs and tissues of fish in Kamyshlybash Lake (Summer 1994-1995)

Fish species	Specimen number	DDT+DDE µg/kg of damp weight			
		Muscles	Fat	Liver	Brain
Cyprinus carpio	4	12.0	107.4	126.9	34.6
	3	*39.1*	*137.3*	*132.4*	*90.7*
Silurus glanis	4	19.3	190.5	18.4	18.5
	6	*21.1*	*312.3*	*79.4*	*30.5*
Esox lucius	3	20.4	198.2	117.0	31.5
	4	*27.4*	*302.3*	*66.3*	*34.3*
Scardinius erythrophthalmus	5	-	-	-	-
	6	*12.7*	*102.6*	*55.8*	*68.3*
Perca fluviatilis	4	75.0	182.0	144.6	32.6
	-	-	-	-	-
Rutilus rutilus aralensis	7	34.3	112.5	122.4	34.3
	4	-	-	-	-

* Upper values - 1994, *Lower values - 1995.*

Table 11. Heavy metal content in the fish bodies in Kamyshlybash Lake (Summer 1994-1995)

	Ingredients in mg/kg			
	Zn	Cu	Pb	Cd
Perca fluviatilis, brain	4.03	1.02	1.43	7.72
Perca fluviatilis, muscle	1.78	0.51	0.92	3.70
Perca fluviatilis, liver	6.87	0.66	1.09	1.78
Perca fluviatilis, gills	7.26	1.12	1.20	5.09
Silurus glanis, brain	2.29	0.72	1.32	1.39
Silurus glanis, liver	4.84	1.03	1.15	5.09
Silurus glanis, spawn	3.56	0.61	1.20	6.94
Silurus glanis, muscle	1.40	0.51	1.20	3.24
Silurus glanis, gills	4.07	0.72	1.03	6.48
Perca fluviatilis, muscle	13.24	0.51	1.09	3.70
Perca fluviatilis, liver	9.17	2.99	1.26	5.56
Perca fluviatilis, gills	8.68	1.39	1.30	8.42
Cyprinus carpio, brain	5.73	1.72	1.09	5.56
Cyprinus carpio, liver	16.29	13.60	1.38	2.32
Cyprinus carpio, muscle	4.46	0.61	1.20	2.78
Cyprinus carpio, spawn	16.42	0.92	1.43	3.79
Cyprinus carpio, male gonads	5.73	0.71	1.38	4.20
Cyprinus carpio, gills	17.06	1.23	1.32	6.31

Table 12. Pollution content in biocoenosis components in Kamyshlybash Lake and Syr-Dar'ya delta in vegetation period 1994-1995

Location	Heavy metals µg/l, mg/kg				DDT+HCCH
	Zn	Cu	Cd	Pb	mcg/l, mcg/kg
Water	15.28-44.56	33.16-110.88	14.32-48.62	152.77-392.84	0.13-2.10
lake	*28.90+3.14*	*58.19±8.46*	*24.16±3.24*	*222.90±24.90*	*0.75±0.15*
Water	2.73-3.18	4.74-4.98	5.16-9.00	37.04-62.89	0.14-0.28
river	*2.96±0.23*	*4.86±0.12*	*7.08±1.92*	*49.93±12.90*	*0.19±0.47*
Sediments	2.42-8.78	3.32-4.64	0.80-1.20	1.85-9.72	20.38-190.90
lake	*6.68±0.83*	*3.75±0.18*	*0.96±0.05*	*7.34±0.89*	*79.60±14.97*
Sediments	11.33-11.84	9.95-10.28	1.38-1.49	13.89-15.28	57.82-103.48
river	*11.58±0.25*	*10.12±0.17*	*1.43±0.06*	*14.58±0.69*	*51.35±12.13*
Soil	5.09-5.38	1.99-2.27	0.69-0.72	7.41	17.45-72.26
lake region	*5.24±0.15*	*2.13±0.14*	*0.70±0.02*		*41.74±16.13*
Macrophytes	0.76-8.78	0.72-15.92	0.29-1.38	1.85-6.54	0.36-183.15
lake	*4.08±0.54*	*2.54±0.62*	*1.02±0.05*	*4.49±0.36*	*46.11±8.91*
Zooplankton	3.95-4.58	1.33-1.66	0.76-0.92	4.63-6.48	9.96-364.1
lake	*4.26±0.32*	*1.49±0.17*	*0.83±0.09*	*5.56±0.93*	*146.76±76.05*
Zoobenthos	1.14-68.75	1.33-2.16	1.63-1.55	5.09-25.46	12.73-166.30
lake	*17.14±12.96*	*1.82±0.15*	*1.20±0.17*	*12.22±3.57*	*94.95±25.90*
Predatory	1.40-9.17	0.51-2.99	0.92-1.43	1.39-8.42	6.30-198.20
fishes	*5.60±1.2*	*0.98±0.20*	*1.18±0.04*	*5.01±0.61*	*87.41±10.51*
Fishes	4.45-17.06	0.61-13.60	1.09-1.43	2.32-6.31	12.40-128.16
	10.95±2.53	*2.97±2.13*	*1.30±0.05*	*4.16±0.63*	*62.15±23.10*
Amphibians	2.78-12.22	1.43-1.89	1.03-1.53	5.09-5.66	163.24-332.97
lake	*8.64±2.25*	*1.56±0.11*	*1.23±0.12*	*5.40±013*	*214.37±27.15*
Near water	2.89-14.55	0.72-4.73	0.16-3.27	1.26-15.87	115.09-138.30
invertebrates lake	*7.80±2.92*	*2.71±1.06*	*1.46±0.66*	*6.83±3.17*	*126.70±11.61*
Birds	2.80-11.97	1.13-40.13	1.03-1.20	1.65-7.58	5.39-218.52
lake region	*6.13±1.60*	*9.84±7.60*	*1.13±0.04*	*4.20±0.99*	*140.47±2.32*

* Upper values - Kamyshlybash Lake; *Lower values - Syr Dar'ya delta.*

Figure 1. Schematic map of Chardara Reservoir, showing sampling stations

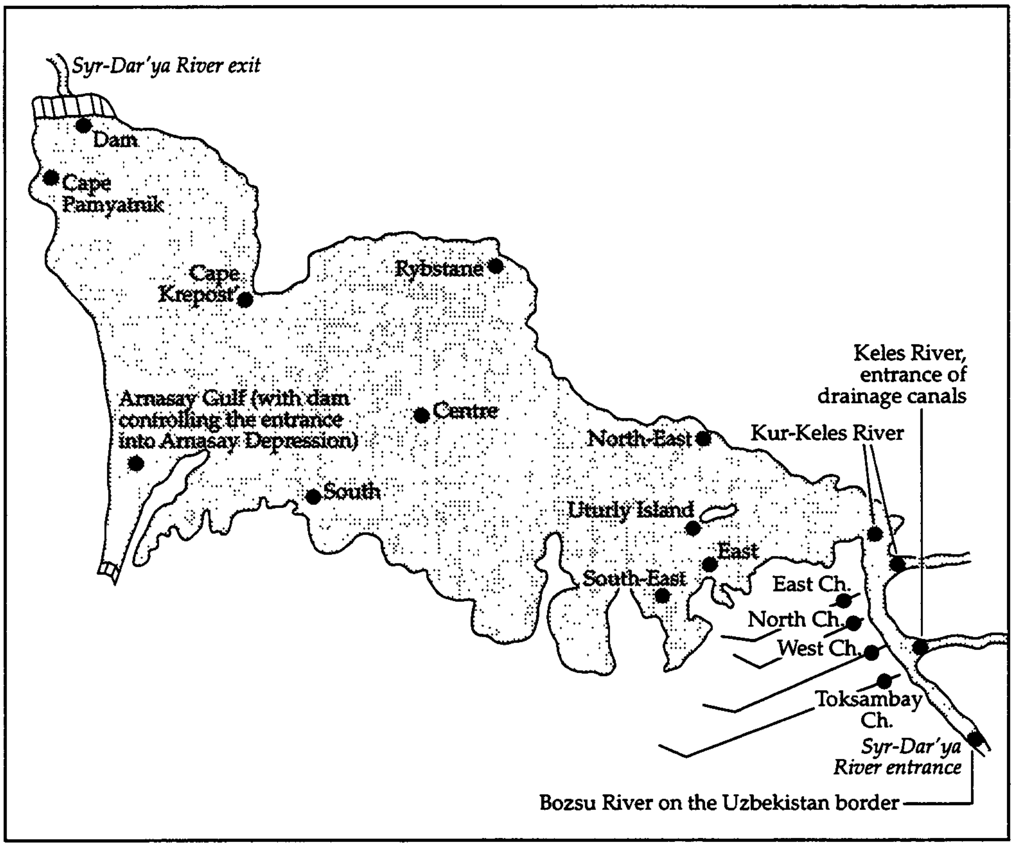
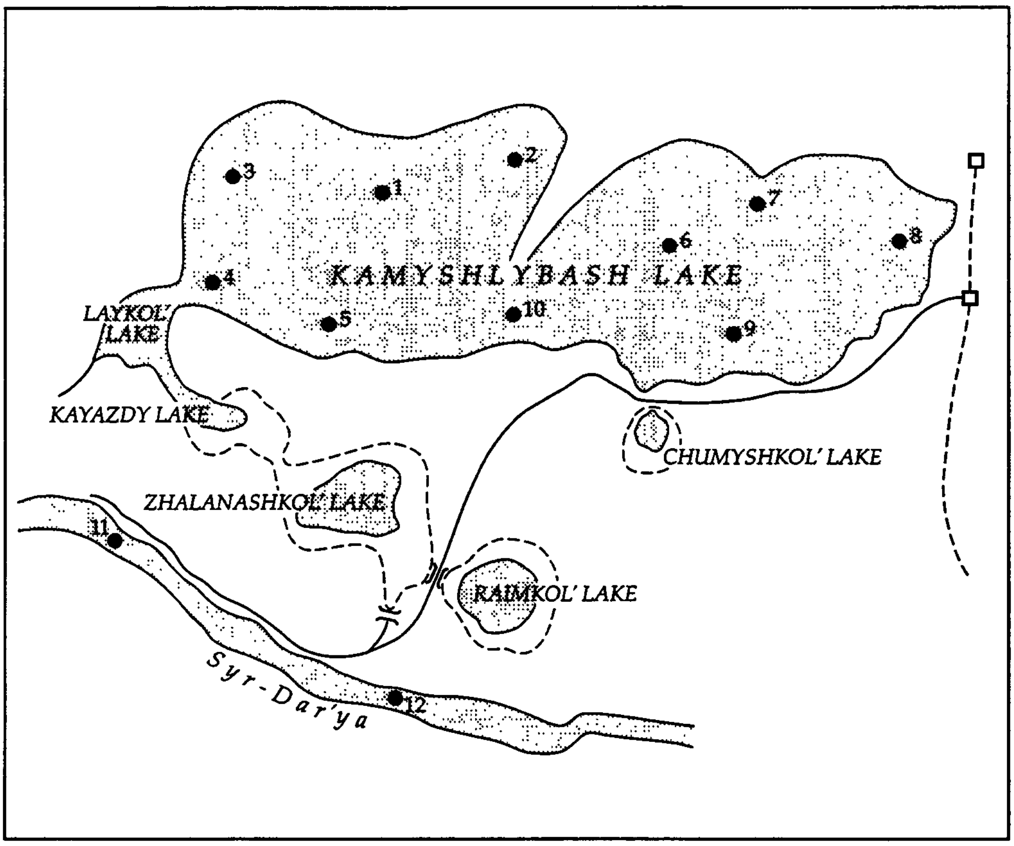


Figure 2. Outline of Kamyshlybash Lake system, showing sampling stations



Chlorine organic pesticide content (DDT & HCCH):

Figure 3. COP in the waters of Chardara Reservoir and the Syr-Dar'ya, Spring 1993 & 1994

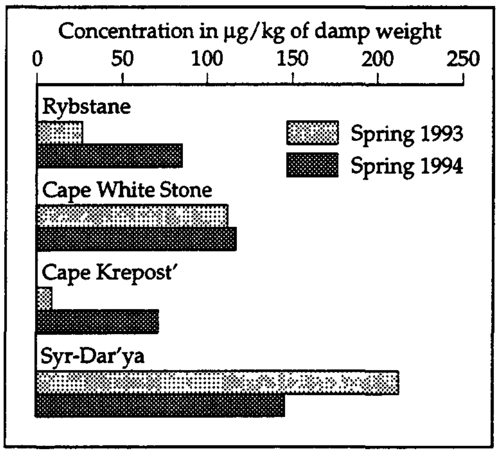


Figure 4. COP in sludge deposits of Chardara Reservoir, 1993 & 1995

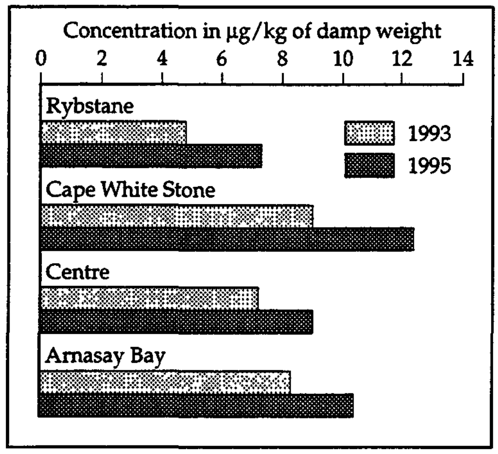
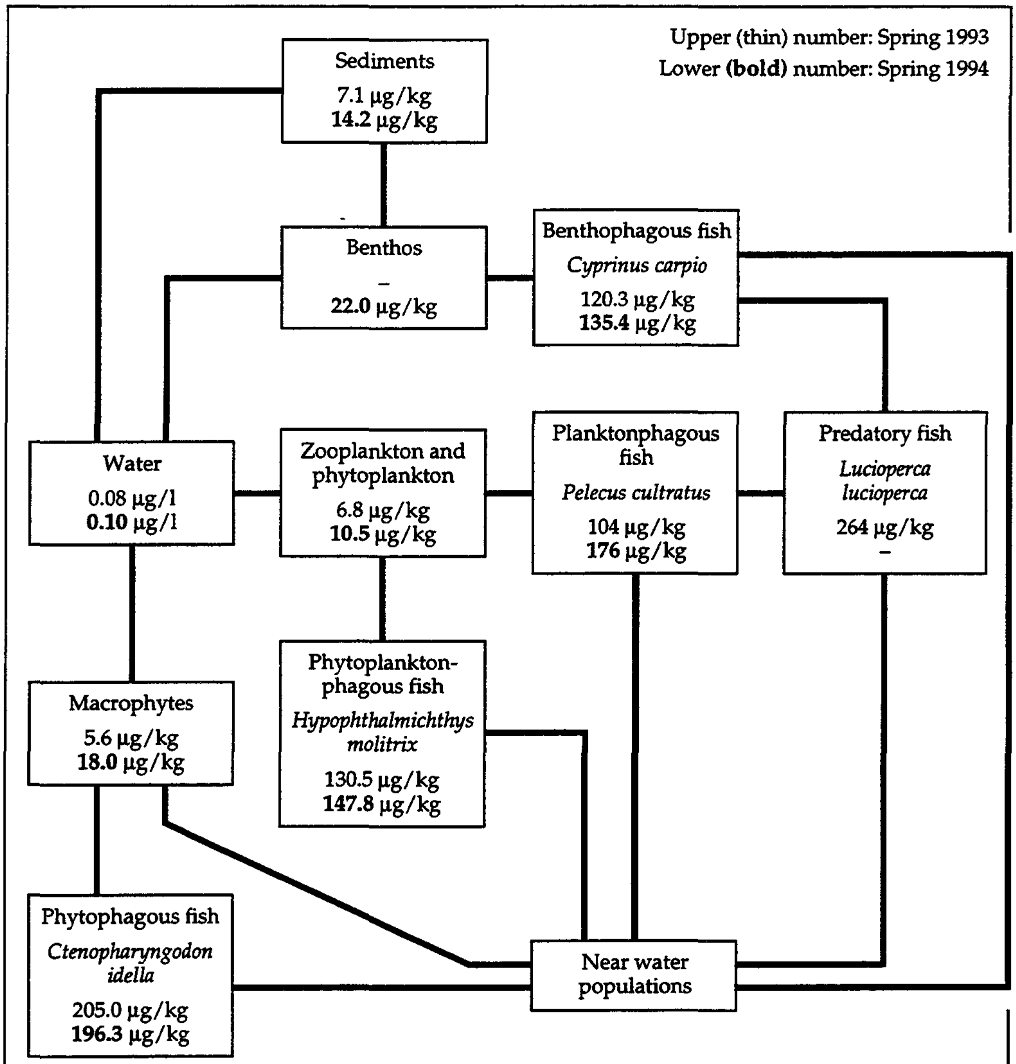
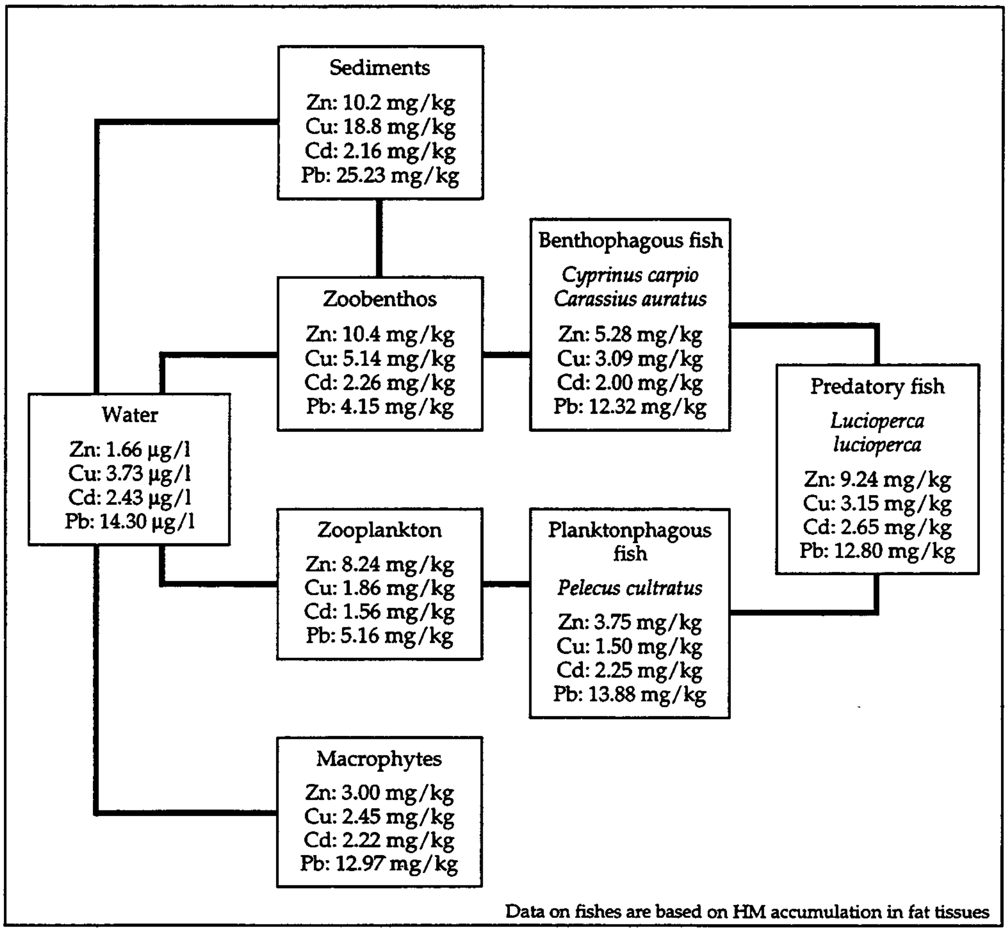


Figure 5. Accumulation of COP in the main components of the Chardara Reservoir water ecosystem, Spring 1993 & 1994 (mean values)



Data on fishes are based on COP accumulation in fat tissues

Figure 6. Accumulation of heavy metal pollutants in the main components of the Chardara Reservoir water ecosystem



Chlorine organic pesticide content (DDT & HCCH):

Figure 7. COP in the waters of Kamyshlybash Lake, 1994 & 1995

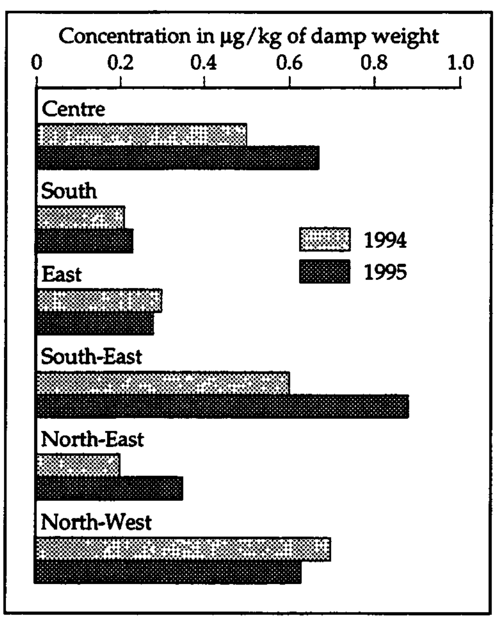


Figure 8. COP in sludge deposits of Kamyshlybash Lake, Summer 1994 & 1995

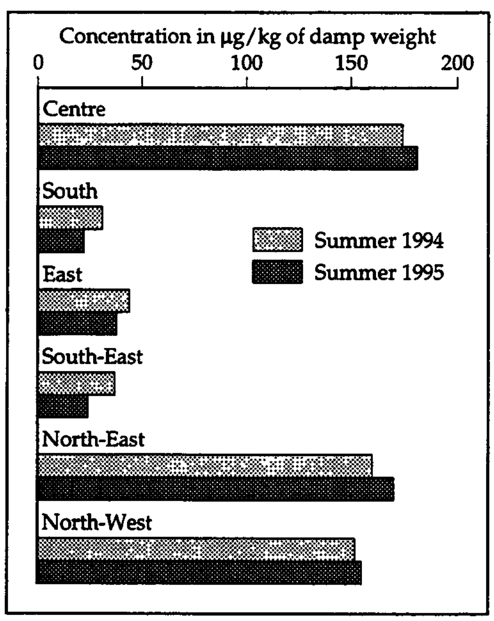
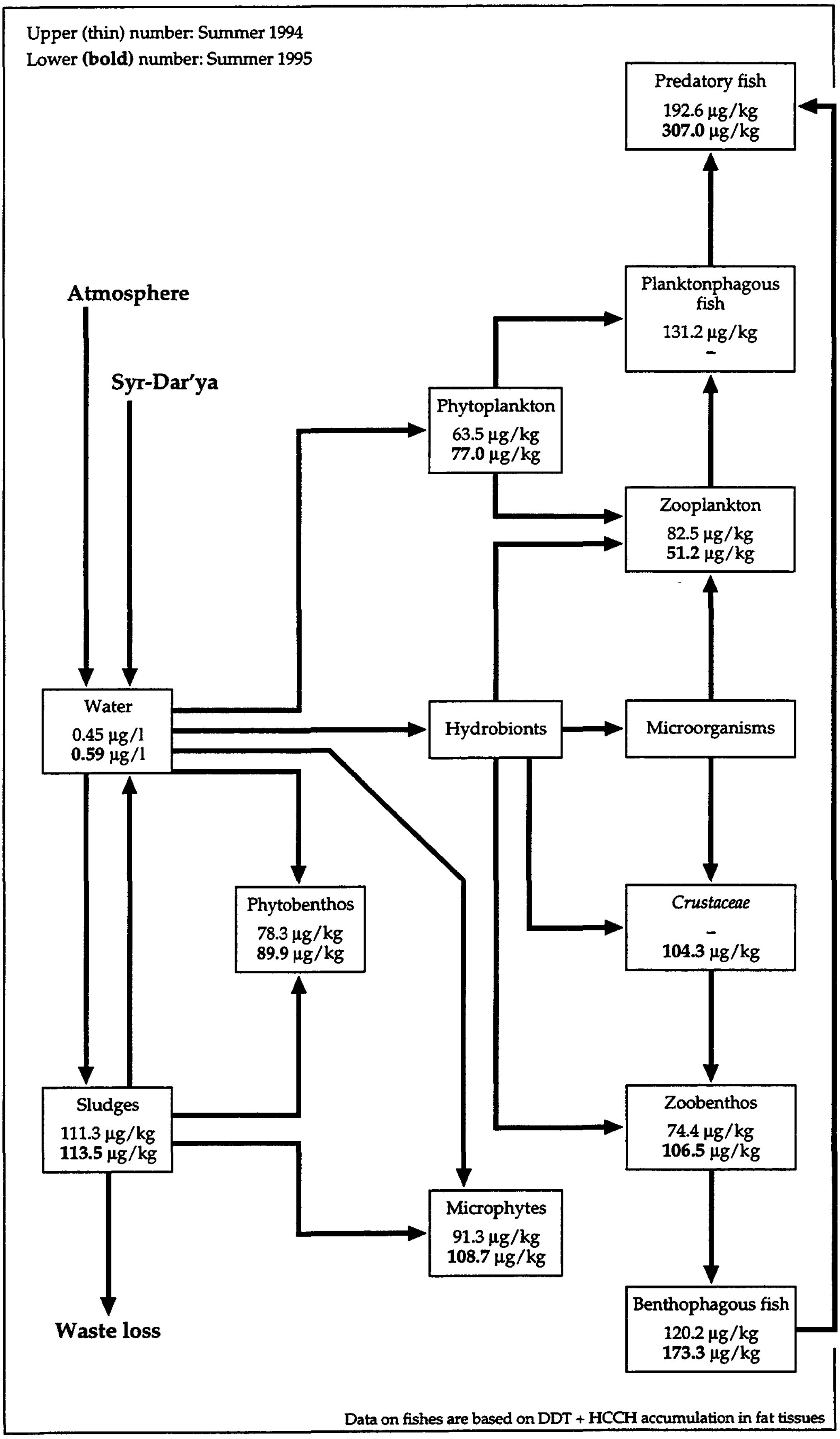


Figure 9. Accumulation of COP in the main components of the Kamyshlybash Lake water ecosystem, Summer 1994 & 1995 (mean values)



Applications of research

AN ELECTRONIC ATLAS AS THE FIRST STEP TOWARDS A GEOGRAPHICAL INFORMATION SYSTEM OF THE ARAL SEA REGION

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Need for a Geographical Information System

The Aral Sea and its basin have been studied intensively since the middle seventies, within the framework of a special research plan for the area, adopted by the former Soviet Union. Dozens of institutes and organizations participated in the programme, studying different aspects of the situation in the Aral Sea Region. A huge amount of information was accumulated during that project. However, the data are stored on paper media and poorly classified. Maps do not normally have any geo-referencing and are often neither compatible nor precise. The accumulated data thus need to be transferred onto magnetic storage and structured according to a predefined system.

Modern methods of presentation and analysis of information in ecological research are based on Geographical Information Systems (GIS). GIS are often used as a means of checking and visualisation by which certain objects, processes or phenomena can be located in space, according to the information contained in a data base. Another important GIS area is the modelling of processes and geographical forecasts.

This is the reason why the setting-up of the GIS for the Aral Sea Region is an important component of the joint BMBF/UNESCO Project "Ecological Investigations and Monitoring of the Syr-Dar'ya and Amu-Dar'ya Deltas in the Aral Sea Region as the Basis of their Restoration".

The Aral Region GIS (ARGIS) is a relational spatial data base containing cartographic, statistic, analytic, modelling data and space imagery. The structure of ARGIS is aimed at supporting various research studies, the priority being ecology.

ARGIS structure

The structure of ARGIS was developed using the example of the Global Resource Information System (GRID). GRID is a powerful tool providing support for the Global Monitoring System of Environment of UNEP, with many users worldwide. ARGIS is compatible with GRID and was developed in several stages.

(a) The Electronic Atlas Compilation (EA): EA contains existing and derived cartographic materials with attached data base, graphs and support text. EA is analoguous to Land Information Systems. EA has open structure, enabling updating and further development.

(b) Land, water, environment, human resources and general inventories and assessment.

(c) Compilation on the EA basis of different models of ecosystems, water and irrigation systems and agrosystems.

(d) Geographical forecast of environment situations and their probability.

(e) Measures for ecosystem conservation and rehabilitation.

The most important and most time-consuming part of ARGIS is the development of EA in the region. There is, at present, worldwide experience in related mapping and GIS projects. During 25 years of computer cartography, dozens of thematic and complex EA of global, regional and local scale have been compiled. Certain ideas and experiences of international projects (ESRI and the Institute of Geography, Russian Academy of Sciences (RAS) - "ArcAtlas: our world") and EA "Man and the Biosphere - Tadjikistan XXI Century" of the Institute of Geography, RAS, were used in our work.

The main stages of EA compilation are the following:

i) adoption of EA topics including maps, their scale, type, projection; additional statistics, graphics and service data;

ii) compilation of big structured data base in a format (Dbase) compatible with different user interests and different software;

iii) compilation of basic electronic maps using various methods of input (digitizing, scanning with subsequent vectorization and editing, retrieval from CD-ROM, etc.);

iv) maps composing and editing, including text and graph bookmarks, user menus, graphic interface, etc.

Electronic Atlas contents

The contents of EA maps are determined by their ecological and practical aims. This includes general maps (topographic scale 1:200 000 (raster format) and 1:500 000 (vector format), physical maps (geology, soils, vegetation, etc.), ecological inventory maps (desertification, pollution, critical areas, etc.). Additional layers consist of remote sensing data from 1962 to 1995. Remote sensing images were used in many instances to update the existing maps. The principles of geo-ecological mapping of arid countries using space data were elaborated in our previous research.

The mapping area was defined in accordance with the project objectives. The Amu-Dar'ya and Syr-Dar'ya deltas are the main areas studied in the project. The causes of degradation of the deltas are related to both the basin water regulation and dessication of the Aral Sea. The deltas are also affected by adjacent deserts (salt-dust storms, etc.). Therefore, the mapping area also had to cover the territories around the Aral Sea, where the effects of desertification are evident. This includes the desert belt from 50 km in the North to 500 km in the South-East from the sea shore in 1961, the deltas, the Aral Sea and its dry bottom.

In EA, maps are compiled in the basic projection (UTM - Universal Transverse Mercator), making use of the developed symbol and colour palette and annotations. The maps in EA may contain the graphic field (the map itself), a set of annotations, legend, scale, set of symbols and text. The map may also contain links with other maps, demos and batch files. The maps may have raster, vector, and raster with vector elements. Certain maps have multilayer structure and are derivatives from the basic maps. The maps were compiled in PC ARC/INFO format and stored as coverages. Certain maps were built using interpolation routines in ILWIS GIS, and vectorized. Attributative data base is stored in Dbase 3 format. Raster layers are stored in ARC/INFO GRID format.

The EA interface is compiled in PC ARCVIEW 1 software. PC ARCVIEW is GIS viewer software, providing some possibilities of map composing and data base query. Users can also work in ARC/INFO or other GIS, compatible with ARC/INFO. ARCVIEW is only a viewer and simple query tool. The choice of ARCVIEW 1 was adopted owing to its moderate hardware requirements. ARCVIEW 1 itself does not provide advanced tools for visualization, adding graphs or texts. Due to this, we currently use Microsoft PowerPoint as the shell programme. If the newest ARCVIEW version will require less memory and hardware, we will switch to that. The primary version of Atlas will be issued on streamer tape and will occupy about 100 MB of disk space. The following versions might be issued on CD-ROM. All information is in English, but Russian or other language versions are possible.

EA currently consists of three main parts: physical, economical and ecological. In the ecological part data is stored, which is important for research in both other parts.

A short overview of EA is shown in Table 1.

The physico-geographical part comprises the topographical maps of 1:200 000 and 1:500 000 scale. They contain several layers, including hydrography, relief, administration, road networks, etc. The attached data base includes the names of settlements, numbers of inhabitants, types of settlements, names of channels and their characteristics.

For better understanding of the information, illustrations such as graphs and diagrams are added to many maps (e.g. climatic and hydrologic maps). Many climatic and hydrologic maps have such features. Many maps were produced on the basis of reclassification of certain basic maps. The range of maps for the Amu-Dar'ya Delta, comprising vegetation, soil, ground water, desertification and others, was compiled by reclassification of landscape maps, with corresponding data base. In the economico-geographical part, the majority of information is linked to administrative territorial units. Three unit levels are distinguished.

i) The territorial units such as kolhoses, sovhoses, or farms, belong to the first hierarchical level. Many maps for the Republic of Karakalpakstan belong to that level.

ii) Second-level maps are attached to administrative districts ("rayon").

iii) Third-level maps contain information on administrative regions ("Oblast") or ("Velayat").

A short description of the above is shown in Table 2.

By making use of the data base, several maps have been derived, including demography, economy, etc. Some maps also comprise additional illustrations, such as graphs and diagrams. An important layer of maps relate to water husbandry and irrigation, in accordance with their significance in the modern society of the region. The majority of maps for this part are made on the basis of statistic data.

The most important part of EA is associated with ecology, and mainly comprises data from the last few years. This part contains several original maps by different authors. The structure is open, similar to that of other parts of EA, so that it may be updated by including new materials.

The ecological part contains derivative maps, composed by using data from the other parts, for example, maps related to aspects of desertification, medico-geographical, geo-ecological inventory of the area, types of ecological situations and forecast maps.

The EA of the Aral Sea Region is not a closed set of data; it is open to allow up-dating using new data, gathered during the implementation of the Sub-Projects of the BMBF/UNESCO Project. This will be the most important task for the future, because, at present, many parts and layers of EA are not adequately filled by information. Another important task for future efforts should be the up-dating of maps by satellite data. Considerable help in this respect has been provided by the EOSAT Company, which supplied us with digital space data from LANDSAT MSS and TM sensors. These will represent a good foundation for precise investigations, calculations and modelling for ARGIS.

Table 1. The structure of Electronic Atlas on the Aral Sea Region

Part	N°	Maps - layers of EA	Scale of resource maps	P - Polygons L - Linear Pt - Point R - Raster (grid)	S - Statistical data G - Graphs & photos T - Texts A - Digital aerospace images
1	2	3	4	5	6
Physico-geographic	1.	Space images (Landsat TM, MSS, Resource MSU-SK, MSU-E, NOAA AVHHR.)	Resolution from 30 to 1 km.	R	T, A
	2.	Topographic	1:500 000 - 1:200 000	P, L, Pt	G, T
	3.	Geologic	1:2 500 000	P	G, T
	4.	Tectonic	1:2 500 000	P, L	G, T
	5.	Quaternary deposits	1:1 000 000	P, Pt	G, T
	6.	Geomorphology	1:1 000 000 - 1: 200 000	P, Pt	S, G, T
	7.	Climatic	1:2 500 000	P, L, Pt	S, G, T
	8.	Agroclimatic	1:2 500 000	P, L, Pt	S, G, T
	9	Underground water	1:1 000 000	P, Pt	S, G, T
	10.	Surface water	1:1 000 000	P, Pt	S, G, T
	11.	Batimetric	1:1 000 000	P, L, Pt	S, G, T
	12.	Soil	1:1 000 000	P, T	S, G, T
	13.	Vegetation	1:1 000 000 - 1: 200 000	P, Pt	S, G, T, A
	14.	Animal world	1:1 000 000	P, Pt	S, G, T, A
	15.	Landscapes	1:1 000 000 - 1: 200 000	P, Pt	S, T, F
	16.	Historical geography	1:1 000 000	P, Pt	G, T
Economico-geographical	17.	Administrative maps	1:1 000 000	P, Pt	S, T
	18.	Population	1:1 000 000	P, Pt	S, T
	19.	Occupation	1:1 000 000	P, Pt	S, G, T
	20.	Social development	1:1 000 000	P, Pt	S, G, T
	21.	Public health	1:1 000 000	P, Pt	S, G, T
	22.	Industry	1:1 000 000	P, Pt	S, G, T
	23.	Resources use	1:1 000 000 - 1: 200 000	P, Pt	S, G, T
	24.	Water husbandry	1:1 000 000 - 1: 200 000	P, L, Pt	S, G, T
	25.	Irrigation	l:; 000 000 - 1: 200 000	P, L, Pt	S, G, T
	26.	Livestock and grazing	1:1 000 000 - 1: 200 000	P, Pt	S, G, T
	27.	Traditional crafts	1:1 000 000	P, Pt	S, T
	28.	Transport	1:1 000 000	L, Pt	S, G, T
	29.	Economical regions	1:1 000 000	P, Pt	S, G, T
	30.	History of development	1:1 000 000	P, Pt	G, T, A
Ecologico-geographical	31.	Desertification processes	1:1 000 000 - 1: 200 000	P, Pt	S, G, T, A
	32.	Air pollution	1:2 500 000	P, Pt	S, G, T, A
	33.	Surface water pollution	1:1 000 000	P, L, Pt	S, G, T
	34.	Ground water degradation	1:2 500 000	P, Pt	S, T
	35.	Environment pollution	1:1 000 000	P, Pt	S, T
	36.	Illness rate	1:1 000 000	P, Pt	S, G, T
	37.	Natural focuses of epidemic	1:2 500 000	P, Pt	S, G, T

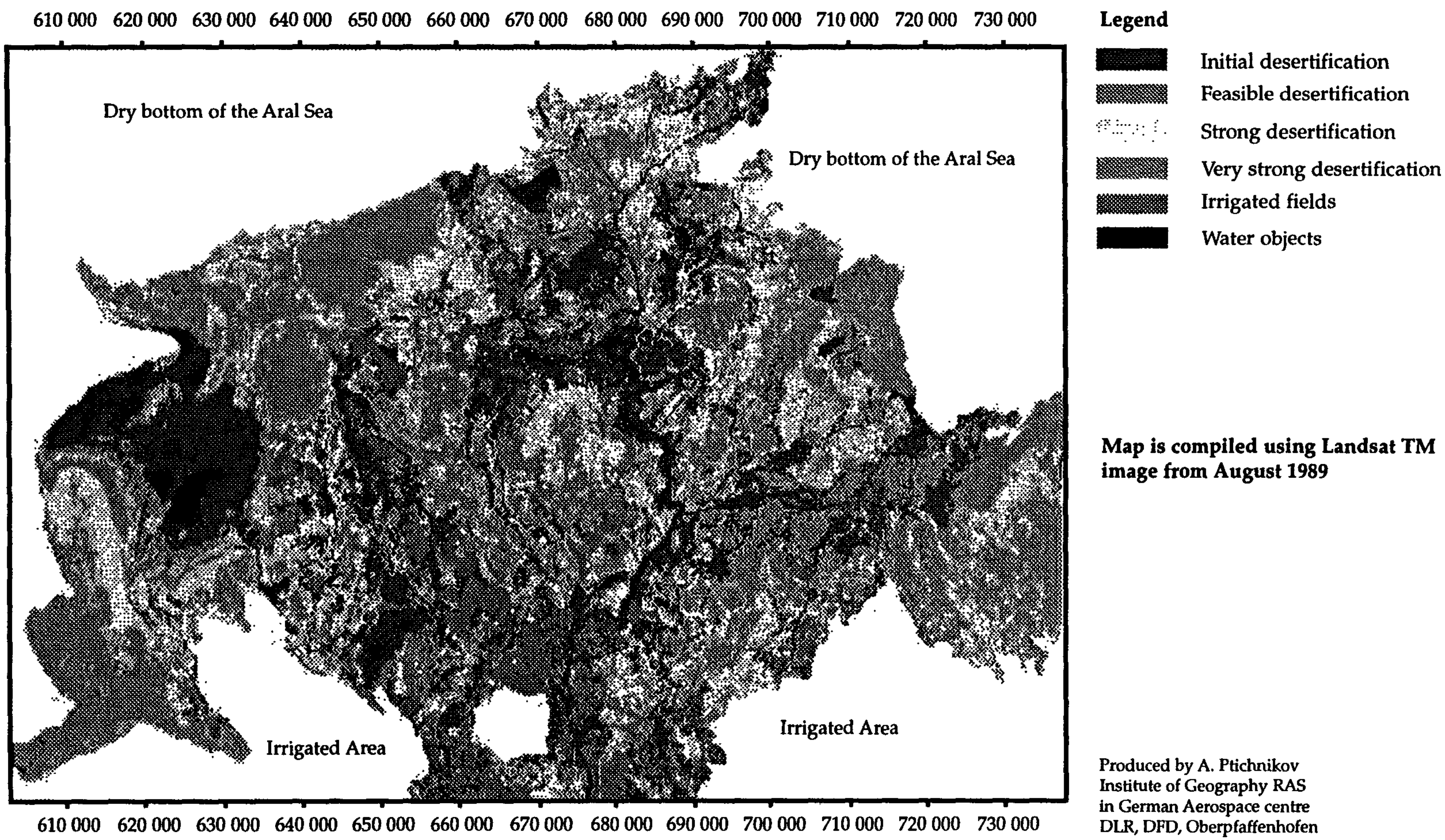
1	2	3	4	5	6
	38.	Soil degradation	1:1 000 000 - 1: 200 000	P, L, Pt	S, G, T
	39.	Vegetation degradation	1:1 000 000 - 1: 200 000	P, Pt	S, G, T
	40.	Ecosystem dynamics	1:1 000 000 - 1: 200 000	P, Pt	S, G, T
	41.	Sea ecosystem degradation	1:1 000 000	P, L, Pt	S, G, T
	42.	Agriculture effectiveness	1:1 000 000	P, Pt	S, G
	43	Geoecological estimation	1:1 000 000	P, Pt	S, G
	44.	Geoecological zoning	1:1 000 000	P, Pt	S, G, T
	45.	Forecast of ecological situation	1:1 000 000	P, Pt	S, G
	46.	Optimization measures	1:1 000 000	P, Pt	S, G
	47.	Anti-desertification measures	1:1 000 000	P, Pt	S, T
	48.	Rare and endangered species	1:1 000 000	P, Pt	S, T, A
	49.	Nature protection	1:1 000 000 - 1: 200 000	P, Pt	S, G, T, A

Table 2. Main contents of cartographic and attributive data base of the Electronic Atlas (EA)

Number of layers in EA (see Table 1)	Main contents of cartographic data base	Main contents of attributive data base
1.	Overview of region for 1962, 1972, 1980, 1984, 1989, 1991, 1994, 1995	
2.	Water objects, settlements, heights, road network	
3.	Age, lithology of rocks and deposits	Stratographic descriptions
4.	Main tectonic structures and faults	Modern vertical movements, seismics
5.	Genesis, depth of quaternary rocks	Modern sedimentation
6.	Genesis, structure, relief forms, processes	Geomorphological profiles
7.	Climatic regions, dynamics of meteoelements	Meteostations data
8.	Agroclimatic data, coefficients, regions	Availability for certain crops
9.	Depth, content, mineralization of ground and underground waters, their dynamics	Different hydrological processes
10.	Runoff, mineralization, chemical composition, ion and solid discharge	Water measuring points data
11.	Bottom relief, dynamics of shore line	Water balance
12.	Soil type and genesis, indicators of their contents, structure, potential use	Availability for irrigation, soil index
13.	Types, productivity, projective cover, ecological significance	Vegetation index, phytodiversion
14.	Species, habitats	Biodiversity
15.	Type of modern landscapes and their features	Dynamic ranges of landscapes
16.	Stages of evolution of environment, landscape age	Evolution ranges of landscapes
17.	Administrative units, settlements	Changes during 19-20 centuries, men/women ratio, urban/rural inhabitants, etc.
18.	Population density, national composition	
19.	Occupation structure, jobs	Dynamics of occupations and jobs
20.	Level of life, income, consuming structure, culture, education	Comparison with other countries
21.	Natality, morbidity, trends, medication measures	Connection with ecological factors
22.	Structure, correlation	Quantitative data

23.	Type of land used	Land use dynamics
24.	Irrigation and drainage performance, channels, reservoirs, their area of influence	Dynamics of reservoirs and artificial ponds. Their assessment for fishery
25.	Structure, areas, productivity, melioration	Dynamics of irrigation
26.	Structure, quantity, types of pastures	Pasturelands dynamics
27.	Structure, ratio of existing and lost crafts	Dynamics of crafts
28.	Structure, volume of transportation	Availability, quality of roads
29.	Specialization, level of economic development	Comparison of economic figures
30.	Stages of land use	Evolution of land use
31.	Structure, level of development	Stages of processes
32.	Focuses, volume, direction of transportation and sedimentation of salt-dust of pollutants	Dynamics of air pollution, and its influence over agriculture, ecoysystems, public health
33.	Volume, mineralization, pollution	Dynamics of mineralization, pollution, sewage water treatment
34.	Volume and mineralization	Dynamics of balance and mineralization of ground waters
35.	Functioning of wells	
36.	Structure and number of diseases	Dynamics of diseases
37.	Structure, number, areas of epizooites	Dynamics of epizooites
38.	Salinization, dehumification, pollution by pesticides and heavy metals	Dynamics of soil state, their validity for irrigation, pesticides impact
39.	Digressive and rehabilitation successions	Dynamics of vegetation cover
40.	Hydrogenic and other non-sustainable ecosystems	Dynamics of wetlands
41.	Productivity of phyto- and zooplankton, fishes	
42.	Profitable and non-profitable farms	Connection of profitability with occupation, migration, etc.
43.	Detection of optimized, depressed, disturbed lands	Indicators of state of natural components and agricultural complexes
44.	Zones of ecological disaster	Indicators of degradations of environment and life conditions
45.	Scenarios of state of environment	Dynamics of environment indicators
46.	Water, chemical, mechanical, soil, phytomeliorations, optimal technologies	Effectivity of various meliorations and technologies, cost of actions
47.	Different meliorations	Desertification damage, cost of rehabilitation
48.	Distribution of rare, endangered and extinct species	Possibilities of their rehabilitation, photographs
49.	Network of natural reserves, including potential	Data on natural and historical sites for protection

Figure 1. Desertification state of the Amu-Dar'ya wetlands ecosystem



Map is compiled using Landsat TM image from August 1989

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A STUDY OF AGRICULTURAL TECHNIQUES FOR GROWING DRY VARIETIES OF RICE IN THE LOWER SYR-DAR'YA RIVER

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Introduction

The climate and nature of the soil of the Deltas of the Syr-Dar'ya, Ili and Karatal have contributed to the success of rice farming in Kazakstan. However, the present cultivation methods require water in considerable amounts - up to 35-40 thousand l/ha. Only about 12-15 thousand l/ha are needed for the rice itself; the rest is wasted owing to the use of rice varieties which require permanent flooding.

Almost all rice exporting countries of the world grow not only wet, but also dry rice varieties, which need only regular rainfall to grow. A study of rice production for the dry sort shows that the cost of growing the dry variety is much lower than for the flooding variety (Table 1).

Up until 1993 nothing was known about the water requirements of the dry rice variety as opposed to the flooding variety in the Lower Syr-Dar'ya or Kazakstan Region as a whole. In 1993, the first experimental studies on irrigation methods and agricultural techniques for growing the Russian dry sort "White Skoms" on the Kazalinsk Irrigated Area in the Lower Syr-Dar'ya Region were initiated. In April 1994, with the help of BMFT and UNESCO, 100 kg each of the varieties "Sandora" and "Korina" were bought from Hungary. Between 1994 and 1995 experimental studies with 3 types of rice were carried out. Irrigation methods for each variety were analysed in order to determine: standard water consumption of the rice plant; water and mineral requirements and rice yield. The aim of the study was to determine the best irrigation method for the cultivation of dry rice varieties.

Methods

The Kazalinsk Irrigated Area (31.4 thousand ha) lies in the Syr-Dar'ya Delta, in the semi-arid zone, about 100-150 km from the Aral Sea. Rice crops alternate with fodder. The soil is gray alluvium, partly waste land and salt flats. Minerals make up 0.6-15% of the soil (dry weight); the humus content is 1.2-1.7%; Nitrogen = 0.126%, Phosphorus = 0.33%. The filtration rate of moisture in the topsoil is 0.11-0.18 m/day. The groundwater level lies at a depth of 1.5-2.0 m; the mineral content of the groundwater = 6-8 g/l.

Data on the soil humidity and filtration rates, growth rate and development of the rice plants, and water input were collected on a daily basis from trial plots. The neighbouring paddy where the regional rice "Marshan" was cultivated under permanent flooding with 10-15 cm water from May to August served as a control. In order to determine the best irrigation methods for the cultivation of the dry sort, three moisture levels were studied: 70% minimum saturation (MS) level of the soil; 80% MS and 90% MS. The optimum amount mineral fertilizer was determined by using fertilizers containing active ingredients in the following proportions:

N = 180 kg/ha and P = 60 kg/ha;
N = 180 kg/ha and P = 90 kg/ha;
N = 180 kg/ha and P = 120 kg/ha.

70% of the fertilizer was applied before sowing, 30% before heading of the rice plants. An average of 120 kg/ha of rice was sown at a depth of 4-5 cm.

Results

Studies show that dry rice varieties need to be irrigated for a total of 90-95 days from sowing to maturity of the grain. The vegetative period lasts 116-130 days. The plants are most susceptible to water loss during the flowering period and pinacle development and at the beginning of the lacteal ripeness of the grain, a total of about 25-30 days. During this critical period, the daily water consumption of the rice plant is at its maximum, ca. 8-10 mm/day. It is imperative that the rice be irrigated every 5-6 days at this time, and every 8-10 days for the remainder of this period. Optimum irrigation of rice requires a total of 800-900 m^3/ha during each irrigation cycle.

In order to maintain 70% soil saturation, a field must be watered 8 times during the irrigation period; 14 times for 80% saturation and 18 times for 90% saturation. The volume of water consumption over the last three years was 9.6-10.2 thousand m^3/ha at 70% MS; 12.4-12.8 thousand m^3/ha at 80% MS and 15.2-17 thousand m^3/ha at 90% MS (Table 2).

Results in trial fields show that the growth and development of the rice plant is dependent on the degree of soil saturation. At 70% saturation levels, germination of all rice varieties is delayed by 2-3 days and the vegetation period lasts 10-12 days longer. Weight loss of the panicle is 12-15%, and there is an increase in the number of weeds by 30-40%. Good growth and development results were achieved with 80% and 90% MS. The maximum weight (measured in 1000 grains) was attained by all rice varieties at 90% MS (Table 3).

The highest rice yields were achieved with 90% soil saturation. Yields fall when the saturation level of the soil is reduced to 80% MS and at 70% MS, less than 2 t/ha are harvested. The varieties "Korina" and "White Skoms" gave good results. After 2 years, the average yield for the "Korina" variety was 3.6 t/ha at 80% MS and 4.8 t/ha. at 90% MS; the yield for "White Skoms" after 3 years was 4.3 and 4.4 t/ha respectively (Table 4).

A soil saturation level of more than 90% causes compression of the topsoil, which then hinders aeration, and (as the ground water level rises), signs of excess moisture and waterlogging become apparent. A reduction in soil saturation to 80% MS saves 25% of the water volume without causing an appreciable loss in yield.

The statistics/figures for water consumption show that at depths of 0-50 cm, an increase in moisture (over 80% MS) has no effect on the biological processes of germination or maturity of the rice plant, and that a saturation level under 80% MS would be adequate. The rice plant is particularly susceptible to water increases during the development of the stalks, but more so during flowering and panicle development and also at the beginning of the grain maturity.

Water deficiency during these critical phases is compensated for in loss of yield, and can be calculated using the following formula, which takes into account the difference between the real and the optimal water volume:

$$\beta(\lambda,t) = g_1(t).g_2(\lambda)$$

The function g(t) is the sum of all the internal (physiological and genetic) factors of the rice plant and can be found using the formula:

$$g_1(t) = \frac{\gamma_o - \gamma_{t,\lambda}}{\gamma_o(1-\lambda)}$$

Where γ_o = Yield achieved with optimal water supply of 90% MS

$\gamma_{t,\lambda}$ = Yield using water supply (λ) during time t

λ = can be found with the formula:

$$\lambda = \frac{\beta_t - \beta_\pi}{\beta_k - \beta_\pi}$$

Where β_t = Moisture at time t

β_k = Moisture at optimal water supply of 90%

β_π = Moisture content during welking at 60-65% MS

The figures show that rice yield is directly influenced by the degree of moisture in the soil. With a soil saturation of 70% during the period of rice swelling and heading, q(t) = 0.21 and during flowering and panicle development and at the beginning of grain maturity, q(t) = 0.48. The greatest loss in yield occurs when the soil moisture level is reduced to 70% during these critical phases. Here, the value of q(t) is twice as large as during the vegetative period, when q(t) is only 0.21. A reduction in soil moisture to 70% during flowering and panicle development causes a 30% loss in the yield of rice.

Optimal conditions for biological development of the dry rice variety is a function of the yield in relation to irrigation:

$$\gamma = f(M) \text{ (fig. 1)}$$

The most efficient and economical irrigaation method which produces the highest profits can be calculated using the following formula:

$$M_{ek} = \frac{M_{opt}(1 - C_n * M_{opt})}{2C_y * Y_{max}}$$

where C_n = irrigation costs \$/t

C_y = expected profit \$/t

The effectiveness of the water consumption (M_{ek}) can be found by:

$$\frac{Y_{ek}}{M_{ek}} = \frac{Y_{max}}{Y_{opt}} \quad \frac{M_{opt}(1 - C_n * M_{opt})}{2C_y * Y_{max}}$$

Water consumption efficiency at different soil saturation levels is shown in Fig. 1.

Section 1: by inadequate water supply, the yield is not sufficient to cover the farming costs.

Section 2: increasing irrigation to ecologically significant levels, guarantees continued growth and maximal profits.

Section 3: increasing the water supply up to biologically significant levels, guarantees maximum yields, but decreases profits and water efficiency.

Section 4: increasing the water supply even further, wastes water, profits are reduced and the system as a whole is inefficient.

The volume of water required to produce one ton of grain was highest for the varieties "White Skoms" and "Korina" at 80% MS (Fig. 2). Here, water consumption amounted to 2.9-3.4 thousand m^3/t. At the 70% MS level, the volume of water needed was 3.8-0.2 thousand m^3/t; under control conditions, i.e. 100% MS, 7.5 thousand m^3/t were used (Table 5). This is 2-3 times higher than it is for the irrigation of vegetable crops in the region.

Water efficiency and yield are influenced by phosphate fertilizer. During field experiments, it was shown that the yield of the variety "White Skoms" could be increased by 40-50% at 70% MS depending on the concentration of phosphore in the fertilizer at the time of sowing. Increased irrigation reduces the effectivness of fertilizers with a higher phosphate content, however, the effect is nevertheless positive and it ensures a high yield. At irrigation methods of 80% MS, higher concentrations of phosphate fertilizers increased the yield by 8-14%; at 90% MS, the increase was 5-8% (Table 6).

The dependence of yield on soil saturation level and phosphate fertilizer shows that it is impossible to achieve high rice yields with an insufficient water supply (70% MS). We recommend the following standards: Nitrogen 180 kg/ha, phosphate 90 kg/ha active ingredients at 80% MS.

Total water supply was provided over 85% by irrigation and 5-6% by rainfall during the vegetation period, and the same amount by groundwater. Water loss through evaporation was more than 60%, through drainage and seepage 10-50% depending on the level of soil saturation (Table 7).

Irrigated lands in the Aral Sea Region have turned into salt marshes and flats. The amount of salts rising from water-logged subsoil depends on the irrigation methods and drainage techniques used. In order to study the exact process of salt accumulation in the soil, and to determine guidelines for the cultivation of dry varieties of rice, special plots were selected, on which random samples were taken for chemical analysis, each month.

The studies show that soil salt content is linked to the level and the mineral content of the groundwater, and also to the seepage rate. When the rate of seepage is equal to or faster than the rate of salt diffusion (0.15-0.20 cm/day), salt will not accumulate in the soil, provided that the groundwater level is deeper than 2 m and the mineral content of the soil less than 6 t/ha. If the groundwater level is above 1.5 m, rising groundwater from the subsoil will maintain a low soil saturation level of 70% MS. However, it is not possible to attain rice swelling and yield by depending on moisture reserves in the soil alone, because salts accumulate in the topsoil from the rising groundwater. It is therefore necessary to irrigate at regular intervals in order to achieve high rice yields, to replace/maintain moisture level and to prevent salt accumulation at the roots. This can be achieved by using 80% MS irrigation methods.

The salt content of the soil decreases by 25-48% by using irrigation methods of 90% and 80% MS. It increases by 17% when the rice is watered at the 70% MS level of irrigation (Table 8).

In the test fields with 80% MS and 90% MS, 0.25 and 1.95 t/ha more salt was leached from 0-100 cm of the topsoil than was added. In fields with 70% MS 2.12 t/ha more salt accumulated in 0-100 cm topsoil than was leached from it (Table 9). The salt accumulation in the 0-60 cm top soil is noticeable.

Analysis of the salt content of the soil in experimental fields shows the significant influx of salt from groundwater resulting from the cultivation of dry rice varieties in the lower areas of the Syr-Dar'ya Region. In order to reduce this influx of salt, the groundwater level must not rise above 2.0 m. This can be achieved by draining at a depth of 2.5 m at a distance of 100 m each.

Conclusions

The following conclusions can be drawn from the results of experiments carried out between 1993 and 1995:

1. The dry rice varieties can be grown in the Aral Sea Region as an alternative to the flooded rice variety. This would save about 1.5-2.0 billion m^3 of water without causing the yield of rice to fall below 400-500 thousand t/year.

2. The dry rice varieties can be grown on irrigated land in the south of Kazakstan, in the South Kazakstan and Shambyl region, by decreasing the area under cultivation in the Aral Sea Region. This has already been tried. In 1994-1995 the varieties "White Skoms" and "Korina" were planted in the Shambyl region using 80% MS cultivation methods; the yield was 2.8-3.2 t/ha. Such yields are regarded as economically productive. It is also possible to grow the dry varieties outside of the present regions. The main expansion must take place on irrigated land, which is suitable for cereal and grass cultivation.

3. In the cultivation of the dry rice varieties, it is necessary to take their biological qualities into consideration, to ensure that the appropriate alternative crop is planted and the right agricultural method applied.

4. The best economical method for growing rice can be achieved with regular irrigation on soil with low salt content at 80% MS during growing period and at full maturity of the grain, and at 90% MS during the remaining period.

5. The yield of dry rice varieties and the efficiency of cultivation can be increased by the addition of mineral fertilizer. The greatest increase is attained by the application of 180 kg/ha Nitrogen and 90 kg/ha Phosphate.

6. The groundwater level plays a significant role in the deposition of salts in the cultivation of the dry rice variety. For rice under constant irrigation, optimal conditions for cultivation are found when the groundwater level lies at 2.0 m or deeper.

Acknowledgement

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References

A. Rau: Water distribution in rice systems (in Russian), Agropromizdat, Moscow, 1988.

R. Engelman: Guide for drainage, Hamburg, 1978.

Yoshihara Oda and Tuyshi Honda: Environmental Control of Tillering in Rice Plants, The 252nd report of the Institute for Agricultural Research, Tohoku University, 1963.

Aron Jugsujunda and W.A. Patricj Jr.: Growth and Nutrient Uptake by Rice in Flooded Soil under Controlled Aerobic-Anaerobic and pH Conditions, Agronomy Journal, 1977, T. 69, pp. 705-710, U.S.A.

Table 1. Production cost (in US$) for 1 ton of rice (SPPI statistics from 1985)

Country	Flooded rice	Irrigated rice
Venezuela	119.0	88.8
Colombia	218.0	204.0
Panama	32.7	258.0

Table 2. Water consumption in thousand m^3/ha

Rice variety	MS % soil	Volume of water consumed in thousand m^3/ ha			
		1993	1994	1995	Average
White Skoms	70%	10.2	9.6	10.2	10
	80%	13.4	12.0	12.9	12.8
	90%	20.6	14.4	16.1	17
Korina	70%		9.6	10.2	9.9
	80%		12.0	12.9	12.4
	90%		14.4	16.1	15.2
Sandora	70%		9.6	10.2	9.9
	80%		12.0	12.9	12.4
	90%		14.4	16.1	15.2
Marzhan	100%	36.8	33.7	37.7	35.9

Table 3. Biometric statistics for rice varieties using different irrigation methods

Rice variety	MS % soil	Growing period days	Plant height cm	Plant density m	Leaves	Weight 1000 grains g	Density weeds m
White Skoms	70%	130	78	87	1.8	25.2	38
	80%	120	85	95	2.1	28.6	27
	90%	120	90	104	2.1	29.6	22
Sandora	70%	138	79	82	1.8	22.2	35
	80%	126	86	86	1.7	25.9	21
	90%	126	86	101	1.7	26.1	18
Korina	70%	127	70	87	2.1	27.3	39
	80%	116	79	98	2.0	29.7	25
	90%	116	80	112	2.2	31.6	27
Marzhan	100%	124	128	110	2.1	31.8	6

Table 4. Effects of soil saturation on productivity

Rice variety	Irrigation method MS%	Rice yield t/ha			
		1993	1994	1995	Average
White Skoms	70%	1.3	2.6	1.9	1.9
	80%	5.0	3.4	3.6	4.3
	90%	5.6	3.6	4.1	4.4
Korina	70%		2.5	2.7	2.6
	80%		3.0	4.2	3.6
	90%		4.8	4.9	4.8
Sandora	70%		1.6	2.1	1.6
	80%		2.4	2.9	2.6
	90%		3.1	3.8	3.4
Marshan	100%	5.6	4.2	4.7	4.8

Table 5. Average water consumption for 1 ton rice (1993-1995)

Rice varieties	Irrigation method in % MS	Water volume in thousand m^3/ha	Yield t/ha	Water consumption for 1 ton rice in thousand m^3
White Skoms	70%	10.0	1.9	5.3
	80%	12.8	4.3	2.9
	90%	17.0	4.4	3.8
Korina	70%	9.9	2.6	3.8
	80%	12.4	3.6	3.4
	90%	15.2	4.8	3.1
Sandora	70%	9.9	1.6	6.2
	80%	12.4	2.6	4.8
	90%	15.2	3.4	4.8
Marshan	100%	35.9	4.8	7.5

Table 6. Effect of mineral fertilizers on yield

Nitrogen/ phosphate fertilizers kg/ha	Soil saturation levels					
	70% MS		80% MS		90% MS	
	Yield t/ha	Water per ton grain m^3/t	Yield t/ha	Water per ton grain m^3/t	Yield t/ha	Water per ton grain m^3/t
N 180-P 60	1.0	7.6	3.6	3.3	4.0	3.7
N 180-P 90	1.4	5.9	3.9	3.1	4.1	3.6
N 180-P 120	1.5	5.4	4.1	3.0	4.3	3.5

Table 7. Water supply (mm)

Water volume mm	Year and irrigation method in % MS								
	1993			1994			1995		
	70%	80%	90%	70%	80%	90%	70%	80%	90%
Water supply:									
Irrigation	960	1280	2000	960	1200	1440	1020	1290	1610
Rainfall	60	60	60	69	69	69	37	37	37
Groundwater	50	24	6	42	21	–	76	44	18
Total	1070	1364	2066	1071	1290	1509	1133	1371	1665
Water loss:									
Evaporation	920	954	999	970	1000	1090	990	1120	1180
Drainage	110	315	705	77	183	296	68	187	345
Underground seepage	40	95	362	24	87	123	55	64	140
Total	1070	1364	2066	1071	1270	1509	1133	1371	1665

Table 8. Salt content of the topsoil in the trial plots (average for 1993-1995)

Irrigation method	Depth cm	Salt content of the soil %					
		Before sowing		Vegetations phase		After harvest	
		Total	Cl^-	Total	Cl^-	Total	Cl^-
70% MS	0-50	0.749	0.132	0.466	0.054	0.896	0.087
	50-100	0.663	0.097	0.658	0.068	0.708	0.050
80% MS	0-50	0.759	0.139	0.471	0.042	0.572	0.430
	50-100	0.669	0.096	0.575	0.052	0.721	0.075
90% MS	0-50	0.767	0.128	0.467	0.041	0.398	0.033
	50-100	0.661	0.096	0.555	0.062	0.433	0.049

Table 9. Salt influx and loss in one metre topsoil t/ha (average for 1993-1995)

	Irrigation method % MS		
	70% MS	80% MS	90% MS
Influx from irrigation	1.35	1.70	2.13
Influx from ground-water	3.14	1.65	0.44
Total influx	4.49	3.35	2.57
Salt loss due to drainage	1.90	2.81	3.40
Leaching into the ground-water	0.47	0.89	1.12
Total loss	2.37	3.70	4.52
Salt influx (+) - Salt loss (-)	+2.12	-0.25	-1.95

Figure 1. Influence of different irrigation methods on efficiency

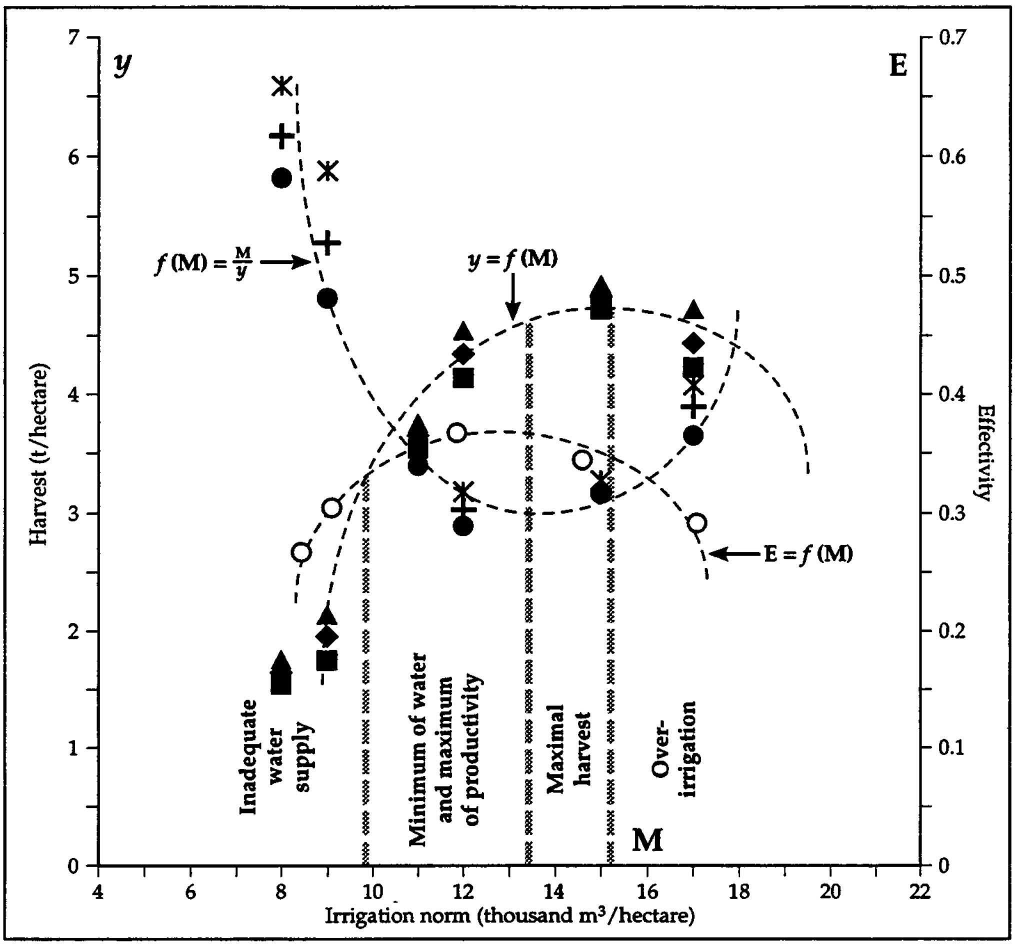
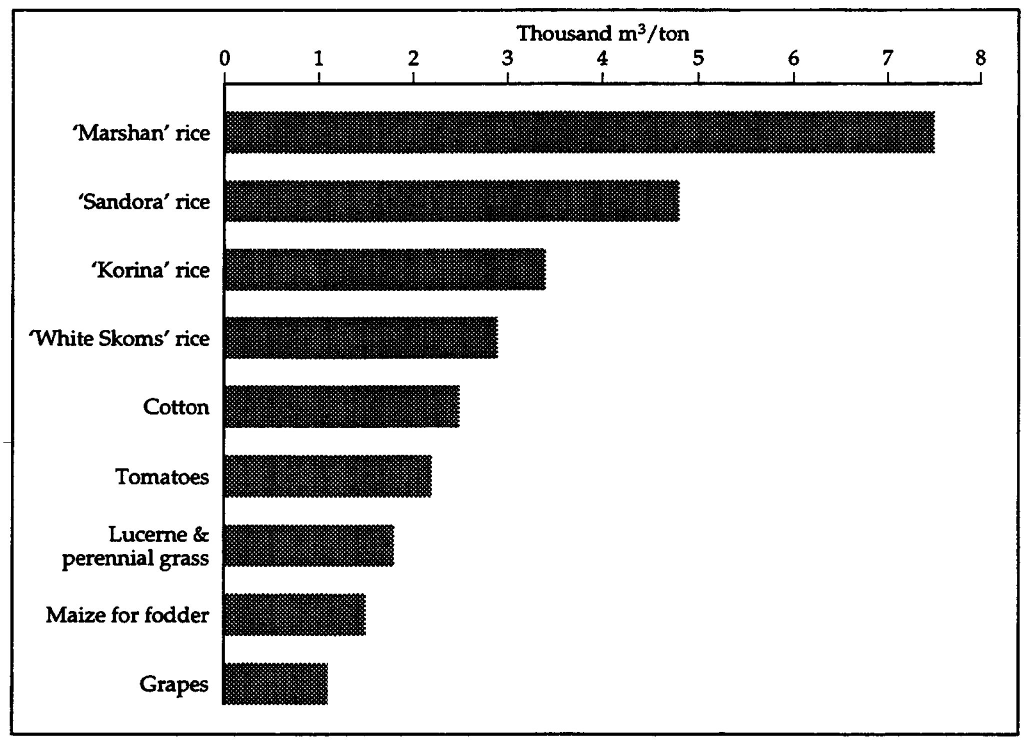


Figure 2. Water consumption per ton of selected crops



WATER REGIME MODEL FOR THE AMU-DAR'YA WITH POSSIBILITY OF PREDICTING POLLUTION TRANSPORT

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Introduction

Due to the limited water resources in Central Asia, the volumes of water for use must be carefully and precisely determined, and the distribution between the users efficiently controlled.

The water resources were formerly distributed from one centre - Moscow. Now, each country in the basin decides independently about the use and control of river discharges, in accordance with international agreements. The former centrally-planned water management has become less predictable, in which rapid changes of situation may occur. Nonetheless, the needs of all users must be respected.

An adequate mathematical tool and database are indispensable to support such water management tasks. Our efforts in the last three years were focused on setting up such a tool. It turned out also, that certain new methods had to be developed for that purpose.

The work consisted of three parts:

- determination of control points in the river system;
- development of a mathematical tool for operational management;
- development of new approaches to information processing, for the evaluation of actions and their consequences.

These three interconnected components have been integrated into a complex model and programme package.

The structure of the water management model for the Amu-Dar'ya system is shown on the flow chart overleaf.

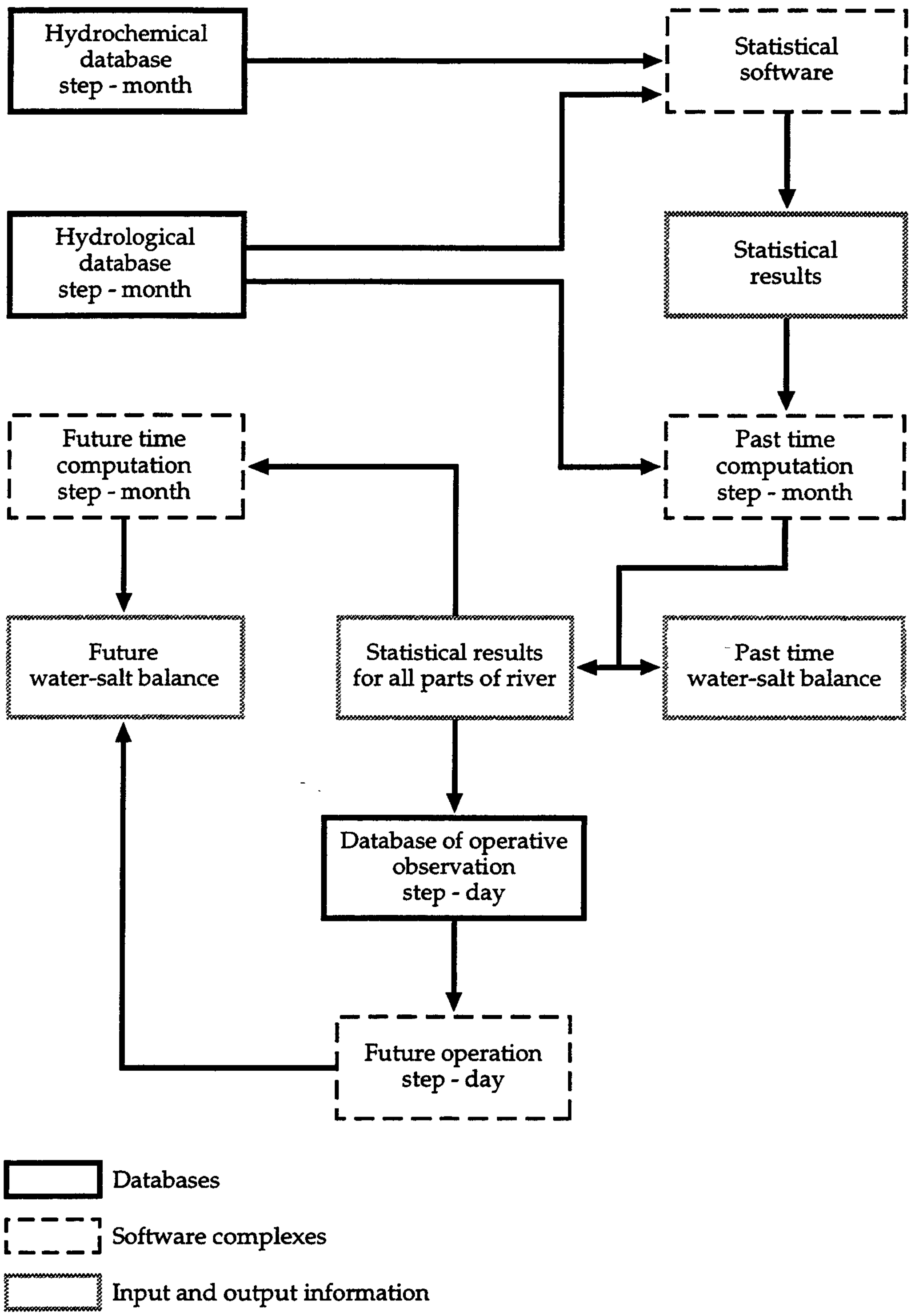
Databases

1. The hydrochemical database contains information on salinity, ions, toxicants, biostructures and metals, based on observations from 1980 to 1992 in 50 points, spread over almost all important sectors of the Amu-Dar'ya river system. The database volume is 700 Kbt.

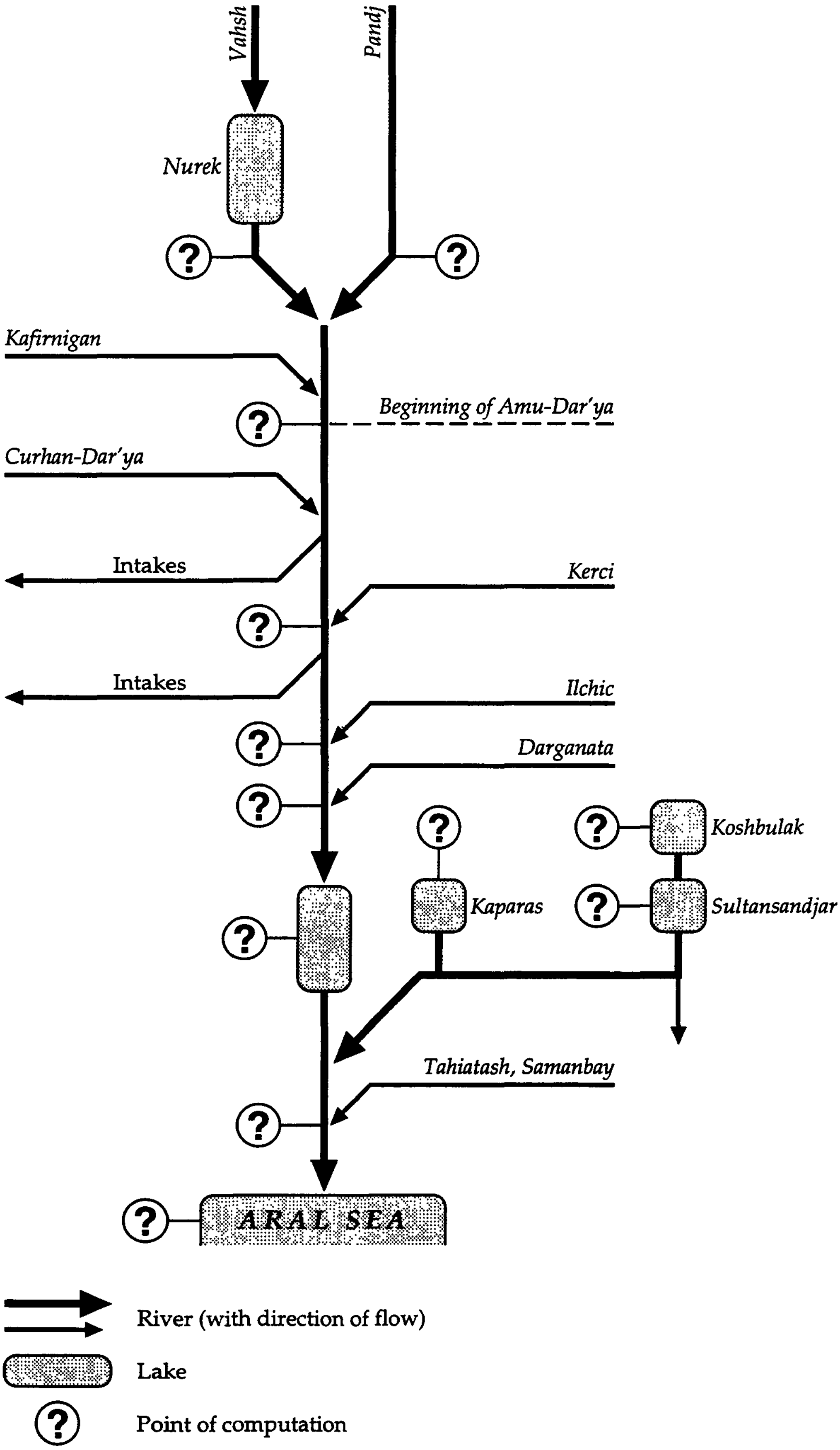
2. The hydrological database contains monthly average discharges in all control sections, from the beginning of the century. This database provides information for the water balance in all parts of the river system, data for statistical analyses of the discharge, pollution balance (combined with the hydrochemical database) and determination of the uncontrolled lateral intake or return flow. Volume - 3700 Kbt.

[1] NPHT, Ekologija, Tashkent
[2] SANIIRI, Tashkent
[3] VODPPROJEKT, Tashkent

Flow chart of the Amu-Dar'ya management model



Computational scheme of the Amu-Dar'ya, with tributaries, water intakes and nodes



3. The operative hydrological database for short-term forecasts and operative discharge and water quality management, comprises more than 400 representative observation points of the irrigation system in Central Asia. It was created by A.G. Savitsky and S.U. Timoshenko, within the work on this project, and has been incorporated in the operative water management model. The first year is 1992. Volume - 4700 Kbt.

The computations were performed along the course of the Amu-Dar'ya, as shown with all details in the diagram on the previous page.

Statistics package

The software package was developed in the framework of this project, for statistical calculations in ecology and hydrology. It has a modular structure which can record and save graphic images in a special and very economical format (created especially for this project). It is provided with a convenient interface and can be used as independent software, for any other research. It is as powerful, but more economical than the well-known STRATGRAF package.

This software has been used for computations, design and scheduling by B. Rahmonov [2]. In the present work, it was used to determine relationships between discharges of the main river, tributaries, return flows, etc, in the control and observation points. It was also used for the study of trends in the hydrological data series (Fig. 1). Trend is considered here as the time-dependent change of mathematical expectation of some variable.

Generally, fluctuating characteristics of a process hide the real trends of the process. In order to smooth these variations, averaging procedures have been used by many researchers, such as sliding averages, or covariations and correlations between subsequent values in the series. However, the reasons why any particular averaging method was used has not been explained.

In September 1993, Professor Yu.M. Denisov [1] developed for the first time a mathematical concept for determining the parameters of smoothing functions. This is illustrated by the following example.

Let us assume a statistical series, with such a scatter of points, that it is impossible to make any judgement about the function which would describe their trend, nor about the mere existence of such a function. A smoothing function is then applied, such as moving averages, using for averaging a certain number of points N. The end points can either be ignored, or averaged by unsymmetrical averaging functions.

So, we have two functions: the real one and the averaged one. The difference between these can be accounted for by means of the magnitude of dispersion. Note, that if N=1, the dispersion is zero, because the averaged function goes through the points of the real function. If, however, N is equal to the number of points of the real series, then the dispersion becomes maximum and the averaged function becomes a constant (a horizontal line), close to the mathematical expectation of the process. Obviously, intermediate values are possible between these two extremes and a function can be formulated which would link the number N of averaging and the dispersion D of the series. Now, an absolutely independent way exists for the determination of dispersion of a statistical series from the trend. This is the so-called structural function of Kolmogorov.

By using the Kolmogorov structural function, presented in tables which show the relationship between the averaging number N and the dispersion D, it is possible to find the needed magnitude of the number N. The important aspect of this treatment of the statistical series is that the selection of averaging number N is not arbitrary, but results from the above mentioned structural function, and thus it has a higher credibility. This approach was included into the programme package and has been used actually in practice. Figure 2 shows an example of the results of the application of this programme.

Another problem had to be addressed in our research - the elimination of random error generated in the reaches between the observation points in the river. Till now, when calculating the water balance along a river, the observed data were considered as primordial, which should by no means be altered. Indeed, the volumes of flow which enter and leave the river reach for which the water balance is made, were considered as the basic input information, without any permissible feedback.

However, observational errors appear in two facets in the intermediate section: if a surplus of water volume is found at one end of the reach, an equivalent deficit will be noted at the other end.

In the case where discharges were measured absolutely exactly, as well as all the other components of the water balance, it would suffice to correct the discharges in the intermediate sections so that the discrepancies disappear. However, random measurement errors are inevitable, and the only way to deal with them is to minimize the discrepancies between the adjacent river reaches.

Anyone who has calculated the water balance by river reaches, will understand that the above is exact, if he makes a diagram by plotting the error at the upper reach versus the error at the lower reach. In most cases, an inversely proportional relationship will appear, with a high degree of correlation. The existence of such a linkage between random errors appears as an amazing occurrence. However, taking into account the above described relationships, it is possible to elaborate the algorithm of the generation of these connections, and more than that, for the elimination of the discrepancies. This will then result in a more exact water balance along all reaches of the whole river. The basis of this algorithm is a three-diagonal matrix, with a dominant main diagonal. This means that a solution must always exist and can be found by the method of "forward and backward sweep". It should be noted that this method can be applied only when at least three river reaches are considered in the water balance, or else the matrix degenerates.

The above mentioned relationship was observed even at the best of the measuring stations, Darganata (see Figs. 3a and 3b). The programme package *"Statistics"* makes it possible to consider the discrepancies in each river section, to make a judgement about the quality of the measuring station, then to correct the data on discharge measurements in accordance with the above explained theory. Fig. 3b depicts the same relationship as Fig. 3a, for the station Darganata, but after the correction.

The practical application of the above described theory is not limited to water resources alone. It can be applied to any other system of transitional structure, with the sole condition, that the transition must be conservative. The substance can be gas, electrical energy, water or like. With very simple computations, it is possible to find out which of the control points are least reliable and to propose measures for their improvement. The selective analysis will reduce costs of the operation of supervising systems, counters, stations, etc.

Software package for the computation of past and future water regimes of the Amu-Dar'ya

The software package is based on modified equations for water and salinity balance. The volume of the package is 5 Mbt. Past water regimes were computed starting in 1980, till the present time. The most complex point of the computation is the Tuyamuyun Storage Reservoir system.

The computation of salinity balance was based on the theory of filtration, and the partial differential equations of diffusion.

A self-learning block is built into the package, which calculates the statistical characteristics of the routing of salinity down the river channel. These statistical characteristics are then used for the computation of future water regimes, improving thus the quality of the calculations.

The programme package is provided with a good interface which supervises the calculations, and comprises help and instruction files. The flow chart of the package is represented opposite.

The software package comprises databases on water quantity and quality, making possible computations from 1981 (the year of implementing Tuyamuyun Reservoir), till the present day. However, the lower part of the Amu-Dar'ya comprises a similar database from 1970. It has to be pointed out, that the package has its own data base, which has software connection with the main database.

An additional data base is included in the package for the space-time distribution of pollution in the Tuyamuyun system. The software package can work with 28,000 observations and produce compact results about trends of water quality in the reservoirs.

Space does not suffice here to describe in this paper all models of the supporting software. Most of these are built on the basis of the equations of multiphase hydrodynamics. The decrease of reservoir capacity due to sediment deposition has also been taken into account.

For predictive computations, the input information consists of data on water sources and assumed water demands of consumers. The objective of the computation is to define such regimes of the reservoirs, which would best satisfy the water demands of the downstream water users. The Tuyamuyun Reservoir system is especially complex, as the same water regime can result from various combinations of the four components of the system.

The unique criterion for determining the sequence of reservoir utilisation was the minimization of losses on evaporation. Namely, each metre added to reservoir water levels increases the free surface of the reservoir, and thus the evaporation. In the case of Sultansandjar and Kosbullak reservoirs the increase of surface area is less than for the channel storage and Kaparas. Hence, the first two had priority when filling the reservoirs, and the other two in the emptying phase.

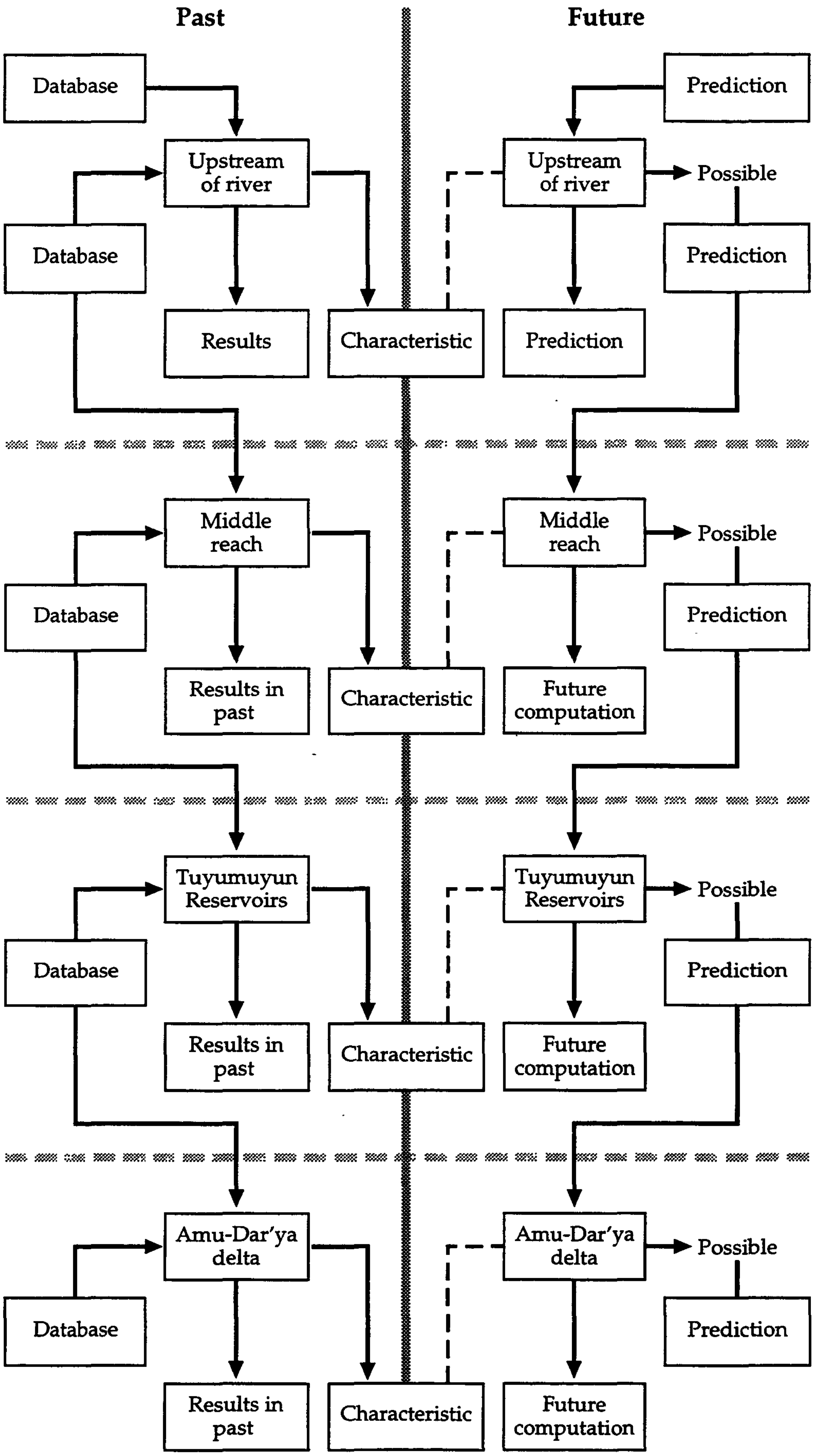
The second rule was that the reservoirs are filled at the same time, while the emptying begins with the channel storage first.

This strategy was incorporated into the model and software, and has also been used in practice.

As the software package was intended for permanent use in water resources management, it was made user-friendly, for wide practical use.

Software package for the computation of Amu-Dar'ya flow, required for real-time management

The concept of the programme package is based on the consideration of time required for the passage of water from the source to the river mouth. The simulation of river flow is by a set of equations and is thus the basis of operational management.


Past
Future
Database
Upstream of river
Database
Results
Characteristic
Prediction
Upstream of river
Possible
Prediction
Prediction
Middle reach
Database
Results in past
Characteristic
Middle reach
Possible
Prediction
Future computation
Tuyumuyun Reservoirs
Database
Results in past
Characteristic
Tuyumuyun Reservoirs
Possible
Prediction
Future computation
Amu-Dar'ya delta
Database
Results in past
Characteristic
Amu-Dar'ya delta
Possible
Prediction
Future computation

The total time of passage of the water down the Amu-Dar'ya river channel (from the inflow of Kafirnigan river to the Samanbay station near the Takhiatash dam) is 12 to 16 days. The velocity is higher for higher discharges.

With a four-hours time step, the programme computes the water level at each section and corrects the obtained volumes by using the relationships established in the above described management model.

The application of this software package disclosed that the predicted and observed water levels differ in either sense by some values. The analysis has then shown that a certain part of the water inflow or outflow (especially small scaled ones) are not represented in the operative data base. The lateral inflow is, however, less variable than the discharge of the main river channel. It was assessed in the following way:

The computations for the prediction were started 10 days before the current time. The model then compares automatically the obtained hydrograph with the actually observed one, and by the least square method allocates the unknown lateral inflow/outflow. Making use of the fact that these are relatively stable, the same correction is applied in the predictive computations. Figure 4 shows the results of real time forecasting in the Amu-Dar'ya, applying the described procedure.

Especially interesting is the forecast of water salinity in the section of the Tuyamuyun Dam. Actually, the Kaparas storage is meant for the drinking water supply, and the forecast of salinity at the entry section of Kaparas is of particular importance. The computations have shown that the negative or positive water waves reach the Tuyamuyun Dam sometimes a month before the arrival of characteristic salinity peaks. Figure 5 shows the correlation coeffecient between the arrival of water waves and salinity peaks, in function of the time lag.

This delay is explained by the fundamental laws of hydrodynamics. The main reservoir of the Tuyamuyun system represents a 120 km long groove (approximately), about 4 kilometres wide and 10-20 metres deep. The celerity of the kinematic wave is then of the order of 10 m/s, and even at discharges of 2,000 m^3/s, it will be about 2-5 m/s. The mass of water travels much slower and will arrive 10 to 30 days later than the flood wave. This occurrence proved to be of great value, because it made it possible to forecast the change of salinity in the section of the Tuyamuyun Dam almost a month ahead, which is about the time needed to fill the Kaparas storage with water. Namely, the water volume discharged in that time is about 1.5 km^3, which is more than enough to fill the Kaparas storage of 960,000 m^3.

Model for water allocation to users

The model described below was created by A.G. Savitsky, for the purpose of the present project. Most of the contemporary models simulate flow in converging river systems, starting from tributaries, which then merge into a river, etc. The water users then abstract water at certain points along the main river. The lower Amu-Dar'ya river system is, however, characterized by divergent flow in the delta. Moreover, the main characteristic of the delta and the middle course of the Amu-Dar'ya is the lack of stability. New intakes and channels are built incessantly. For the sake of ecological rehabilitation of the Aral basin, a system of polders will be constructed, which will create very flexible water regimes.

Bearing this in mind, the model and software were developed with the following capabilities:

- ability to compute divergent water systems for irrigation and water transport;

- ability to adapt to any modifications of the irrigation systems;
- user-friendliness, enabling the use of the model by specialists of limited computer training;
- ability not only to simulate the flow, but also to make predictions needed for the management of reservoir cascades and inter-connected hydraulic engineering structures.

The developed software package can be applied to any irrigation system, in which up to 20 reservoirs operate simultaneously, with 40 head regulators, 40 water users, 20 water inflows.

The programme can work in two modes: (i) simulation and (ii) prediction modes.

The main scientific novelty of the developed model consists in the definition and mathematical description of a new component of the hydraulic network - the Hydro-Technical Divider (HTD).

The main task of the HTD is to abstract water from the main flow and to divert a given discharge into a new irrigation system.

Two types of dividers were considered: the first regulates the flow in the main channel and the second functions laterally.

Two types of control points were introduced in the hydrographic net: the first determines the discharge and salinity and compares these with the real observations, if such exist; the second type not only makes the comparison, but also replaces the computed hydrograph by the observed one. This is very important, in order to take into account the unmeasured inflows or outflows.

Particularly difficult is the computation of prospective management of a complex irrigation system, when the possibility exists of supplying water to the users through altenative systems of HTD. In converging systems this problem does not exist.

Considering simultaneously all matrices of incidence, for all types of objects in the net, the best variant can be found of such systems with alternative ways of water conveyance. An important feature of the system is that a reservoir is considered both as a source and a user of the water, at the same time.

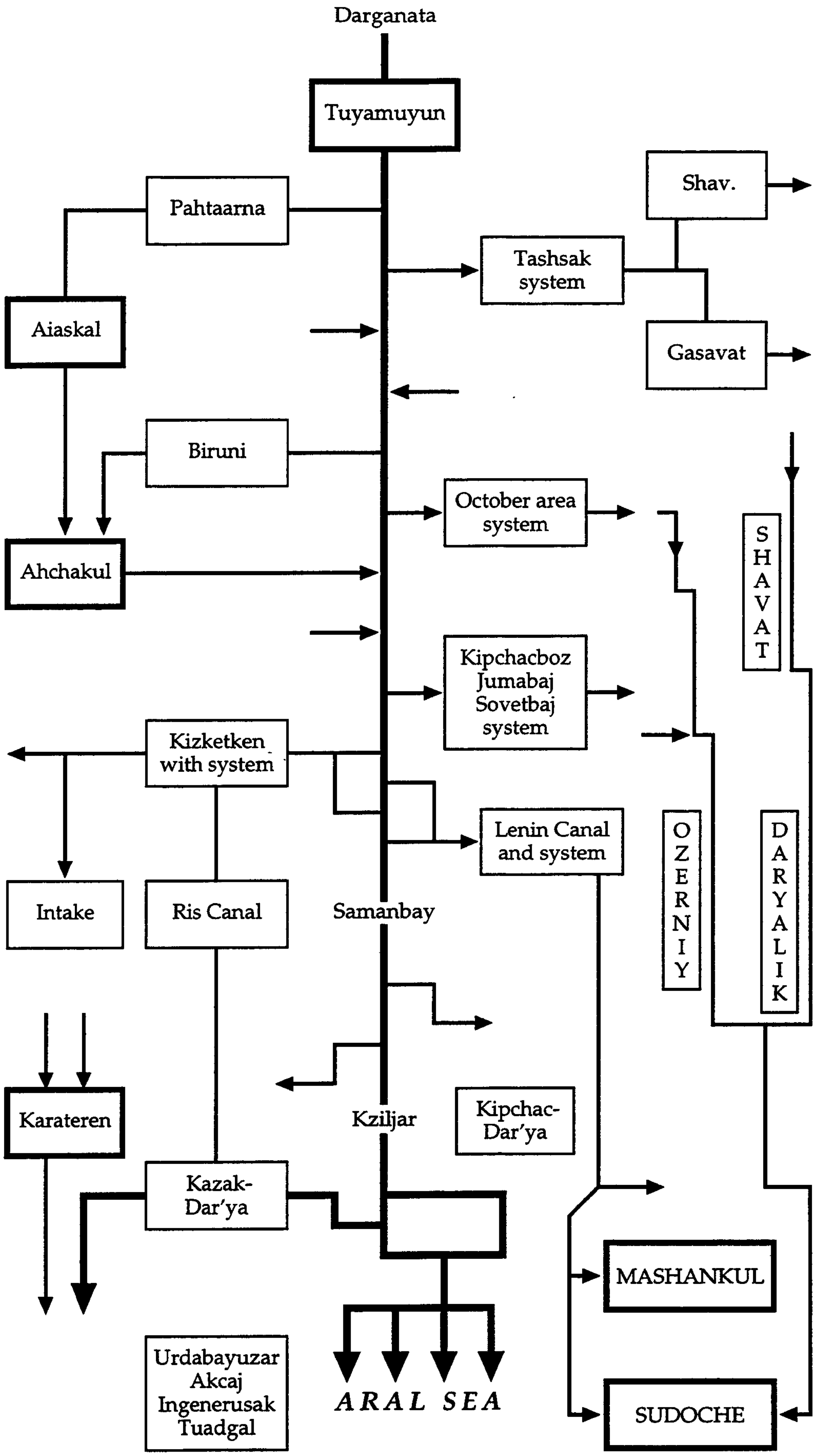
Any optimization principle can be used; actually, the principle proportional deficits were applied here. The computation, orientation, input of information are fully automatic.

Calibration was performed on the case of Kashkadarya - a tributary of the Amu-Dar'ya. The diagram overleaf shows the complexity of the Kashkadarya system. It represents also the irrigation network as seen by the programme. Scanning proceeds "top-bottom" and then "left-right".

It is unfortunate, that the Amu-Dar'ya delta could not be used for verification of the model, as only one point of observation - Samanbay - operates in that region.

After having calibrated the model on the Kashkadarya system, the computation of the delta for the real situation was started. The delta region with water intakes and irrigation systems is diagramatically represented below, as it is structured in the model.

At present, information is being collected in order to verify the model once again,


Darganata
Tuyamuyun
Pahtaarna
Shav.
Tashsak system
Gasavat
Aiaskal
Biruni
October area system
Ahchakul
SHAVAT
Kipchacboz Jumabaj Sovetbaj system
Kizketken with system
Lenin Canal and system
OZERNIY
DARYALIK
Intake
Ris Canal
Samanbay
Karateren
Kziljar
Kipchac-Dar'ya
Kazak-Dar'ya
MASHANKUL
Urdabayuzar Akcaj Ingenerusak Tuadgal
ARAL SEA
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bearing in mind that it will be used by different institutions and specialists. The programme detects the smallest errors and informs the user, proposing also how to correct them.

The developed model will no doubt be used for the management of the lake systems in the Aral region. Presently, discussions are going on between the countries of the Aral Basin on the evaluation of different projects and measures, concerning the main rivers and the polders, as well as the flow regulation. The developed model with its programmes and data bases will provide the necessary expert tool for finding rational solutions and evaluating their effects.

In addition to water-salt balance, the ice cover also had to be taken into account, especially after the catastrophic floods of 1992 which caused very serious ecological damage. The model has proved that the ice dams appear during the decreasing, rather than the increasing limb of discharge hydrograph (Fig. 6). This part of the study was created by D.N. Tikhonova.

The problems were studied in an empirical way, hence the great amount of information obtained can not be represented here. These have been already used for the regulation of water release from the Tuyamuyun Reservoir in Winter.

Conclusions

As a result of several years of efforts, a mathematical tool was created for the simulation of any technically feasible measure aimed at the regulation of discharge and water quality of the Amu-Dar'ya. It is obvious, that, whatever time is spent on the collection and observation of water quality characteristics, these will help to understand the process, but will hardly be used for operative management.

Only mathematical systems of models and software programmes can help to integrate into a unique structure the whole complex of knowledge and become an indispensable tool for operative management of the largest river of Central Asia - the Amu-Dar'ya.

In the present paper we report that such a tool has been created. We are aware, however, that the software will have to be modified in the future and supplemented as need be, in accordance with the tasks which may appear in the rapidly changing real-time situation.

We do hope that our software package will also be used outside of Uzbekistan, as it has been prepared to fit situations in all similar regions.

At present, in 1996, the described software is being used in the World Bank project on the search for strategies of water resources use and distribution in Central Asia. A similar software package is also being elaborated for the Syr-Dar'ya.

References

1. Denisov, Yu. M. and T. Ya. Ibrahimova (1996): 'Methods of Hydrological Computations of Annual Mean- and Extreme Discharges for Rivers with Intensive Use of Water Resources' (in Russian) Trudy SARNIGMI 149 (230), 'Mathematical Modeling of Mountain River Runoff', Tashkent, pp; 22-40.
2. Rahmonov B.A. et al. (1996): 'The Implementation of Biologically Active Fields for the Biological Cleaning of Polluted Sewage and River Waters', UNESCO/BMBF - present volume.

Figure 1. Relationship between salinity and water discharge at Darganata

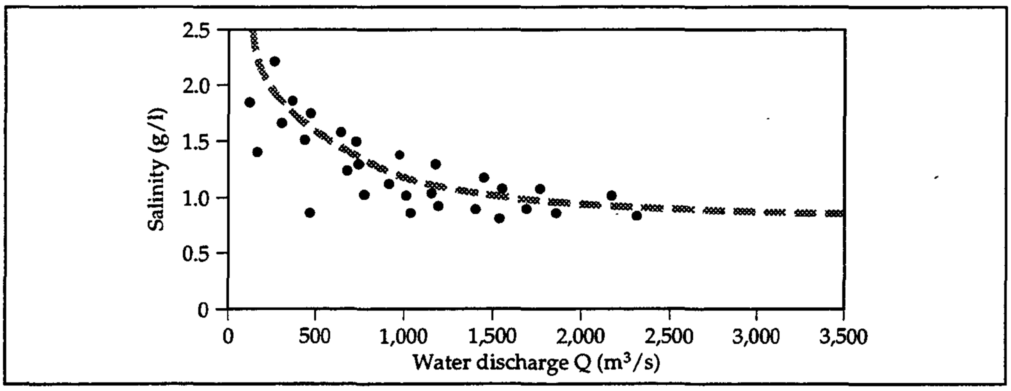


Figure 2. Trend of salinity variation at Darganata

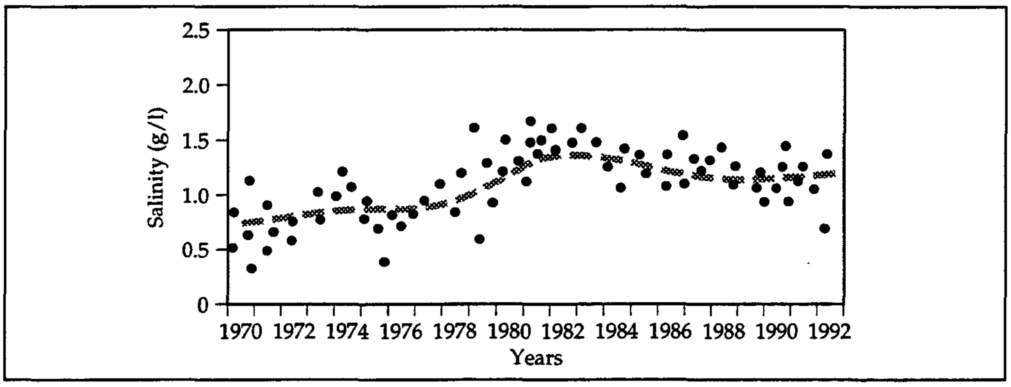
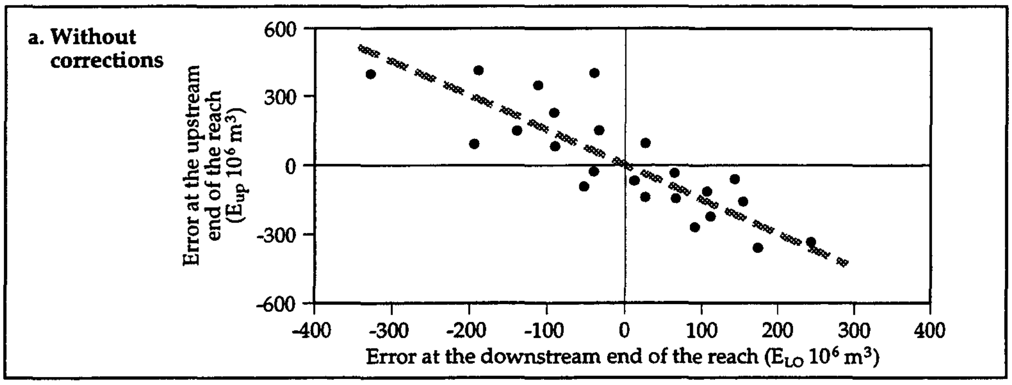


Figure 3. Correlation between computational errors at the reaches "Kerki-Darganata" and "Darganata-Tuyamuyun"



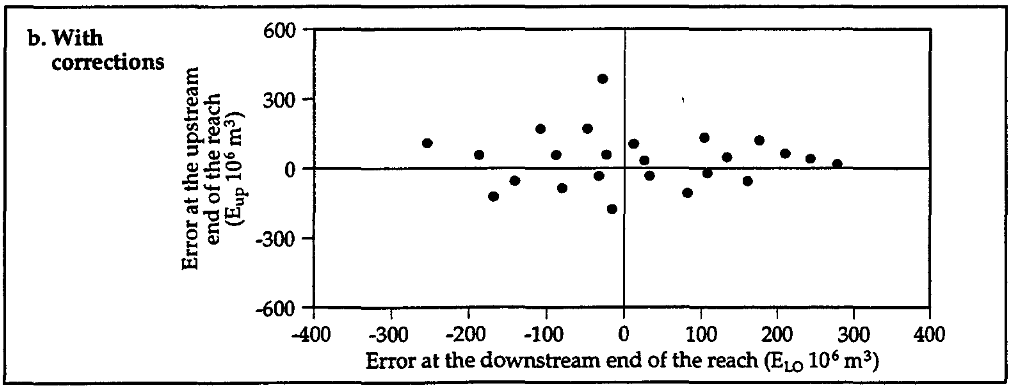


Figure 4. Predicted water discharge at Darganata

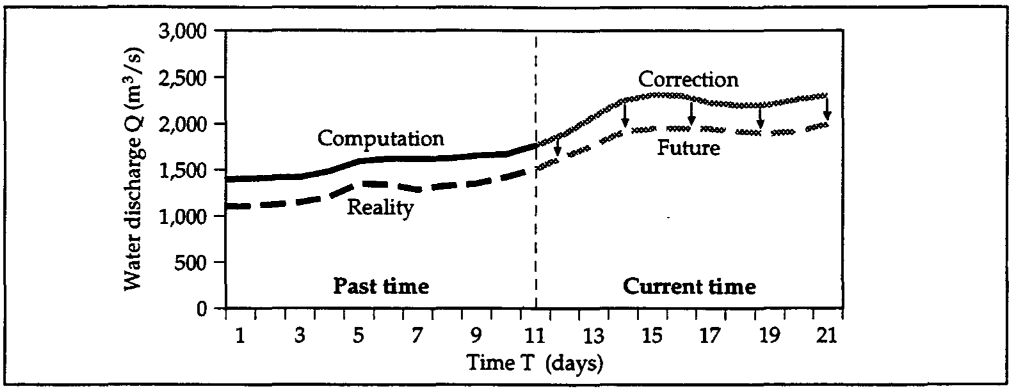


Figure 5. Variation of correlation coefficient R between salinity and time lag (in days) between arrival of flood waves and salinity peaks

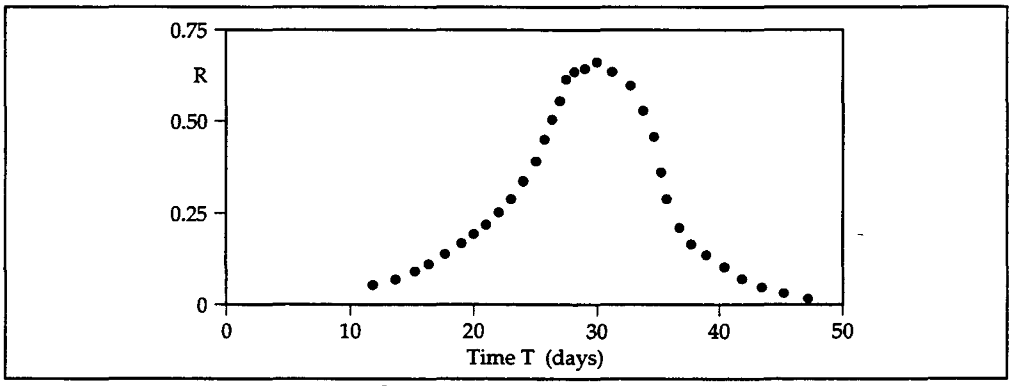
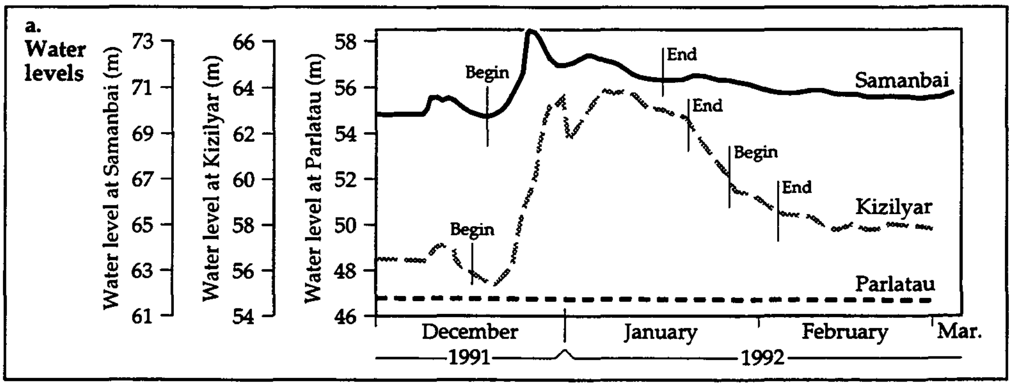
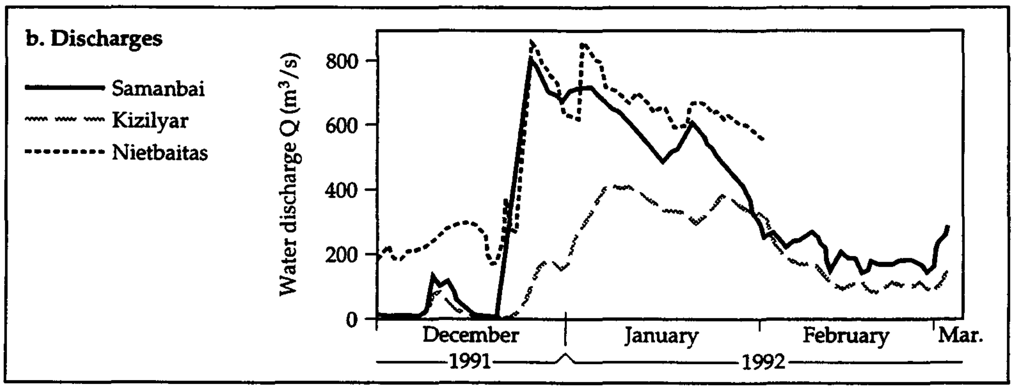


Figure 6. Variation of water levels and discharges in the lower part of the Amu-Dar'ya





THE IMPLEMENTATION OF BIOLOGICALLY ACTIVE FIELDS FOR THE BIOLOGICAL CLEANING OF POLLUTED SEWAGE AND RIVER WATERS

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Introduction

The water resources deficit in the Aral Sea Basin, the increasing pollution and deterioration of the quality of drinking water, require measures for the improvement and restoration of the quality of water bodies. The situation is especially alarming in the Priaralye (Aral Sea region), where the poor quality and shortage of potable water are associated with socio-economic difficulties and degradation of living conditions.

In the last decades, the salinity of the lower Amu-Dar'ya river water has increased to 1.4-1.6 g/l, with maximum values up to 2-2.5 g/l. Pollution by organo-chlorine pesticides reaches 0.8-1.0 mg/l, by oil products 0.3-0.4 mg/l; organic substances exceed 2-3 times the permitted limits of BOD and COD, etc. As a consequence, the health of 65% of adults and 61% of children has deteriorated in Karakalpakstan. Mortality reaches 682 persons per 100, 000, and out of 100, 000 babies, 45 to 60 are still-born. The difficult economic situation is aggravated by the lack of good quality drinking water.

At present, the best policy for preventing the pollution of water resources consists in efficient water treatment at local levels. Biological and bio-engineering methods of water treatment are preferable, making use of the water purification capability of macrophytes and soil strata [1,2,3,6,12]. In the near future, such methods seem to be the most realistic and economically appropriate, combining natural ecosystems (water-soil-flora-fauna) with an engineering approach to waste-water treatment.

Drinking water quality in the Southern Aral Sea

The main sources of drinking water supply in the lower part of the Amu-Dar'ya basin are irrigation canals, lakes and reservoirs. Water quality has been surveyed continuously and some improvement was recorded in comparison with the preceding years (1989-1991), owing to the higher run-off in the basin, and measures for water quality management. However, the water quality has not improved in rivers and water bodies, such as: the Mezhdurechye reservoir, or the Glavmiaso canal; nor of the water supply in towns: Muinak, Kungrad, Tahiatash, and rural settlements. High concentrations of oil products, pesticides, biogens, bacteriological contaminants were recorded. The content of trace metals - Cu, Zn, Ni - increased, and the water quality in the Mezhdurechye reservoir worsened (Table 1, data for 1993-1995), because of poor management and ecological deficiencies.

Laboratory research of bio-engineering technology

Bio-engineering technology of water treatment for rural settlements is economical, needs low investments and maintenance costs and lower requirements as regards the qualifications of the personnel.

Semi-industrial experiments were conducted from 1991 to 1995 in the laboratory of the CEWM on seven installations, representing shallow wetlands, equipped with bio-engineering infiltration constructions (BIC), on which five types of macrophytes were grown: *Phragmites communis, Typha angustifolia, Typha latifolia, Scirpus lacustris, Acorus paludis* (Fig. 1). One of the installations was used for mixed cultures and another one for control, without macrophytes. The filter package of thickness 1.3 m is made of layers of granular material.

Water was provided in doses of 100-300 litres to the top of the installation, where in a process of unsteady filtration, the water depth gradually decreased from 50 cm to 5 cm, creating the necessary conditions for the development of sustainable biocenoses. The efficiency of the water treatment was then determined by comparing water samples taken from the top of the installation and from the effluent at the outlet, as well as taken along the height of the column.

The following parameters were determined, by standard methods of analysis: BOD_5, COD, oxygen content, temperature, pH, mineralization, salt composition, NH_4, NO_3, NO_2, Phosphorus, oil, pesticides, trace metals; then hydro-biological parameters (zooplankton, periphyton, zoobenthos) and microbiological data (pathogens - bacteria, viruses, protozoa and helminths) in the different layers of the installation.

Phenological observation of plants (density, height, root systems development, evapo-transpiration) and physical and hydrodynamic characteristics of the filter layer (clogging and infiltration velocity) were also conducted.

The tested inflow consisted either of sewage water, with a high level of organic contaminants, or water of a quality similar to polluted river water. The main variables in the examined water were: BOD_5 50-280 mg/l; COD 80-350 mg/l; NH_4 2-70 mg/l; suspended particles 40-400 mg/l; pH 6.8=8.0; coliform bacteria and E.coli 0.04-0.01; salinity up to 3.4 g/l; alpha-gamma HCH up to 0.28 mkg/l; DDT and metabolites - up to 0.276 mkg/l.

Results: Hydro-biological and microbiological parameters of BIC tested in the CEWM Laboratory

The quality of water for which the BIC was tested corresponds to that of the water from Mezhdurechye reservoir, in the Muinak region (Table 1).

As known, the effect of hydrobionta on water quality can be positive or negative. While their phyto-, zoo- and bacteria-plankton enhances self-purification, excessive development of hydrobionts causes eutrophication and deterioration of the water quality. Therefore, in the BIC, the quantity, quality and rate of growth of hydrobionts, had to be controlled.

26 types of phytoplankton were identified in the tests, belonging to 4 species of algae: Cyanophyta, Chlorophyta, Bacillariophyta and Euglenophyta (Table 2).

For contact times between 2-5 days, 16 to 25 types of organisms were detected on the plants of the installation.

As compared to the water in the BIC, the phytoplankton in the drainage collectors and natural water courses is much richer, with up to 35 types, abundance from 140 to 2,500 million specimen per litre and biomass between 0.84 and 60.7 g/l, dominated by diatom algae.

Apparently, phytoplankton development in the bio-engineering installations is restrained by the activity of the macrophytes, which are powerful competitors in using the available biogenic and other nutrients.

 The largest quantity of biomass was observed in installations with mixed macrophytes.

Micro-organisms have an important role in the detoxication of various pollutants in aquatic ecosystems. Up to 645.1 million of cells were found in the root zone (Fig.2). Microbiological species are found, such as coliform bacteria, different streptococci, spores of sulfide reducing clostridia and other bacteriophages.

Considerable improvement of sanitary-epidemiologic parameters of the water (pathogenic bacteria of intestine group) was noted in the research using macrophytes (Table 3).

The absence of mosquitos was marked in some types of macrophytes, for instance *Acorus paludis*. This proves the phytoncid behaviour of some macrophytes and their role in water protection measures.

Hydrochemical indices of treated water quality

The hydrochemical parameters of water were considerably improved by the biological treatment, using macrophytes [1,4,8].

Appreciable effects were obtained in BIC with different types of macrophytes, and well balanced aerobic-anaerobic conditions could be obtained, controlling the water quality by changing the time of contact (T_C) of the water body with the artificially formed biocenoses.

Oxidation, mineralization and sorption processes were intensified in the BIC of macrophyte biocenoses, as well as the decontamination of pesticides, settling processes and hemosorption of trace and heavy metals.

The main elements of the BIC biocenoses which determine the purification were:

1. macrophytes and algae;

2. microorganisms in the water body (algae, bacteriaplankton, periphyton, zooplankton, etc);

3. microorganisms in the root and silt layer (bacteriaflora, zoobenthos, phytobenthos, etc);

4. micro-organisms in the filter soil and package layer (some fungi, bacteria, etc.).

As regards the physico-chemical, biochemical and biological processes, the purification progressed in three stages:

a) in the water body, in contact with the macrophytes;

b) in the root zone, soil and filter layers, where the purification is intensified by the rhizosphere, and activity of the filter materials; and

c) in the anaerobic processes of the lower part of the BIC.

During contact times from one to five days, the water quality in the BIC was transformed from high saprobity to oligosaprobity (Table 4). The concentrations of total nitrogen, phosphorus, organic substances (BOD, COD) were reduced by ten to one hundred times. Concentrations of some trace metals, which are listed in the water quality standards, were reduced over 5 to 7 times.

Chemical analyses have shown that 22-38% of organic contaminants were removed in the water body of the BIC, and the remaining 62-78% in the filter zone by the biological activity of the biocenosis. The efficiency of BIC is shown on Figures 3a and 3b.

In 3-4 days of contact, the following reductions were obtained (minima and maxima) in the water body: BOD_5 23.5-84%; COD 27-78%; NH_4 46-86%; NO_2 46-100%; NO_3 42-95%; P 36-90%; suspended particles 44.8-95.6%; Cu 43.2-85.7%; Fe 65.5-98.7%; Zn 87-99.6%; Pb 45-95.6%; Cr 97.3-100%; Cd 98-100%; Md 96-98%;

in the effluent (after filtration): BOD_5 77-98.3%; COD 71-95%; NH_4 78-99.9; NO_2 97-100%; NO_3 68-999%; P 80-99%; suspended particles 91-99%; Cu 86-99.9%; Fe 73.2-99.9%; Zn 98.6-99.9%; Pb 87.5-99.9%; B 99.1-99.9%; Cd - 100% and Mn 99.9%.

It should be noted, that a high effect of cleaning (over 50%) was already achieved during the first day of contact.

The intensity of water quality transformation in the functional part of the BIC increased in the direction of filtration. The root zone was a powerful agent in the purification process.

As regards the efficiency of different macrophytes, the best results were obtained by the plant mixture: *Phragmites communis, Acorus paludis, Scirpus lacustris, Typha latifolia;* next in order of efficiency were single macrophytes: *Acorus paludis,* followed by *Scirpus lacustris, Phragmites communis* and *Typha latifolia.*

The high purifying capability of macrophytes and their advantage compared to other devices, without plants, could be seen by the comparison with the control installation (without macrophytes), the efficiency of which is shown on Fig. 3b (b). In 3-4 days, the cleaning effects were: BOD_5 and COD 23%; NH_4 11.4-23.7%; NO_3 4-52.6%; P 8.5-65.2%; suspended particles 41-65%. An increase of nitrogen was observed in the effluent, caused by secondary pollution. This phenomenon was absent in the experiments with plants.

A parabolic relationship between efficiency (E) and time of contact (T_c) was found statistically, by the least squares method, for N = 1-5 days:

$$E = AT_c^2+BT_c+C$$

The values of the constants A, B and C are given in Table 6.

The correlation coefficient of this approximation was high - 0.8-0.99. The calculations have shown that acceptable purification is attained in 1.5-2 days of contact in the BIC. By the above relationships, the needed contact time can be determined, in order to reach the desired level of purification for various contaminants and selected types of macrophytes.

It was also necessary to determine the accumulation of contaminants by the metabolism of macrophytes, and the intensity of detoxication. The experiments demonstrated the appearance of pesticides - DDT, HCH in the plants one day after the water pollution. The distribution of pesticides is non-uniform, different in various parts of the plants. Constant concentration of DDT and HCH, up to 0.05 mg/l, passes through the root system and reaches the leaves and stems, where it is used in the synthesis and metabolism of organic matter [2,3].

A complicated situation was observed with the metabolites of DDT: DDD and DDE. Experiments with alpha-HCH indicated its decrease during 11 days, with *Phragmites communis*, from 7.52 to 0.83 mkg/l, with *Typha angustifolia* to 0.508 mkg/l. Accordingly, the efficiency of the treatment (purification) was 89% and 93%, respectively (Table 7).

The concentration of lindan gamma-HCH was reduced from 1.66-2.02 mkg/l to 0.205 mkg/l, by the presence of *Phragmites c.* (efficiency E = 88%) and to 0.4 mkg/l of *Typha angustifolia* (E = 80%). The rate of accumulation of pollutants is the highest in the first days of contact in the BIC.

Some accumulation of pesticides is found in bottom sediments and silts, because of their intake by root systems of plants and the activity of soil micro-organisms (such as fungi, e.g. *Mucor Alternaria, Aspergillus, Cryptococcus,* etc). Decomposition of pesticides is also caused by the actions of algae and aquatic micro-organisms.

The high efficiency of BIC has been proved also by the accumulation of pesticides in the root zone and their upward spreading into the body of the plants. In particular, during the infiltration through the filter layer, the water interacts with the whole root system. This effect is enhanced by the purifying potential of the soil, in which abiotic processes (oxidation, hydrolysis, etc) also contribute, in addition to the biotic factors (macro- and micro-organisms, accumulation of contaminants in macrophytes, etc).

It is important to let these installations function in winter. At the beginning of the vegetation season, the residual contaminants migrate into the leaves and stems of the macrophytes, during their growth. Thus, by harvesting the macrophytes, the contaminants will be removed together with the plant biomass.

Perennial water plants - macrophytes - have robust root systems which increase the filtration rate through the installation, without losing the purification efficiency, and preventing the clogging of the filter. This helps the maintenance and increases the reliability of the units. As shown on Fig. 4, the rate of infiltration is 10-16 times higher in BIC, than in the control unit without plants.

Proposed technology for polluted water treatment in the field

On the grounds of the laboratory tests, a proposal was prepared for bio-engineering technology applied in field conditions. The main components of the proposed technology are the following (Fig. 5):

1. biological pond with water macrophytes;

2. bio-engineering infiltration structure with macrophytes;

3. clean water reservoir.

The biological ponds are formed by a sequence of submergible pervious dikes, with a width of 6 to 10 m. Each subsequent dike in downstream direction is 0.15-0.2 m lower than the preceding one, the most upstream dike being 1.0-1.5 m high. On the subsequent dikes, macrophytes are cultivated, in the following sequence:

1. *Acorus paludis;*

2. *Typha angustifolia, Typha latifolia;*

3. *Phragmites communis, Scirpus lacustris.*

This sequence is adapted to the biological properties of the macrophytes. The water depth is 0.3-0.4 m over the first dike, (with *Acorus paludis*), and over the last one (with *Phragmites communis*), the water is 0.9-1.0 m deep. This arrangement makes it possible to build up the appropriate biocenoses in each section of the biopond, thus allowing the complete removal of pollution. Favorable conditions are secured for photosynthesis.

After the biological pond, the water enters into the bio-engineering units (BIC), which are the main technological components of the process, and where the profound cleaning of the water occurs. The BIC are biological ponds with artificial (special) filter material in the basis, 1.3–1.6 m thick. The natural filter is made of sand, sandy loam, gravel, shingle, etc.

This creates favourable conditions on the substrate for the vital functions of micro-organisms. On the filter, macrophytes – *Acorus paludis, Phragmites communis, Scirpus laustris* are cultivated. The depth of water in the BIC is about 1.2 m.

Maintaining in the BIC horizontal flow (through the bands of macrophytes) and vertical flow (infiltration), an artificial hydro-biocenosis is formed, with selected macrophytes and respective micro-organisms, which are best adapted to the type of the polluted water. The interconnected components and environmental factors are integrated into a unique system.

The necessary surface area of the BIC is calculated by the formula;

$$S = QT_C / H$$

where: Q – water consumption m^3/day;

H – depth of water layer (0.6-1.0 m)

T_C – contact time with biocenosis, days

The contact time T_C can be adopted as 0.5-1.0 day, or calculated by means of the diagrams (Fig. 3a and 3b), or Table 4.

It must be underlined, that the BIC should operate round the year. In winter, the water purification takes place in the root zone of the filter layer, where heterotrophic processes of the metabolism continue to act, owing to the higher specific density of micro-organisms in the filter layer.

From the BIC, the treated water enters into the clean water reservoir, through drainage pipes or other means.

Harvesting of the macrophyte biomass is an important activity for the operation of the system.

Implementation of bio-engineering technology and results of field research

The recommended bio-engineering technology was implemented in the village of Kziljar, Muinak region, Karakalpakstan, in summer 1994.

The Kziljar settlement is in the northern part of Karakalpakstan, about 20-22 km from Muinak. The population is about 600 inhabitants, mainly employed in fishery and animal husbandry. Drinking water is taken from the Mezhdurechye reservoir, and the quality of tap water does not meet the standards.

The bio-engineering technology introduced consists of:

1. biological pond with submerged dams, on which are grown *Acorus paludis, Typha angustifolia, Typha latifolia, Scirpus lacustris* and *Phragmites communis;*

2. bio-engineering infiltration structures (BIC), with cultivated *Acorus paludis, Phragmites communis,* and *Scirpus lacustris.*

The layout of the bio-engineering installation is shown on Figure 5. The water has been diverted from the Mezhdurechye reservoir, which is practically the only source of drinking water for the neighbouring settlements. For the filter layer, local materials have been used, such as gravel, crushed stone, sand and sandy loam. A first washing of the filter layer was executed in the implementation period, by which the dry residuum in the effluent was reduced from the initial 6 g/l (and more) to 2.0 g/l.

The results of the tests have confirmed a significant improvement of the water quality, by most of the hydro-chemical, ecologic and toxicologic indicators, as shown in the tables. The quality of the treated water satisfies the criteria for drinking water of the State standards (GOST). The salinity and hardness of the water are close to those of the river water. It can be expected that in the further exploitation of the installations, salinity and hardness will also improve, the excess of ions being absorbed by the vegetation.

The installation could treat between 10,000 and 12,000 litres of water per day, which could satisfy the demands of a rural settlement of 200-240 people (with 50 litres per day per capita).

In view of the importance of improving the quality of river water and providing safe drinking water for the population, the research of bio-engineering methods of water treatment need to be continued.

The BIC operating in Kzyljar village has proved its efficiency. In a letter to UNESCO, dated June 1996, the villagers expressed their satisfaction at being provided with water from the BIC and pleaded for further implementation of similar structures in the region. Also, the construction of a new installation has started in 1996 in the Tashkent region (sponsored by USAID).

References

1. Magmedov, V.G. (1988): "Main types of water conservation structures, based on water cleaning by macrophytes" (in Russian), Vodnie Resursi, N.2., Moscow, pp 150-155.
2. Merezhko, A.I. (1987): "The importance of macrophytes for water conservation and water quality" (in Russian), In the book: Ecological requirements of irrigation systems, Kiev, Urozhai.
3. Morozov, N.V. (1988): "Bio-technological methods for the elimination of pesticides from natural waters", (in Russian), Vodnie resuri, No.5, pp 85-98.
4. Rahmonov, B.A. (1985): "Control of the quality of natural waters by combined biological improvements", (in Russian), Thesis, Institute for Water Problems, Tashkent.
5. Ruziev, I.B., Rahmonov, B.A. (1991): "The use of macrophytes for the protection of water bodies from pollution by agricultural wastewaters", (in Russian), Abstract, Proceedings, 2nd Conference on the Toxicology of Fisheries, St.Petersburg, pp 115-117.
6. Yunusova, F.F., Shapalova, A.M., Muralimov, M.M. (1985): "Deep purification of waste waters of a hydropower plant on the Syr'Darya, by means of biological ponds with higher vegetation" (in Russian),/"Waste water purification and treatment of atmospheric water by closed water management systems of industrial enterprises", Proceedings VODGEO, Moscow, pp 65-69.
7. Timofeyeva, S.S., Bespalova, V.Z. (1989): "Macrophytes for the Elimination of Mercapto-chemicals", (in Russian), Vodnie Resursi, Moscoiw, pp. 103-107.
8. Bersberg, Elkins et al (1986): "Role of Aquatic Plants in Wastewater Treatment by Artificial Wetlands", Water Research, Vol. 20.3, pp. 363-368.
9. Bucksteg K., Muller, H.H., Mortl R. (1985): Erste Erfahrungen mit 12 Sumpfpflanzenklaranlagen/ Korrespond. Abwasser, 32, N 5., pp 376-383.
10. Dafner G. (1987): Betriebserfahrungen mit einer Pflanzenklaranlage/GWP Wasser, Abwasser, 128, N.4 pp 241-246.
11. Kickuth R. (1982): Das Wurcselraumverfahren - ein Kostengunstiges Klarverfahren fur dezentralen Einsatz in Kommunen und Gewerbe / Tropenlandwirtschaft, 83, October; pp 141-154.
12. Haberl R. Diebold W., Parsian R. (1983): Darstellung verschiedener Systeme der Abwasserreinigung mit Macrophyten / Oesterreichische Wasserwirtschaft, N. Ç-10, pp 213-225.
13. Saure F. (1983): "Cultures de jacinthes d'eau sur eaux résiduaires"/Bulletin direction études et recherche, A. N.3-4, pp 29-33.

Table 1. Water quality in Mezhdurechye reservoir – 1993-1995

Compound		Mezhdurechye reservoir	Glavmyaso Canal	Tap water			Drinking water wells
				Muinak	Kungrad	Tahiatash	
pH		6.6-7.9	7-8	1.0-1.8			6.8-8.2
Salinity g/l		0.84-1.96	0.9-2.0	1.0-1.8			1.2-2.48
Hardness mkg/l		7.4-13.8	7.4-20.3	9-11.8			9.4-18.5
Ca	mg/l	101-184	68-184				116-184
Mg	mg/l	29-138	41-138				43-112
HCO_3	mg/l	150-201	151-250				290-336
Cl	mg/l	120-411	120-418	220-237			210-738
SO_4	mg/l	257-628	254-628	430-450			501-737
Na+K	mg/l	108-197	83-411				70-700
NH_4	mg/l	0.37-1.05	0.09-1.0	0.07-0.15	0.04-0.082	0.12-0.52	0.05-0.34
NO_2	mg/l	0.005-0.29	0.028-0.05	0-0.05	0-0.04	0-0.005	0.008-0.15
NO_3	mg/l	5.0-49	14-45	6.3-30	10-40	2-18	15-186
COD	mg/l	63-171	17-171	24-85	18-49	20-37.4	74-222
BOD	mg/l	3.8-10.2	2.37-9.48	2.4-7.8	2.0-6.5	2.5-7.8	1.2-13.8
Oil	mg/l	0.22-0.84	0.05-0.66	2.0-0.8	0-0.32	0-0.35	0.09-0.3
P_2O_4	mg/l	0.005-0.03	0.005-0.1		0.008-0.13	0.003-0.08	0.01-0.22
HCH	mkg/l	0.02-0.624	0.053-0.098	0.02-0.05		0.01-0.072	0.03-0.07
HCH	mkg/l	0.055-0.217	0.024-0.058	0.03-0.091		0.013-0.06	0.055-0.007
DDT	mkg/l	0.07-0.268	0.077-0.2	0-0.022		0-0.095	0-0.02
DDD	mkg/l	0-0.182	0-0.16	0-0.029		0-0.114	0-0.013
DDE	mkg/l	0.019-0.243	0.047-0.1	0-0.079		0-0.189	0-0.043
Saturn	mkg/l	0-1.5					
Propanid	mkg/l	0-0.583	-				
B	mkg/l		0.26-1.9				
Fe	mg/l	0.13-0.52	0.5-2.82	0.1-0.92	0.17-1.43		1.4
Cu	mkg/l	0-8.9	0.1-3.7	0-0.8	0-1.3		0.066
Zn	mkg/l	0.9-28.9	0.9-32	0.6-3.3	0.76-4.8		0.7-7.8
Cr	mkg/l	0-7.2	0-10.8	0-3.5	0-1.8	0.73-6.1	6-9.4
F	mg/l	0.08-2.6	0.17-0.69	0.06-0.3	0.08-0.1	0.1-0.12	0.10
Ni	mkg/l	1.8-30	0.4-4.2	0.8-10.8	0.7-6.7	0.08-5.2	3.2
Pb	mkg/l	1.4-6.8	1.4-2.4	0.9-5.6	1.8-3.07	0.1-0.3	1.3
Mn	mkg/l	3.2-24.8	4.6-24	2-6.4	4.0-14.2	4.0-14.2	0-25
Cd	mkg/l	0-0.14	0-2.7	0.64-7.8	0-1.1	0-0.17	0-2.3
Hg	mkg/l	0-3.6	0-3.6	0-0.01	0-0.01	0-0.02	0-0.036

Table 2. Number of types and biomass of phytoplankton in BIC water body (upper row - in summer; *lower row - in autumn*)

BIC type and Macrophyta	Cyanophyta	Chlorophyta	Euglenophyta	Bacillariophyta	Total	
	Phytoplankton biomass in g/m³				Biomass	Number of types
1. Control	0.11	37.0	38.5	–	76.0	8.0
	1.7	*0.004*	*0.95*	*0.02*	*1.8*	*4.0*
2. *Acorus*	3.0	–	11.0	–	14.0	4.0
paludis	–	*0.002*	*0.01*	*0.08*	*0.09*	*5.0*
3. Mixed	3.0	0.55	10.3	–	14.0	6.0
macrophyta	*0.012*	–	–	–	*0.012*	*2.0*
4. *Scirpus*	2.1	–	10.5	–	13.0	– ?
lacustris	*1.2*	–	–	*0.08*	*1.3*	*3.0*
5. *Typha*	0.24	0.85	32.0	–	40.7	5.0
angustifolia	–	–	–	–	–	–
6. *Phragmites*	0.03	–	16	0.003	16.0	5.0
communis	*0.6*	*0.003*	*0.1*	*0.03*	*0.73*	*11 ?*

Table 3. Number of intestinal bacteria and saprophytes in BIC laboratory with macrophytes in purification process (upper row - water body; *lower row - effluent*)

Organisms 1000 cells/ml	Initial	T_k = 12 hours				Initial	T_k = 3 days
		BIC with:					*Acorus paludis*
		1	2	3	4		
Saprophyta	26	26	28	25	28	0.26	0.037
		23	*10*	*8.2*	*2&6*		*0.005*
Pathogenic bacteria of intestine group	46.0	41.0	41.0	20.0	38.0	0.222	0.01
		1.0	*0.1*	*0.1*	*0.1*		*0.002*

1. Control; 2. *Phragmites communis;* 3. *Typha angustifolia;* 4. Mixed culture.

Table 4. Efficiency of water purification in the laboratory tests of BIC (upper row - water body; *lower row - effluent)*

Contact time-days T_c	BOD_5	Concentration in mg/l					Suspended particles
		COD	NH_4	NO_2	NO_3	P_2O_3	
1	2	3	4	5	6	7	8
1. Control BIC							
Initial	65.3	130.5	10.6	0.29	38.1	3.2	160
1	60.8	116	9.2	0.192	43.7	2.8	90.8
	39	*86*	*5.8*	*0.05*	*25*	*0.71*	*2.0*
3	48.2	93	7.9	0.148	29	1.98	39.11
	41.1	*72*	*5.0*	*0.08*	*44*	*0.71*	*2.0*
2. BIC with *Typha latifolia*							
Initial	56.7	184.6	13.2	0.185	14.09	2.0	176
1	36.8	122	10.8	0.127	12.54	0.37	48.4
	3.19	*17.2*	*3.16*	*0.02*	*4.43*	*trace*	*3.0*
3	30.66	76.2	3.14	0.039	3.89	0.19	26.9
	1.9	*12.7*	*cn.*	*0.006*	*1.03*	*cn.*	*3.0*
3. BIC with *Scirpus lacustris*							
Initial	-	52.7	67.9	5.385	46.5	0.97	-
1	38.8	38.8	55	3.146	32.07	0.31	-
	-	*14.4*	*14.8*	*0.072*	*4.52*	*cn.*	-
3	1	13.2	20.84	1.62	20.2	0.21	-
	-	*8.3*	*1.58*	*0.057*	*3.17*	*cn.*	-
4. BIC with *Acorus paludis*							
Initial	24.7	58.6	57	4.07	56.5	1.87	-
1	9.65	42.1	41.0	1.6	29.6	0.89	-
	2.29	*15.3*	*3.21*	*0.028*	*3.8*	*cn.*	-
3	3.8	14.3	6.6	0.55	9.4	0.38	-
	0.44	*9.5*	*0.75*	*0.011*	*3.01*	*cn.*	-
5. BIC with *Phragmites communis*							
Initial	122	366	20	2.0	52.1	0.8	180.7
1	96.5	295	17	1.0	29	7.7	85
	28.1	*92*	*4.01*	*0.09*	*13.3*	*3.0*	*5.6*
3	52	130	11	0.38	9.3	6.1	32
	12.0	*55*	*2.1*	*0.005*	*4.2*	*0.9*	*4.8*
6. BIC with mixed plant community							
Initial	63.2	198.9	10.6	0.6	37.3	2.13	112
1	49.4	140	4.16	0.25	23.1	1.05	72
	7.9	*53*	*0.5*	*cn.*	*4.2*	*0.31*	*5.0*
3	22.1	90	2.05	0.07	9.6	0.65	21
	4.7	*26.2*	*0.35*	*410*	*1.08*	*0.18*	*4.8*

Table 5. Efficiency of water purification in the laboratory tests of BIC Lowering of metal concentrations (upper row - water body; *lower row - effluent)*

Contact time	Concentration mg/l				
Days	Fe	Cu	Zn	Pb	Cr
Initial	0.784	0.074	0.80	0.30	3.8
1. BIC with *Typha angustifolia*					
2 days	0.326	0.026	0.3	0.038	0.2
	0.016	*0.015*	*0.01*	*0.01*	*0*
4 days	0.027	0.02	0.035	0.027	cn.
	0.013	*0.01*	*0.005*	0.005	*0*
2. BIC with *Acorus paludis*					
2 days	0.312	0.052	0.22	0.052	0.91
	0.166	*0.026*	*0.005*	*0.001*	*0.009*
4 days	0.112	0.42	0.05	0.02	0.1
	0.07	*0.01*	*0.0*	*cn.*	*0.0*
3. BIC with *Phragmites communis*					
2 days	0.374	0.055	0.13	0.082	cn.
	0.12	*0.02*	*0.015*	*0.01*	*cn.*
4 days	0.129	0.028	0.01	0.01	cn.
	0.06	*0.008*	*0.011*	*0.003*	*0*
4. BIC - Control (without macr.)					
2 days	0.62	0.068	0.70	0.21	3.0
	0.22	*0.04*	*0.18*	*0.09*	*0.01*
4 days	0.58	0.052	0.30	0.19	2.05
	0.2	*0.04*	*0.18*	*0.12*	*0.007*

Table 6a. Coefficient of correlation R and constants A, B and C in equation: $E = AT_c^2+BT_c+C$

	BIC with											
Compound	*Phragmites communis*				*Acorus paludis*				*Typha angustifolia*			
	A	B	C	R	A	B	C	R	A	B	C	R
BOD_5	-0.76	21.11	2.62	0.95	-2.78	29.1	2.96	0.93	-2.89	25.66	0.76	0.92
	-24.9	*108.9*	*0*	*0.98*	*26.17*	*109.9*	*0*	*0.99*	*-26.7*	*110.7*	*0*	*0.99*
COD	-5.40	34.31	0	0.88	-3.38	28.93	1.32	0.97	-5.31	34.07	0.58	0.88
	-18.1	*82.49*	*0*	*0.95*	*-23.2*	*99.32*	*0*	*0.49*	*-22.2*	*95.43*	*0*	*0.98*
Oxid.	-3.39	24.82	0	0.90					2.53	23.8	0	0.90
	-19.7	*85.99*	*0*	*0.97*	–	–	–	–	*-18.8*	*82.66*	*0*	*0.97*
NH_4	-2.11	23.88	0	0.95	-2.4	28.66	0.72	0.95	0.33	13.9	0.31	0.74
	-21.9	*92.76*	*0*	*0.98*	*-26.7*	*111.4*	*0*	*0.99*	*-19.1*	*85.86*	*0*	*0.94*
NO_2	-7.38	51.83	0	0.94	-16.8	81.28	0	0.97	-9.85	55.08	0.54	0.90
	-30.5	*124.7*	*0*	*1.0*	*-27.7*	*115.1*	*0*	*0.97*	*-28.3*	*117.8*	*0*	*0.99*
NO_3	-8.47	49.48	0	0.93	-9.34	53.15	0	0.93	-8.08	41.6	0	0.84
	-24.9	*105.1*	*0*	*0.97*	*-26.3*	*109.4*	*0*	*0.98*	*-23.1*	*97.18*	*0*	*0.94*
P_2O_4	-6.71	38.82	0	0.88	-8.08	38.4	0	0.89	-7.37	40.35	-0.22	0.79
	-25.6	*107.1*	*0*	*0.97*	*-27.0*	*113.2*	*0*	*0.99*	*-28.9*	*110.8*	*0*	*0.97*
Suspend	-8.28	49.83	0	0.93	-5.85	45.5	0	0.98	-8.99	45.02	0	0.9
part.	*-31.1*	*128.1*	*0*	*1.0*	*-29.9*	*121.9*	*0*	*1.0*	*-31.3*	*126.5*	*0*	*1.0*
Cu	-2.89	30.76	0	0.94	-0.85	17.34	0	0.95	-0.47	20.37	0	0.95
	-8.42	*57.68*	*0*	*0.98*	*-8.67*	*57.85*	*0*	*0.98*	*-7.25*	*51.33*	*0*	*1.0*
Fe	0.42	21.20	0	0.94	-4.87	40.33	0	1.0	-0.58	16.6	0	0.8
	-6.6	*49.76*	*0*	*0.99*	*-8.95*	*59.86*	*0*	*0.99*	*-8.85*	*58.02*	*0*	*0.93*
Zn	-8.4	49.07	0	0.97	-8.97	60.25	0	0.99	-6.43	48.79	0	0.97
	-11.7	*71.68*	*0*	*1.0*	*-12.1*	*73.42*	*0*	*1.0*	*-11.1*	*69.3*	*0*	*0.99*
Pb	0.28	21.81	0	0.95	-1.97	29.86	0	0.92	-4.01	34.89	0	0.84
	-7.81	*55.52*	*0*	*0.98*	*-9.03*	*81.03*	*0*	*0.99*	*8.23*	*58.7*	*0*	*0.95*

Note: Upper values – water body
Lower values – after infiltration

Table 6b. Coefficient of correlation R and constants A, B and C in equation: $E = AT_c^2+BT_c+C$

Compound	BIC with: *Scirpus lacustris*			
	A	B	C	R
BOD_5	-7.71	47.91	0	0.97
	-22.3	*98.23*	*0*	*0.99*
COD	-5.02	32.08	0	0.91
	-18.2	*81.15*	*0*	*0.97*
Oxid.	-3.89	27.95	0	0.97
	-	-	-	-
NH_4	-8.84	40.76	0	0.87
	-24.5	*105.2*	*0*	*0.99*
NO_2	-8.63	122.4	0	0.98
	-29.8	*39.38*	*0*	*1.0*
NO_3	-5.22	39.38	0	1.0
	-30.2	*123.2*	*0*	*0.83*
P_2O_4	-10.8	56.78	0	0.83
	-30.8	*124.0*	*0*	*1.0*
Suspended particles	-9.22	50.82	0	0.98
	-28.9	*118.9*	*0*	*1.0*
Cu	-	-	-	-
Fe	-	-	-	-
Zn	-	-	-	-
Pb	-	-	-	-

Note: Upper values – water body
Lower values – after infiltration

Table 6c. Coefficient of correlation R and constants A, B and C in equation: $E = AT_c^2+BT_c+C$

	BIC with:											
Compound	*Typha latifolia*				Mixed cultures				Control (without macr.)			
	A	B	C	R	A	B	C	R	A	B	C	R
BOD_5	-8.41	38.25	-0.72	0.93	-3.30	30.7	0.18	0.90	-1.78	15.81	-0.3	0.85
					-17.4	*84.42*	*3.90*	*0.96*	-	-	-	-
COD	-8.14	43.95	0.22	0.95	-3.17	28.25	1.87	0.94	-0.95	10.7	0.49	0.88
					-14.5	*70.43*	*4.35*	*0.98*	-	-	-	-
Oxid.	-1.75	20.25	0	0.94	-3.88	29.79	0.90	0.92	-1.42	13.21	0.68	0.88
					-17.1	*80.51*	*3.72*	*0.95*	-	-	-	-
NH_4	-6.89	38.67	0.98	0.87	-3.98	34.18	1.08	0.95	0.68	8.37	-0.39	0.93
					-15.3	*77.91*	*4.49*	*0.95*	-	-	-	-
NO_2	-17.7	85.4	0	0.96	-14.4	75.72	4.12	0.94	-7.10	44.28	0	0.76
	-31.7	*128.4*	*0*	*1.0*	-18.4	*90.48*	*5.93*	*0.96*	-	-	-	-
NO_3	-10.8	54.7	0	0.93	-4.2	33.53	3.07	0.90	-1.12	13.9	-0.46	0.78
	-24.3	*101.1*	*0.25*	*0.97*	*18.51*	*77.53*	*4.96*	*0.89*	-	-	-	-
P_2O_4					-4.94	39.3	1.09	0.90	0.81	10.23	0.82	0.8
	-5.51	*38.82*	*0.38*	*0.96*	*-16.5*	*85.58*	*5.44*	*0.97*	-	-	-	-
Suspend part.	-8.83	48.78	1.49	0.91	-8.45	50.1	2.02	0.94	-1.35	19.01	2.34	
	-29.3	*120.0*	*0*	*1.0*	*-18.3*	*89.7*	*8.21*	*0.95*	-	-	-	-
Cu	-	-	-	-	-	-	-	-	-0.99	14.7	0	0.81
									-3.69	*28.81*	*0*	*0.89*
Fe	-	-	-	-	-	-	-	-	-1.66	16.31	0	0.87
									-7.53	*49.24*	*0*	*0.99*
Zn	-	-	-	-	-	-	-	-	-0.58	18.39	0	0.92
									-9.98	*62.83*	*0*	*0.98*
Pb	-	-	-	-	-	-	-	-	-0.32	10.75	0	0.71
									-4.81	*35.55*	*0*	*0.91*

Note: Upper values – water body
Lower values – after infiltration

Table 7. Efficiency of the treatment of organo-chlorine pesticides (alpha-gamma HCH) in laboratory tests of BIC comprising: (A) *Phragmites communis* and (B) *Typha angustifolia* (upper row - alpha-HCH; *lower row - gamma-HCH)*

Macrophytes	Tested object	Initial concentration	Contact time		
		mkg/kg	1 day	4 days	11 days
A	Water	7.521	-	2.415	0.830
		1.66	-	*0.578*	*0.250*
Phragmites	Macro	0	0.329	-	0.147
communis	phytes	*0*	*0.054*	-	*0.650*
	Bottom	0	0.004	-	0.004
	sediments	*0*	*0.012*	-	*0.008*
B	Water	7.087	-	1.326	0.868
		2.024	-	*0.505*	*0.405*
Typha	Macro	0	0.061	-	0.278
angustifolia	phytes	*0*	*0.047*	-	*0.218*
	Bottom	0	0.004	-	0.017
	sediments	*0*	*0.01*	-	*0.01*

Table 8. Efficiency of investigated BIC in Kzildjar village

		Inflow into the BIC	Outflow from the BIC
BOD_5	mg/l	6.0 - 13.8	2.3 - 3.4
COD	mg/l	40 - 110	17 - 28
NH_4	mg/l	0 - 0.5	trace
NO_2		0 - 0.05	0
NO_3	mg/l	8 - 47	1.0 - 8.0
P_2O_4	mg/l	0.6 - 2.3	0.05 - 0.08
Oil		0.3 - 0.84	0.005 - trace
α-HCH	μg/l	0.06 - 0.08	0 - 0.002
β-HCH	μg/l	0.024 - 0.086	0
γ-HCH	μg/l	0.03 - 0.189	0
DDT	μg/l	0.077	0
DDD	μg/l	0.085	trace
DDE	μg/l	0.02 - 0.110	0
Cu	μg/l	0.037	0.01
Zn	μg/l	2 - 20	0 - 5.6
Cd	μg/l	0.014 - 0.1	0.02
Fe	μg/l	0.05 - 0.09	0.01 - 0.02
Fe	μg/l	0.437	0.2
Pb	μg/l	0.041	0.005
Mn	μg/l	0.01 - 0.08	0.002 - 0.005

Figure 1. Cross section of the experimental installation in the laboratory of CEWM, Tashkent

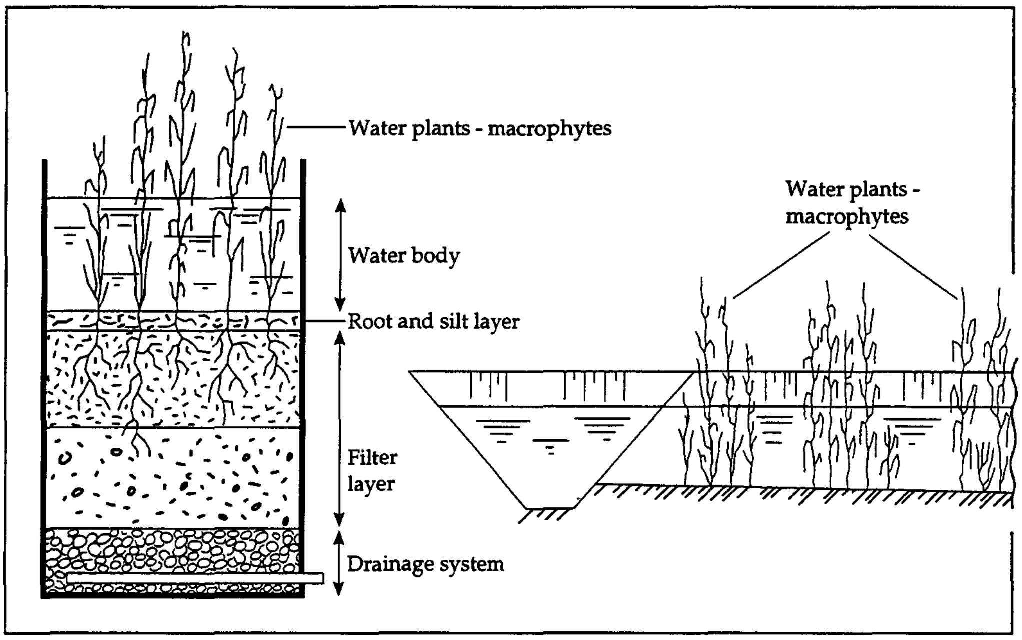
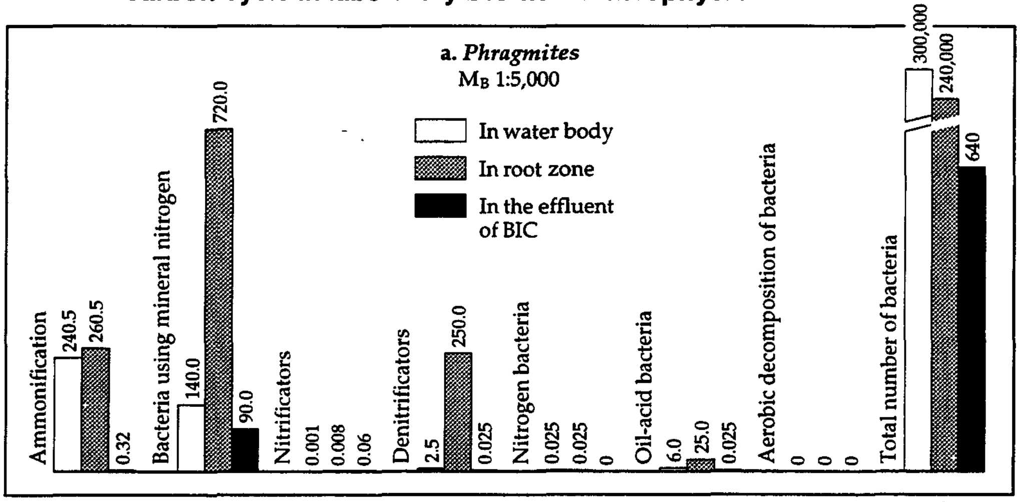


Figure 2. Content of main group of micro-organisms of nitrogen and carbon cycle in laboratory BIC with macrophytes



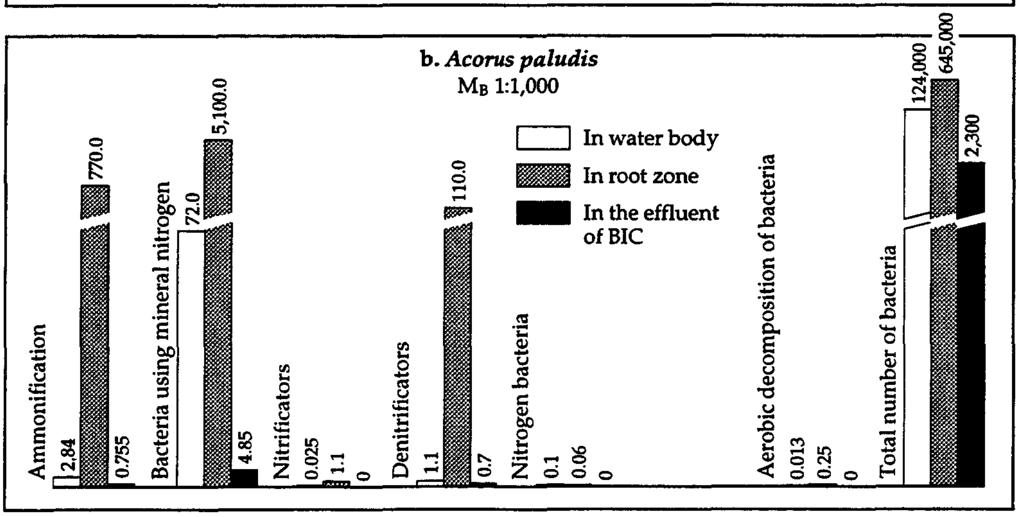


Figure 3. Efficiency of water purification in the BIC, in function of the contact time T_c

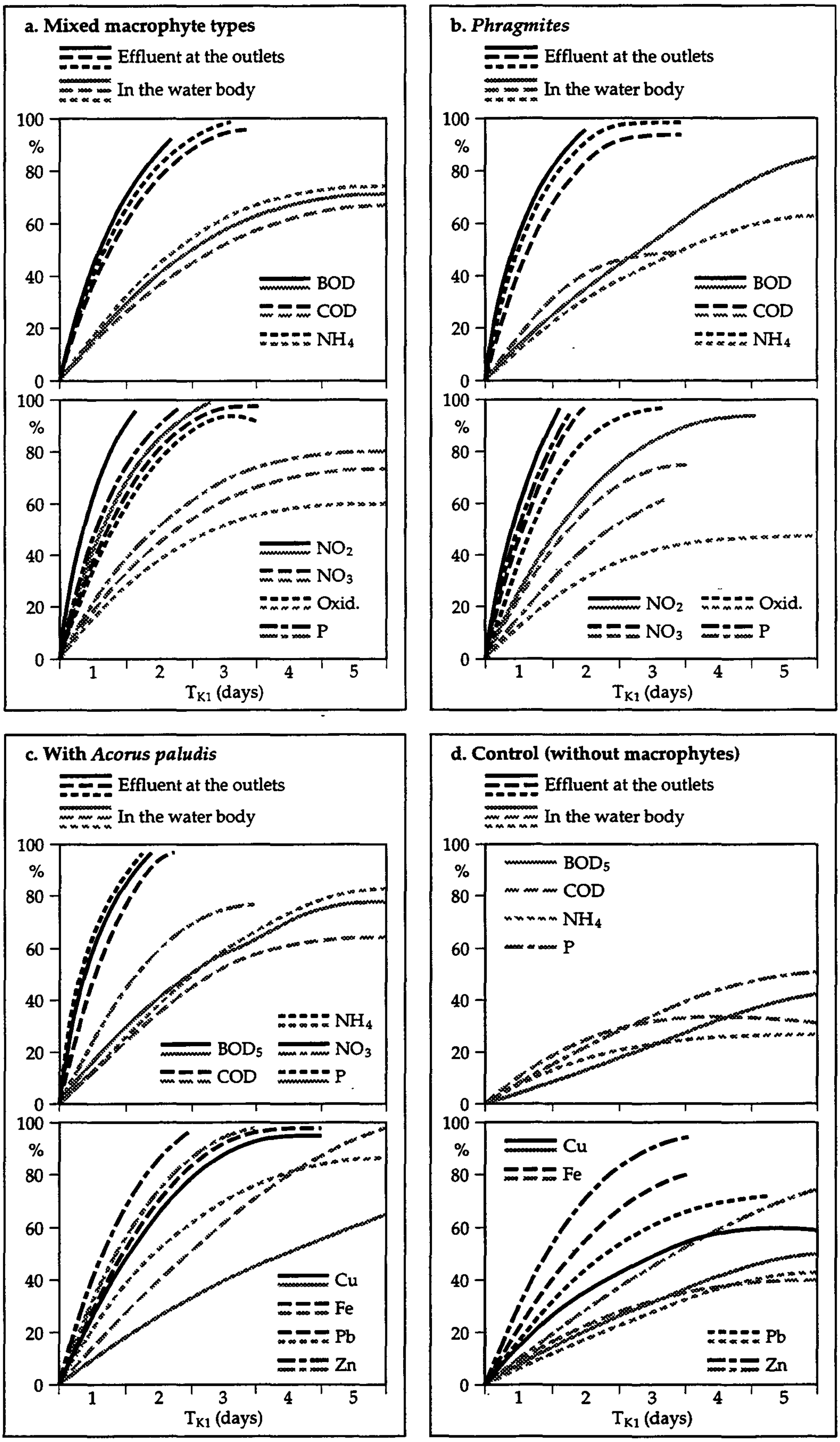


Figure 4. Dynamics of infiltration rate and growth of macrophytes

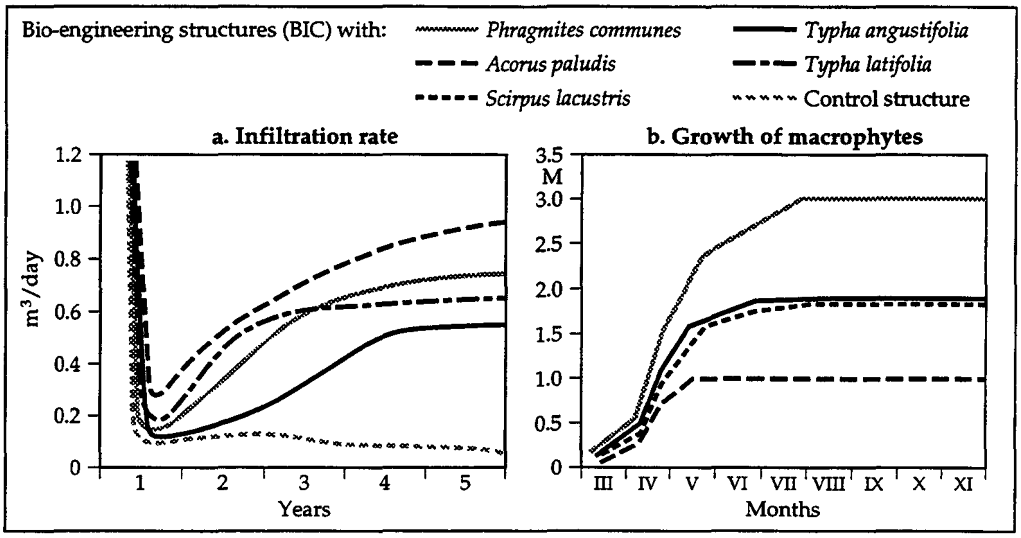
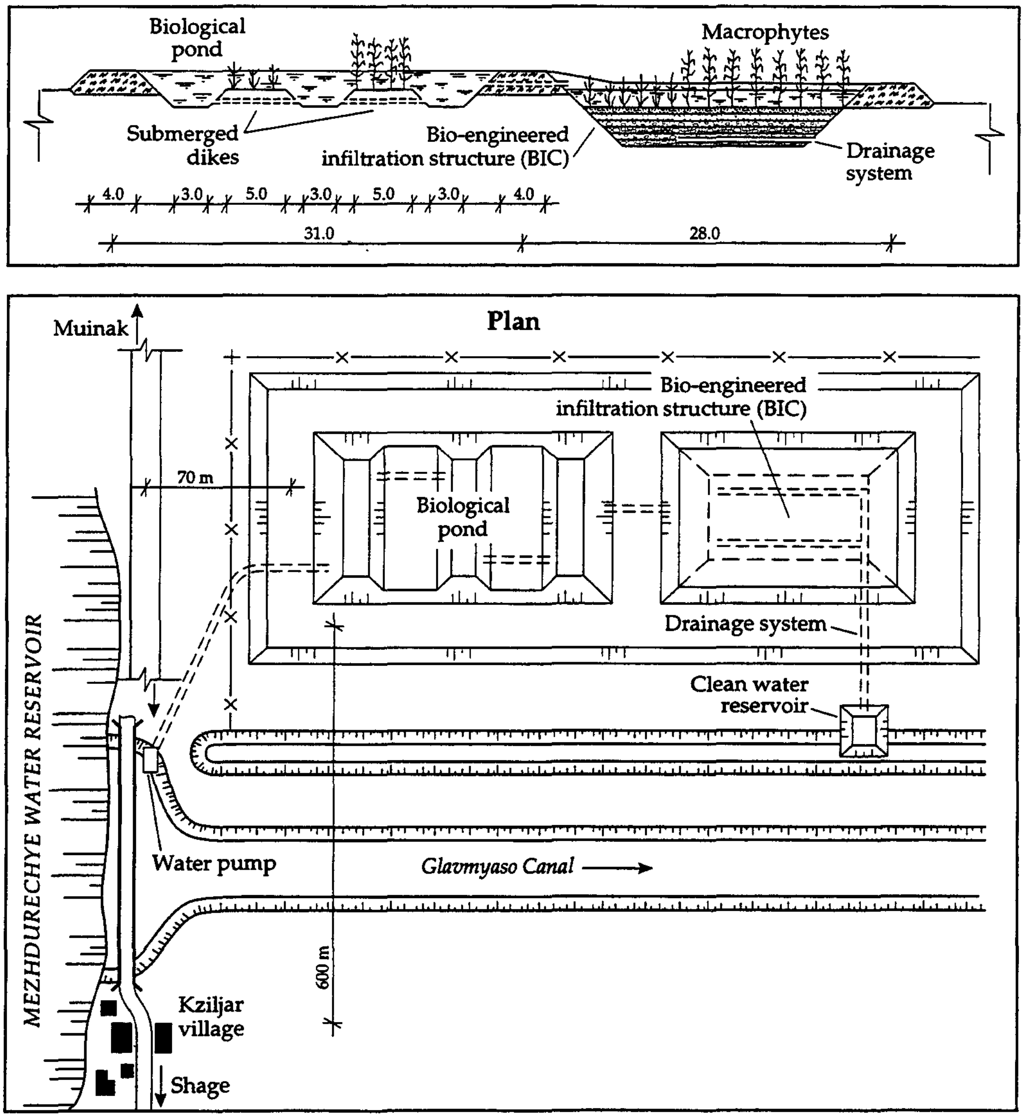


Figure 5. Schematic plan of bio-engineering structures (implemented in Kziljar village)



COMBINED HYDROPONIC AND DRIP IRRIGATION ON SALINE AND SANDY SOILS OF THE LOWER REACHES OF THE AMU-DAR'YA

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Introduction

Conventional furrow irrigation of saline soils in Karakalpakistan cause major losses of water because of the absence of lined canals and effective artificial and natural drainage, causing considerable run-off water at the end of the furrows. The consequences of this situation are a rising groundwater table and increasing soil salinization. The yields of crops on sandy and heavily saline land decreased 2-3 times.

The transition to a market economy in Uzbekistan accentuates the need for effective use of water resources, agrochemicals, labour and energy resources in agriculture. Modern, efficient technology must be adopted, in order to improve soil fertility and increase the intensity and productivity of agriculture.

The Ecology and Water Management Centre in Tashkent has built pilot plots and tested modern technologies of combined hydroponic irrigation for vegetables and drip irrigation for orchards and vineyards, in the natural and climatic conditions of Karakalpakistan.

Combined hydroponic irrigation in open air

Hydroponic technology in greenhouses has been widely used in many countries (e.g. Netherlands, Denmark, USA, Israel, Czech Republic, etc), and vegetable yields of 30-50 kg/m^2 have been attained [9]. In Karakalpakistan and the Horezm region, greenhouse productivity is much lower, only 4-9 kg/m^2 and 1-2 kg/m^2, because of the absence of scientific agrotechnics.

The main components of hydroponic systems are concrete and polymer flumes hydraulically connected to the mixing tank (reservoir), and to the installation for preparing mineral and nutrient ingredients for plant cultivation, pump, supply and distribution pipes. Plants are usually grown on special substrate filled into the flumes [6,8,9]. The type and quality of substrate influences the yield of crops, which have different root systems, evapotranspiration being also influenced by the rate of irrigation and the water holding capacity of the substrate. A most important task is to determine the optimal regime of irrigation and nutrient supply, in function of the local climate (temperature, moisture, wind), stage of plant growth, its variety and types, and must be adjusted during the vegetation season. There are many recommendations as regards the content and volume of nutrients (fertilizers and micro-elements) and the scientists must, according to their knowledge and experience, elaborate the optimal water and nutrient regime for the local soil and climate. Next, automation and mechanization of hydroponic technology needs to be promoted.

The Ecology and Water Management Centre has set up an experimental pilot station of open-air hydroponic irrigation, on one hectare of sandy soil - the first of its kind in Central Asia.

The pilot plant was set up not far from the city of Nukus, on the sandy soil of the

Kyzylkum desert, on the land of a military unit. Surface irrigation of such soils failed because of the high infiltration rate, rise of saline groundwater, water-logging, increasing soil salinity, which all damage the crops.

The objective of the project is to prevent infiltration losses and impact on the groundwater, introducing new technologies which would guarantee two yields of vegetable/melon crops on sandy soils. The layout of the hydroponic irrigation system is shown in Fig.1.

The head installation comprises:

- a filter to eliminate suspended particles and toxic substances from the irrigation water;
- an operating system for discharge and pressure control.

The distribution pipe network comprises the main water supply conduit with valves and measuring devices, and polymer wavy tubes 63 mm diameter, made of high pressure polyethylene. These are very robust and have low inside roughness.

The main conduit is joined by three 100 m long distribution pipes, and these by 25 m long irrigation tubes, at spacings 0.5-1.0 m perforated by holes (diameter 0.3-0.8 mm) placed at 120 degrees with respect to the tube axis. Each tube irrigates two furrows (flumes), which are 40 cm deep and lined by polymer film coats. The furrows are filled with a mixture of humus, sandy soil and sawdust. The humus contains 20-30% of organic matter, of which: total nitrogen: - 0.45-0.80%; P_2O_3: - 0.19-0.25%; K: - 0.48-0.63%; lime: - 0.18-0.45%; MgO: - 0.09-0.18%; SO_2: - 0.06-0.15% and some other micro-elements. The discharge of the irrigation tubes was 250 litres per hour. 14 different types of crops were tested. Evaporation from the surface of the furrows was reduced by polymer films. The optimal soil moisture was maintained in the range of 80-90% of soil saturation.

The discharge was measured by water metres, mineralization – by electro-conductivity. Water quality was determined by ion-selective recorders: pH, oxygen, temperature, NPK (nitrogen, phosphorus, potassium) content, etc. During the vegetation season, complete chemical analysis was performed 3-4 times for irrigation water, including micro-elements, and 4-5 times for soils. The moisture content through the depth of the furrows was measured every day. Phenological observations of the plants were carried out every 10 days and zootechnical analyses 2-3 times. Foliage moisture analysis was made for the determination of irrigation time. Samples and analyses were repeated three times and processed statistically.

On the experimental open-air hydroponic plot, the adaptability to the proposed technology was tested on 14 crops, which included: cucumber, tomato, water-melon, beans, sweet pepper, cotton (Chimbal variety), fennel, potato, sunflower, carrots, onion, etc.

Irrigation water was supplied to the plants through holes perforated at spacing 0.5-1.0 m, with a capacity of 6 litres per hour.

The discharge of distribution tubes is defined as:

$$Q_{d.tb} = L_{d.tb} * n_h * q_h$$

where: $L_{d.tb}$ - length of distribution tube, m

n_h - number of holes per metre

q_h - discharge per hole, l/sec

The discharge of the main tube is:

$$Q_{mt} = Q_{d.tb} * n_{d.tb}$$

With regard to head losses, the efficiency of the irrigation system is defined by:

$$\eta = \eta_n \times \eta_{itb} \times \eta_{d.tb} \times \eta_{m.tb} = 0.90 - 0.96$$

where: η_n - hole efficiency

$\eta_{i.tb}$ - irrigation tube efficiency

$\eta_{d.tb}$ - distribution tube efficency

$\eta_{m.tb}$ - main tube efficiency

The cross-section of the distribution conduit was calculated for pressure 1.4-2.0 m, and flow velocities 0.15-0.8 m/sec. The criterion to start irrigation was that soil moisture saturation must not drop below 75%.

The combined hydroponic system demands a water supply once each day, or once in several days (2-3). The total irrigation demand in 1993 was 5,600 m^3 per hectare, which is 1.3-1.5 times less than in traditional surface irrigation.

Evapo-transpiration of plants in hydroponic conditions is higher than in surface irrigation, but the plants use water more efficiently, resulting in higher productivity. For instance, the yield of tomato in hydroponic conditions was 3.75 kg/m^2, as compared to 1.75 kg/m^2 in soil (furrow) irrigation. Table 1 illustrates the water regime and transpiration intensity of tomato, in hydroponic and soil irrigation, for each hour of the day.

An optimal irrigation and nutrient supply of plants increases the efficiency of using solar energy (PRA - photosynthetic radiation activity). While PRA did not exceed 0.5-1.0% in traditional conditions, it reached 3-5% in hydroponic conditions [9]. Traditional furrow irrigation does not provide the proper ratio between water-air-solid substances - 25:25:50. Therefore, the plant continuously suffers either from over-irrigation or water shortage. The hydroponic system ensures favourable air conditions, especially in the root zone: the oxygen content of about 7-12% enhances the possibility of the plant to use mineral components from the soil. High water table and its mineralization results in the appearance of toxic, non-soluble forms of nutrients (Table 2).

The quantity and composition of nutrient changed during the vegetation season, in function of the development stage of the plants and their needs for different elements. For example, the total quantity of NPK is recommended in the range of: nitrogen: 12-40%; phosphorus: 14-44%; potassium: 30-65%. Each crop has its proper requirements. For instance, Fig. 2 shows the nutrient need of the tomato.

Cucumber has increased needs in phosphorus during blooming (76%), then it decreases, but still stays high (67-70%). Tomato increases potassium intake from seedling to fruit ripening time. The nitrate and ammonium intake of tomato decreases towards flowering and increases towards yield time. Surplus of chemicals causes their accumulation in the plant tissue. For example, the content of nitrates may increase up to 2500 mg/kg, which hinders the development of high yields. Deficit of some elements is also harmful to plants. For instance, magnesium and calcium must be in the proper proportion. Deficit of magnesium leads to calcium surplus and causes a disease called "chloroses". The change of pH also drastically changes the migration and mobility of some elements. Table 3 shows the demand of cucumber for chemical elements, after chemical analysis of its foliage.

Acid reaction increases the mobility of aluminium, magnesium and iron in the soil, hence their presence in the nutrient. Increase of pH, on the other hand, causes the change of phosphorus valences from one to two and three.

Comparison of tomato biomass formation (Fig. 3) shows that in hydroponic cultivation, the biomass of tomato is 1.5 to 2.0 times higher than in soil conditions.

The content of substrate influences the yield of different crops by 20-50%. In the first experiments, local substrate composed of humus, sand and sawdust was used as the installation for fertilizer and micro-element mixing was not yet in operation. The physical characteristics of substrate are given in Table 4 [6,8].

The yield of different crops was (in 100 kg per hectare): cucumber 8.6-13.6; tomato 27-37.5; water melon 19-26.5; sweet pepper 6.8-7.4; cotton 2.1-2.3; carrots 22-25; potato 16-25. Figs. 5-9 show some of these cultures. The tests have shown that hydroponic cultivation is cost effective for cucumber, tomato, water melon, beans, sweet pepper, carrots, green crops, etc; however, it is not cost effective for sunflower and melon.

By the described technology, low productivity land - such as sandy, heavily saline soils, with high groundwater table - (0.5-1.5 m below the ground) could be used efficiently, with two yields in a vegetation season. The technology makes several soil cultivation operations unnecessary and thus reduces labour 5 to 10 times. It is ecologically safe, there is no salt leaching. The vegetation season is shortened by 15 to 20 days. Capital investment is 3-4 times lower than for green-houses. Water conservation reached 30-50%. The return time of capital investments is 1.3-3.0 years. The market system stimulates private landowners who are interested in high yields in Karakalpakstan, where an increased tendency for soil salinity is noted.

Drip irrigation of orchards and vineyards using mildly saline water

The importance of micro-irrigation is increasing now, because of the deficit of water resources, rising groundwater table and soil salinization [11]. Drip irrigation in Uzbekistan is implemented on an area of 4,000 hectares, which is less than 0.1% of the irrigated land [4]. It should be noted, that in some other countries (e.g. Israel, Jordan, Cyprus), drip irrigation is applied on a large scale, 50-80% of the irrigated land [7]. There is no real experience in using drip irrigation in the Aral Sea region, particularly in the specific natural, climatic, soil and water conditions in Karakalpakstan. At present, decrease of the groundwater table is observed, due to the falling level of the Aral Sea, accompanied by leaching of salt from the sandy soils, spreading of desertification, impacts of wind and precipitation in the lower Amu-Dar'ya basin.

Conventional methods of surface irrigation cause secondary salinization, due to the rising level of the highly saline groundwater. However, foreign technology cannot be implemented immediately, without adapting it to local conditions, crop varieties, etc. Irrigation regimes must be worked out, salt and water balance determined for the irrigated fields, and so on. A specific problem of this region is the removal of salt from the soil by the bio-mass of salt tolerant crops [1,2,3]. These should be cultivated along the edge of the underground moisture contour [5], where the salt was shifted by irrigation with saline water. At the same time, the halophyte crops reduce evaporation from the soil surface, because of the mulching effect of plants between the main crop lines.

The main objective of this investigation was to prove the feasibility of drip irrigation for orchards, vineyards, wind-breaking forests and other crops in the Muinak region, situated within the Aral Sea disaster zone.

The pilot station is situated at the state farm "Muinak". The prevailing soil stratum is sandy loam with a mixture of sand and loam. The salt content is 0.3-0.4%, mainly soluble chlorides, sulfates up to 0.4-0.8 g/l and low content of humus: 0.14-0.68%. Biogeneous elements exist in the soil: NO_3 50-87 mg/kg; K_2O 48-72 mg/kg and only traces of phosphorus. The water and physical characteristics of the soils are shown on Table 5.

The layout of the drip irrigation system is shown on Fig. 4. It consists of the head installation and the water supply net.

The head installation includes a silting basin (10x10x3 m³), a pump with measuring devices, filters for removing fine sediment particles, pressure gauges and valves.

The irrigation network consists of the main supply line of wavy polymer tubes of 12 m length and 120 mm diameter, distribution net 150 m long, 63 mm diameter. The trickling line of "Agrodrip" type (German made) has a total length of 2,300 metres (23 tubes of 100 m each), 20 mm diameter. The trickling lines consist of an outer tube of 20 mm diameter and an inner tube of 16 mm, with a spiral water pressure dissipator in the space between these tubes, and drip outlets at spacing 90 cm.

The discharge of outlets depends on the number of drippers per meter (2.03-8.10 litre per hour per 1 metre tube length). Permissible silt content in the water: maximum particle diameter 0.15 mm, maximum concentration 50 mg/l; permissible hydrobionta - 5 mg/l. The tubes are from time to time flushed for silt deposition, under 2.5 atm pressure. Optimum operational pressure in the system is 1-1.5 atm. The moistening takes place in the strips of plant rows. The area of the plot was one hectare.

On one half of the plot, 665 bushes of vineyard were planted (3.0x2.0 m per bush), and 120 apricot trees (6.0x6.0 m per tree) on the other half.

The space between the bushes and trees was occupied by salt tolerant cultures for mulching, to reduce evaporation from the soil, and as a biological method to remove salt from the soil. The cultures were sorghum, sugar beet, *Glycyrrhiza glabra* L. (a Mexican crop), and others. They were irrigated also from the polymer tubes.

The pressure losses are calculated according to the formula:

$$h=k^* h_{tb}^*L \text{ MPa}$$

where: k - correction coefficient, the value of which varies from 0.96 to 1.05, for irrigation water temperature changing from 5 to 45 centigrade;

h_{tb} - pressure loss per 100 metre tube length, depending upon the discharge at the beginning of the tube.

The irrigation rate was determined in function of the meteorological parameters measured at the pilot station: wind action, temperature, air humidity, soil moisture. Chemical and physical properties of the soil were also studied: soil texture, infiltration rate, water holding capacity. Further measurements comprised: drippers discharge, wetting zone, water turbidity. Agrotechnical measurements were also taken, including phenomenological observation of the plants.

By drip irrigation, water is provided only to the root zone, which occupies 10-33% of the planting area, depending upon the type of culture and the seedling patterns. The moisture dynamics has the following stages: infiltration, moisture spreading, evapotranspiration.

The measured moisture contours in the root zone of vineyards, after supplying 24 litres of irrigation water, are shown in Fig. 5. The parameters of moisture distribution are given in Table 6.

The root zone of vineyards and orchards reaches a depth of 120 cm, with a diameter of 160 cm. The spacing of drippers – 90 cm – enables the covering of the wetting zone and avoiding critical wilting points, as 70% of saturation is maintained around the border of the moisture zone [5].

The irrigation rate for one plant was determined by the formula:

$$M_o = 0.67 * \gamma * (d^2/4) * h * (B_m - B_i) \text{ m}^3 \text{ per plant}$$

where: γ - specific weight of soil, t/m³; d - diameter of moisture distribution, m; h - depth of moisture distribution, m; B_m - maximum soil saturation, in percentage of dry soil weight; B_i - natural soil moisture, in percentage of dry soil weight.

The irrigation rate is then the sum of specific discharges for each plant:

$$m = M_o * n \text{ m}^3/\text{ha}$$

where n is the number of trees per hectare.

The duration of irrigation is determined after the formula:

$$t_n = 1000m/n_i * q \text{ hours}$$

where: n_i - number of dripper outlets per hectare;

q - discharge per dripper, litres per hour.

The duration of irrigation for sandy loam and light loam soils was 2-3 hours. The time lag between subsequent irrigations varies between 1-2 days and 3-10 days. The discharge for each tree or vineyard is 5 to 7 litres per hour.

The cumulative water volumes applied for vineyard irrigation are shown on Fig. 6. The total volume applied was 1,440 m^3/ha, with irrigation rates of 60 m^3/ha for each application, without considering the water volumes used for salt leaching.

The corresponding water volume for conventional furrow irrigation would be 3,500 m^3 per hectare, with irrigation rates of 500-700 m^3/ha per application.

At the same time, the planned mineral fertilizers were supplied with the irrigation water, including nitrates - 280 kg/ha, phosphates - 160 kg/ha, potassium - 60 kg/ha. More intensive growth of plants was observed on trees under drip irrigation, with the leaf area greater by 30% than with traditional furrow irrigation.

Water saving amounted to 40-42.2% for vineyards and 32.7-40.7% for apricot orchards.

Although in 1994 the mineralization of irrigation water fluctuated between 0.8 and 1.7 g/l, no salt accumulation in the soil was noted, thanks to the action of the added halophylic crops. The yield of sorghum was 1,100 kg/ha, and *Glycyrrhiza glabra* L. also grew successfully.

Conclusions

For the first time in Central Asia, in the natural climatic and soil conditions of

Karakalpakstan, micro-irrigation technologies: combined hydroponic irrigation in open air, and drip irrigation, were investigated on pilot plots.

The efficiency and short term (2-3 year) capital return were proved for open air hydroponic irrigation on low quality soil, including heavily saline and highly permeable sandy soils. The proposed technology makes it possible to obtain in a season two yields of vegetables, such as tomato, cucumber, potato, beans, carrots, and others. The yield of these crops is 2-3 times higher than by conventional surface irrigation. At the same time, hydroponic irrigation prevents the rising of ground water, soil salinization, saves water and reduces labour. This technology could well be used to grow expensive medical plants.

The efficiency of drip irrigation was tested on the pilot plot, with vineyards and orchards and other crops. The problem of using mildly saline water was solved by removing the extra salt from the soil by the biomass of salt tolerant cultures. In the areas where groundwater levels are sinking owing to the falling Sea levels, and the consequent leaching of salt from the sandy soils by precipitation, conditions are becoming favourable for large-scale implementation of drip irrigation.

The two technologies described in the paper could contribute substantially to increased agricultural production, and thus to the alleviation of the social and ecological crisis in the Aral Sea region.

References

1. Aliev, R.I. (1993): Drip irrigation of orchards by saline water on sandy soils in the arid zone, using biological methods of soil desalination, Moscow (in Russian).
2. Grammatikagi O.G., Aliev R.I. (1991): Application of halophytes as biological drainage in case of drip irrigation of orchards with saline water, on sandy soil VNIIG, Moscow, pp 183-186 (in Russian).
3. Novikova A.V. et al (1986): Drip irrigation on berkhan sands, Selskoe hozyaystvo Uzbekistana, No. 7, Tashkent (in Russian).
4. Drip irrigation transactions (1995) SANIIRI, Tashkent (in Russian).
5. Risse L.M., Cheswiss J.L. (1989): Simplified Design Procedure to determine the Wetted Radius for a Trickle Emitter, ASAE, Vol. 32 (6), Nov.
6. Bukuras N. (1989): Growth of fruits in green houses, Tashkent, p. 136 (in Russian).
7. Drip irrigation in the U.S.A., Australia and Israel (1971), Express information on irrigation systems abroad, No. 2, Moscow (in Russian).
8. Hydroponics in agriculture (editor Alpatieva A.V.) (1965), Moscow, p. 310 (in Russian),
9. Industrial Hydroponics 1988, Erevan, p. 162 (in Russian).
10. Rzakov R. M. (1991): Exploitation and conservation of water resources in Central Asia, Tashkent, p. 166 (in Russian).
11. Razakov R.M. and Rahmatov R.T. (1991): Reclamation of sandy soils by using saline water for irrigation, Tashkent (in Russian).
12. Rahmonov et al. (1996): The implementation of biologically active fields for biological cleaning of polluted sewage and river waters, BMBF/UNESCO Project.

Table 1. Water regime and transpiration intensity of tomato in hydroponic and soil irrigation

Parameters	10 a.m.	01 p.m.	04 p.m.	07 p.m.	10 p.m.	01 a.m.	04 a.m.	07 a.m.
1.	85.9	83.4	82.7	83.5	84.0	83.7	84.3	84.8
	85.4	*80.0*	*79.0*	*78.0*	*77.5*	*76.0*	*75.5*	*77.5*
2.	250	300	288	230	110	100	114	150
	232	*270*	*204*	*132*	*50*	*40*	*50*	*70*
3.	54.0	48.5	46.6	50.0	60.0	70.0	73.0	70.0
4.	25.5	31.1	33.0	27.0	21.0	17.5	17.0	15.5
5.	22.5	28.0	29.5	30.0	26.0	23.0	20.0	19.0
	21.0	*26.0*	*27.6*	*28.0*	*26.0*	*22.0*	*19.0*	*18.0*

(upper row: hydroponic conditions
lower row: soil conditions)

Note: 1. Total water content in % of wet weight
2. Transpiration intensity g/m^2 per hour
3. Relative air humidity, %
4. Air temperature, °C
5. Substrate temperature, °C

Table 2. Chemical forms of elements in function of soil aeration

No	Chemical element	Normal form (Aerobic conditions)	Anaerobic conditions caused by over-irrigation
1	Carbon	CO_2	CH_4
2	Nitrogen	NO_3	NH_2 and NH_3
3	Sulphur	SO_4	H_2S
4	Iron	Fe***	Fe**
5	Manganese	Mn***	MN**

** - bivalent compound
*** - trivalent compound

Table 3. Presence of chemical elements in cucumber leaves for pH = 5.5-6.5

Part of leaves	Elements (in g/kg of wet plant)							
	NO_3	P	K	Mg	Ca	S	Cl	Mn
Upper	0.4 - 0.2	0.36 - 0.25	4.5 - 3.0	1.2 - 0.6	4.0 - 2.0	0.6 - 0.4	1.2	0.03
Stem	1.2 - 0.1	0.24 - 0.16	5.0 - 3.5	0.24 - 0.16	1.2 - 0.4	0.08 - 0.04	1.8	traces

Table 4. Physical characteristics of substrate types

No	Substrate type	Specific weight g/cm^3	Density g/cm^3	Porosity %	Moisture %
1	Peat	0.64	2.15	71.5	40
2	Keramzite (5-10 mm)	0.46	2.52	81.5	69
3	Sand	1.85	2.56	28.0	13
4	Vermiculite	0.41	1.55	74.9	81
5	Sand-sawdust-humus	1.21	2.31	52.2	35

Table 5. Soil characteristics at the pilot station

Samples from horizons cm	Specific weight g/cm³	Density g/cm³	Soil saturation %	Maximum soil saturation	Permeability mm/min	Porosity %	Mechanical content
0 - 25	1.30	2.40	17.0	21.7	0.08	46	Sandy
25 - 50	1.35	2.51	20.6	25.0	0.05	43	Light loam
50 - 100	1.35	2.55	20.6	25.7	0.05	43	
100 - 150	1.35	2.60	20.7	25.2	0.05	43	

Table 6. Parameters of moisture distribution

Soil saturation %	110	100	90	80	70
Depth cm	30	60	80	105	135
Width (diameter) cm	30	40	90	125	160

Figure 1. Combined hydroponic open-air irrigation system

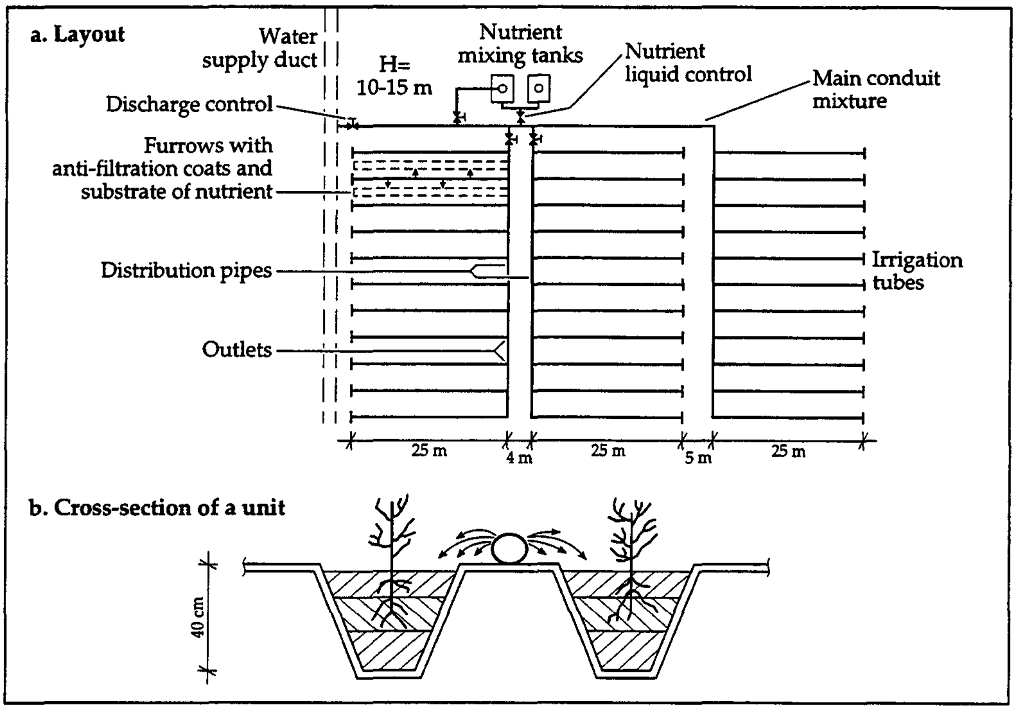


Figure 2. Nutrient feeding to tomato, in function of development stages

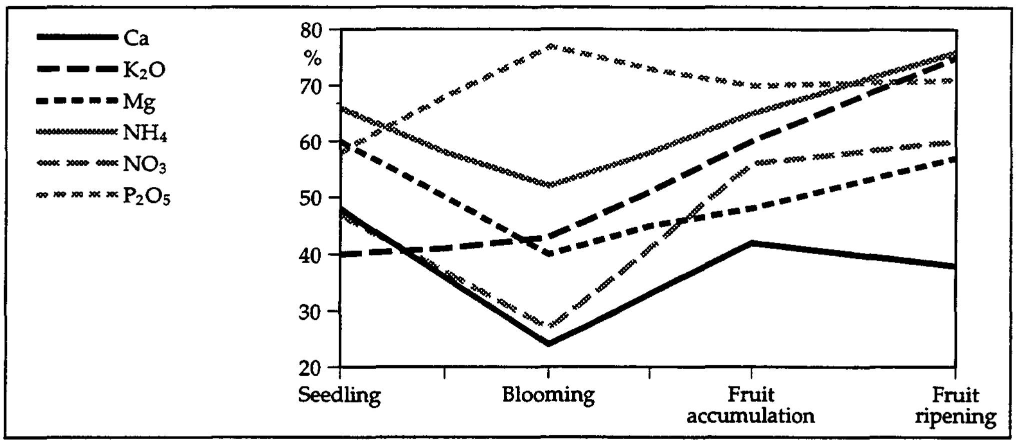


Figure 3. Comparison of tomato biomass formation

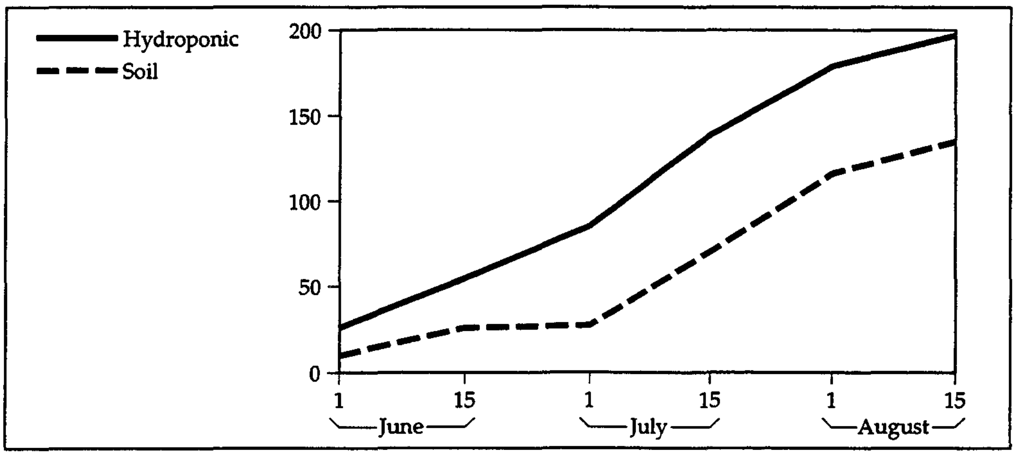


Figure 4. Layout of head installation unit and drip irrigation net

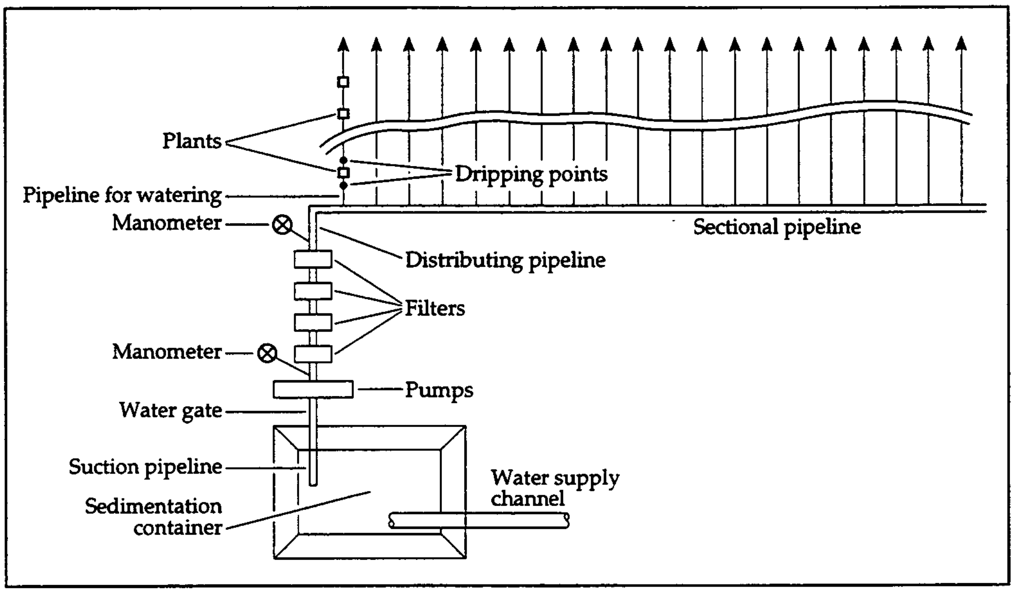


Figure 5. Soil moisture contours in irrigated strip (% of saturation)

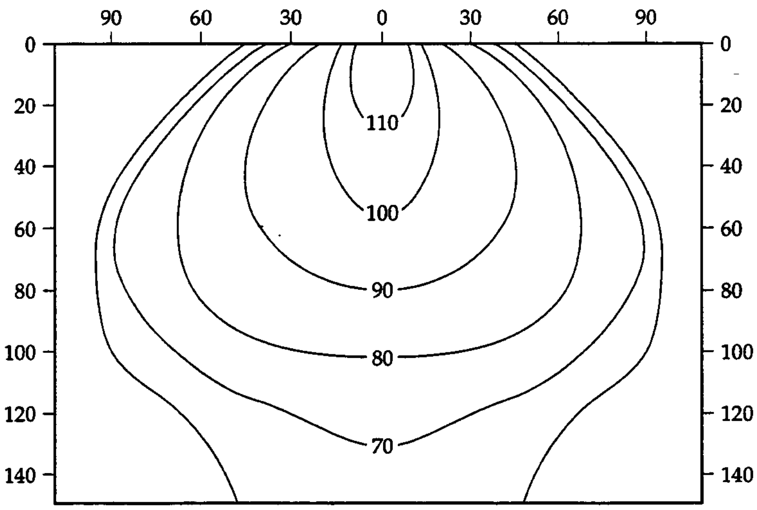
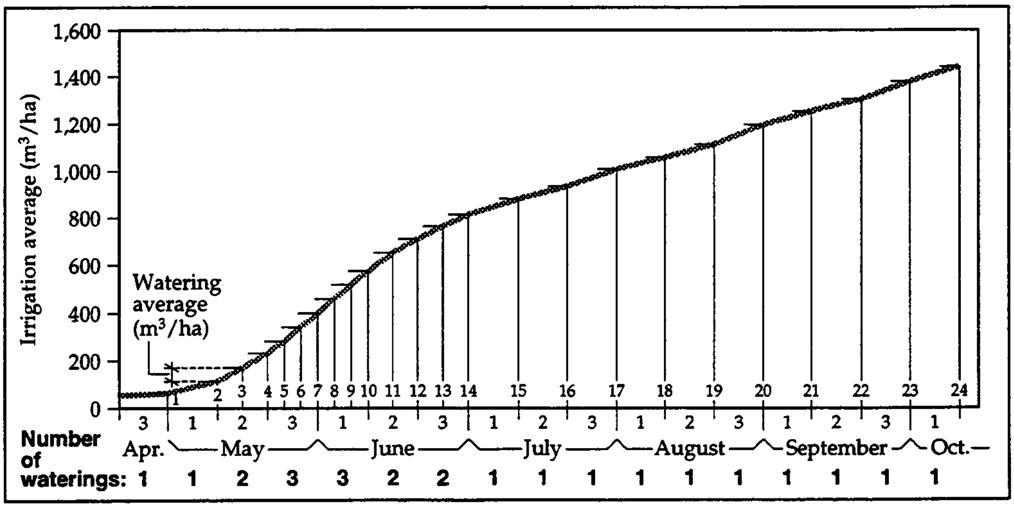


Figure 6. Cumulative water demand deficit of vineyard covered by drip irrigation



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