HYDROBIOLOGY OF THE ARAL SEA

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The ecological crisis of the Aral Sea has been widely discussed during recent years in both the scientific and popular literature. However, only the consequences of anthropogenic desiccation and increased salinitywere usually discussed with little note of the role played by introduced species in this ecosystem (Micklin, 1991; Williams, Aladin, 1991; Keyser, Aladin, 1991). Here, we review the role of introduced species during periods of varying salinity.

The Aral Sea is a giant (66000 km^2 in 1960) continental closed lake. This relatively young water body appeared in the early Holocene as a terminal reservoir of Syrdarya river (Fig. 1A). During the Pleistocene glacial epoch the Aral basin contained only small hypersaline ponds and marshes. After the Aral depression filled with water in the early Holocene, flora and fauna of Aral Lake derived from freshwater inputs of the Syrdarya river and then later of Amudarya river. The Amudarya had previously flowed into the Caspian Sea (Fig. 1A). Inhabitants of water bodies in the Aral depression during transgressions of the ancient Caspian Sea, when Aral was a gulf of Akchagyl or Apsheron seas (Fig. 2), completely died out when regression followed transgressions of the Caspian waters. At the beginning of Holocene, the Aral Sea aquatic fauna was of mainly freshwater origin with new invaders from the Caspian Sea and other saline water bodies of Central Asia appearing only later.

Most ancient invaders from the Caspian Sea arrived at the Aral Sea via Uzboy about 5000 B.P., when run-off from the ancient Amudarya and Syrdarya rivers had filled the Great Aral. The Great Aral was a giant lake joining the depressions of Aral and Sarykamysh lakes, and its level was over +58-60 m asl (Fig. 1A). At this stage, water from the Great Aral drains to the Caspian Sea in the southwest from Sarykamysh depression (Fig. 1A). Ancestors of recent Aral thorn sturgeon, other relatives of Caspian fishes, and possibly some other Caspian hydrobionts were able to overcome the current in Uzboy and colonize the Aral Sea.

At the beginning of the 1960's anthropogenic desiccation of the Aral Sea begun. At that time the lake was inhabited by dozens of fish species and more free-living invertebrates (Table 1). Note that some of these species were recently introduced by humans into the lake ecosystem.

The fist introductions of exotic species into the Aral Sea occurred at the end of the 1920's, when *Alosa caspia* (Caspian shad) и *Acipenser stellatus* (starred sturgeon) were introduced from the Caspian Sea. This introduction cannot be considered as successful because these fishes did not naturalize in Aral Karpevich, 1975). Furthermore parasites of starred sturgeon roe (*Polypodium hydriforme*) and gills (*Nitzschia sturionis*) passed onto aboriginal thorn sturgeon and caused strong epizooties. Thorn sturgeon before introduction of starred sturgeon did not suffer from these parasites because they were absent from the Aral Sea (Dogel, Byhowsky, 1934; Dogel, Lutta, 1937). Thus, the first attempt of exotic species introduction to the Aral Sea can be considered extremely unsuccessful.

After the Second World War attempts to settle exotic species in the Aral Sea continued. The main basis of these actions was the idea that because there were few plankton-eating fishes and sturgeons in the Aral Sea, introduction of new consumers of plankton and benthos would increase fish productivity (Karpevich, 1947, 1948, 1953, 1960, 1975). On the basis of these considerations, from the Caspian Sea again starred sturgeon (*Acipenser stellatus*) was again introduced in 1948-1963, and in 1958 a subspecies of thorn sturgeon (*A. nudiventris derjavini)* from Ural river was introduced. These sturgeon introductions were again unsuccessful. Both species failed to persist and only in 1958 were some individuals of starred sturgeon caught (Karpevich, 1975).

In the same years (1954-1956) mullets (*Mugil auratus*, *M. salensis*) were introduced from the Caspian. This attempt was also unsuccessful (Karpevich, 1975) probably because these planktophages new for the ecosystem could not find sufficient amount of convenient food to survive.

More successful was the introduction (1954-1959) and acclimatization of Baltic herring (*Clupea harengus membras*). This exotic planktophage from the Baltic Sea became naturalized in the Aral Sea, and caused significant changes in the zooplankton community. Beginning in 1957 Baltic herring appeared in large number in catches. The pressure on zooplankton increased sharply and the average summer biomass of zooplankton decreased more than 10 times – from 160 mg/m^3 to 10-15 mg/m^3 (Karpevich, 1975; Yablonskaya, Lukonina, 1962; Kortunova, 1975). Introduced plankton-eating fishes led to the extermination of such large organisms of zooplankton as *Arctodiaptomus salinus* and *Moina mongolica*. Decreased zooplankton abundance and biomass instantly affected the number of herring and their number decreased also (Kortunova, Lukonina, 1970).

During the aforesaid planned introductions, many fish and invertebrate species were introduced accidentally. Among them were many non-commercial fishes. For example, six species of gobies, three of them – bubyr (*Pomatoschistus caucasicus*), monkey goby (*Neogobius fluviatilis pallasi*) and round goby (*N. melanostomus officinus*) naturalized successfully. Also, the successful introduction of silverside (*Atherina mochon pontica*) and pipefish (*Syngnathus nigrolineatus*) quickly invaded the whole Aral Sea. During planned acclimatization of plankton-eating fishes in the Aral Sea, two shrimp species (*Palaemon elegans* and *P. adspersus*) were accidentally introduced and (*P. elegans*) acclimatized successfully (Karpevich, 1975). This established shrimp became a concurrent of aboriginal amphipod *Dikerogammarus aralensis* and gradually forced out it from the benthic associations (Andreeva, 1989; Aladin, Potts, 1992). So, even before anthropogenic desiccation and increase salinity the Aral Sea ecosystem had undergone significant changes due to planned and accidental introductions of exotic species.

At the same time (1958-1960), besides introductions into the Aral Sea proper, a complex of fishes and invertebrates introductions were carried out into deltaic areas of Syrdarya and Amudarya. From river Don, were introduced four mysid species (*Paramysis baeri, P. lacustris, P. intermedia, P. ullskyi*), two of them (*P. lacustris, P. intermedia*) became numerous in 1961, one species (*P. baeri*) did not acclimatize, and the third (*P. ullskyi*) has naturalized but remained uncommon (Karpevich, 1975). Also, introduced were three species of freshwater fishes from China: grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophtalmichthys molitrix*) and *Aristichtys nobilis* along with incidental introductions into the deltaic areas of three other species of this complex: black carp (*Mylopharyngodon piceus*) and snakehead (*Ophiocephalus argus*). Except for *A. nobilis*, all these species naturalized successfully and became of commercial value (Karpevich, 1975). These naturalized Chinese fishes and mysids, which invaded estuaries of Amudarya and Syrdarya, migrated many kilometers from the deltas into the Aral Sea proper. When comparing consequences of introductions in deltaic areas with those in the Aral Sea proper one may note that the first were more successful and had fewer negative consequences than the second. However, even in the case of the deltas, there were no significant rises in catches of commercial fishes or increase food resources.

As seen above, by 1961 the Aral Sea, its deltaic areas and estuaries had been transformed due to planned and accidental introductions. On the eve of oncoming ecological catastrophe connected with diversions of riverine waters for extensive irrigation development, the Aral Sea had been subject to many exotic species introductions. While biodiversity had increased by fourteen species of fishes and four species of invertebrates, only a few of these species had commercial value or could serve as a food for fishes. Many species of fishes were introduced accidentally and only increased the pressure on the nutritional chain without giving benefits to the fisheries. Promised increase of commercial catches and raised nutritional value of invertebrate associations did not occur. At the same time, due to predation by introduced fishes or competition with introduced invertebrates, two aboriginal species of zooplankton (*Moina mongolica* и *Arctodiaptomus salinus*) and one species of zoobenthos (*Dikerogammarus aralensis*) disappeared completely. Thus the whole series of planned introductions into the Aral Sea and deltas between 1927 and 1961 must be considered unjustified and in some cases even harmful. The scientific-journalistic expedition “Aral-88” in 1988 conducted after “perestroika” also noted the negative consequences of planned and accidental introductions at the Aral Sea during the aforesaid period (Seliunin, 1989).

Since 1961 anthropogenic regression of the Aral Sea has continued unabated except for a single year in 1968, when water input was enormous (Fig. 3). Only in that year total amount of river run-off and precipitation exceeded evaporation from the surface (The Aral Sea, 1990). This rapid anthropogenic desiccation and salinization of the Aral Sea prompted efforts to introduce euryhaline species able to endure constantly increasing salinity.

At the beginning of 1960’s a polychaete, *Nereis diversicolor,* and a bivalve, *Abra ovata,* were introduced from the Sea of Azov. The first species became numerous since 1963 and the second since 1967. In the middle of 1960’s there was an unsuccessful attempt to introduce bivalve mollusk *Monodacna colorata* (Karpevich, 1975). In the middle and end of 1960’s and in the beginning 1970’s there were attempts to introduce planktonic invertebrates. Candidate for introduction included two euryhaline copepods – *Ca-*

lanipeda aquaedulcis and *Heterocope caspia*. The first species naturalized successfully and since 1970 is a dominant zooplankter of the Aral Sea (Kazakhbaev, 1974; Andreev, 1978) and substituted for the former dominant *Arctodiaptomus salinus*, exterminated by Baltic herring. The second exotic species did not naturalize. During these introductions of planktonic copepods, larvae (zoëa) of crab *Rhithropanopeus harrisii tridentata* were accidentally introduced into the Aral. Since 1976, this benthic crustacean is widespread in the southern water area of Aral Sea (Andreev, Andreeva, 1988), but due to certain causes (they will be considered below) is absent in the northern water area – in the so-called Small Aral.

Acclimatization of euryhaline planktonic and benthic invertebrates could be regarded as an example of well thought-out and successful introduction. These euryhaline species succeeded to save the feeding value of zooplankton and benthos under conditions of the Aral Sea anthropogenic salinization. A positive role of euryhaline acclimatizants is especially clear since the beginning and middle of 1970's when salinity of the Aral water exceeded 12-14 g/l and fresh and brackish water organisms of plankton and benthos began to die out. However, rising salinity negatively affected the ichthyofauna. The early stages of ontogenesis in freshwater fishes originally dominating in the Aral Sea were particularly vulnerable. Survival of larvae and fries of these fishes sharply began to decrease even at salinity increases of 1-2 g/l from 8-10 g/l. Nearly all freshwater fishes and invertebrates existed in the Aral Sea at the upper limit of their salinity tolerance range, and this explains why they have disappeared so quickly (Karpevich, 1975; Aladin, Kotov, 1989; Plotnikov et al., 1991). During only one decade, since the anthropogenic desiccation began, more than 50-70% of fishes and free-living invertebrates became extinct in the Aral Sea. Under these extreme conditions, when acclimatization of euryhaline invertebrates was successful, the idea of introducing euryhaline commercial fishes was suggested. At the end of 1970's plaice (*Platichthys flesus*) from the Sea of Azov were introduced. Since 1981 this exotic for the Aral Sea commercial fish is ubiquitous in catches (Lim, Markova, 1981). Of the 20 aboriginal fish species in the Aral Sea, only the euryhaline stickleback (*Pungitius platygaster aralensis*) remains. All other aboriginal fishes disappeared due to salinization and only some of them remain in deltas and deltaic water bodies of Amudarya and Syrdarya. Successful acclimatization of plaice allowed fisheries to continue on the Aral Sea. At the beginning of the1980's, besides stickleback and plaice, the accidentally introduced atherine and 2-3 species of gobies were also present. While the Baltic herring was also present, it was present in small numbers and did not formed large schools.

At the end of 1970's and in the beginning 1980's the last attempt to introduce sturgeons in the Aral Sea was undertaken. In this case Russian sturgeon (*Acipenser guldenstadti*) was introduced (Lim, Markova, 1981). But this attempt could not be successful because the salinity of the Aral Sea reached 18-20 g/l, which is very high for this species. Besides, natural anadromous migration for spawning was prevented because the deltas of Amudarya and Syrdarya had become very shallow.

In the middle of 1980's attempts to introduce euryhaline invertebrates into Aral Sea continued. One tried to introduce two species of bivalves (*Mytilus galloprovincialis* and *Mya arenaria*) from the Sea of Azov. Both introductions were unsuccessful. In the first case, it was because of the absence of solid bottom substrates essential for mussel attachment. The second species was released in shallows, which dried up within months due to continuous lake level lowering. If this quick desiccation of shallows had been taken into consideration, successful introduction of *Mya arenaria* may have been possible. In the same years was introduced planktonic copepod *Acartia clausi*, but it did not naturalized in the Aral Sea. Possibly due to insufficient number of released individuals but perhaps also because the ecological niche was already occupied by acclimatized *Calanipeda aquaedulcis*.

At the end of 1980's the history of planned and accidental introductions in the Aral Sea was ended (Table 2). Since then, only natural colonizations, unconnected with human activity, have occurred.

In 1989 continued desiccation of the Aral Sea led to its division into two lakes (Fig. 4), which have evolved in different ways. The Small Aral Sea, located in the North, receives run-off of the Syrdarya River and began to overfill due to positive water balance. The surface area of this lake is small, and evaporation from its surface is less than inflows from the Syrdarya, atmospheric precipitation and ground waters. As for the Large Aral Sea in the south, its water balance is negative, and evaporation from its huge surface is still higher than the small inputs of the Amudarya River, atmospheric precipitation and ground waters (Aladin, Plotnikov, Potts, 1995). These difference in the hydrological regimes of the two new lakes has led to stabilization of the Small Aral Sea level and continued desiccation and salilnization of the Large Aral Sea.

The salinity of the Aral Sea was about 28-30 g/l. at the moment it divided into two lakes at about +40 m asl (Aladin, Plotnikov, Potts, 1995; Aladin, 1995) and their fauna and flora were similar. But biological differences between this two water bodies appeared very quickly due to different hydrological regimes. In 1961 before anthropogenic desiccation and salinization the Aral Sea was a brackish lake with average salinity 8-10 g/l, and its level was about +53 m asl (Zenkevich, 1963). Its ecosystem was characterized by low biodiversity and biological productivity. With salinization and level fall biodiversity and productivity decreased and the ecosystem was transformed from brackish water into mesohaline where surviving aboriginal and introduced euryhaline and marine species of fishes and invertebrates predominated (Plotnikov et al., 1991). At the time dividing into two lakes, only 7 species of fish, 10 common zooplankton species, and 11 common benthos species were present.

The recent history of the Aral Sea can be viewed as including three critical periods (Plotnikov et al., 1991) followed by the current period in which two distinct lakes are evolving differently. As seen above, the first crisis in 1957-1960 was associated with planned and accidental introductions into the Aral Sea ecosystem. The second crisis period took place in 1971-1976 when salinity of Aral increased to above 12-14 g/l and brackish water species of fresh water origin disappeared. The third crisis was initiated in 1986 when salinity exceeded 23-25 g/l and lasted until the Aral Sea division in 1989. During this time brackish water species of Caspian origin became extinct (Plotnikov et al., 1991). The current period began with partition of the Aral Sea in which both parts inherited a common fauna. The zooplankton community consisted eleven species (Rotifera – 5, Cladocera – 1, Copepoda – 5). Rotifers included 5 euryhaline widespread species: *Synchaeta vorax*, *S. cecilia*, *Notholca acuminata*, *N. squamula* and *Brachionus plicatilis*. The single Cladoceran representative was the euryhaline species of caspian Onychopoda – *Podonevadne camptonyx* surviving at the limit of its salinity tolerance. The Copepoda were dominated by two euryhaline species: *Calanipeda aquaedulcis* and *Halicyclops rotundipes aralensis*, but also included three species from Harpacticoida. Besides these species, zooplankton also included larvae of benthic invertebrates and protozoans, mainly Tintinida. Thus, at partition the Aral Sea zooplankton included one recent invader (*Calanipeda aquaedulcis*), one ancient invader (*Podonevadne camptonyx*) and nine euryhaline species, some of which were widespread in the region while others could be considered as aboriginal. As one can see the portion of recent invaders in zooplankton was 9%.

Eight species (Bivalva – 2, Gastropoda – 2, Polychaeta – 1, Ostracoda – 1, Decapoda – 2) remained in the zoobenthos. Bivalves were represented by 2 species: the recently introduced *Abra ovata* and the ancient invader, *Cerastoderma isthmicum*. Gastropods were represented by two widely euryhaline species of genus *Caspiohydrobia*. Polychaetes were represented by the introduced euryhaline *Nereis diversicolor*. Ostracods included only one euryhaline species *Cyprideis torosa*. Decapoda were represented by two accidental invaders – shrimp *Palaemon elegans* and crab *Rhithropanopeus harrisii tridentata*. Besides these species, the zoobenthos included some Protozoan species. Thus at partition the Aral Sea zoobenthos included four recent invaders (*Abra ovata*, *Nereis diversicolor*, *Palaemon elegans* и *Rhithropanopeus harrisii tridentata*), one ancient invader (*Cerastoderma isthmicum*) and three euryhaline species (*Cyprideis torosa* and two species of *Caspiohydrobia*). Part of the last group is widespread in the region and could be considered as aboriginal. Thus, 50% of the zoobenthic species were recent invaders.

An exception to sharing of a common fauna between the two lakes is that since 1976, crabs became abundant in the Large Aral Sea following their accidental introduction. Because currents spread their larvae, settling of this crab was slow and followed the current patterns. As the Small Aral generally did not receive water from the Large Aral, the crab's larvae did not colonize the northern water area of the Aral Sea prior to partition in 1989.

Note also that some authors (Starobogatov, Andreeva, 1981) describe more than twenty species of gastropods from the genus *Caspiohydrobia*, instead of the two listed here. This difference arises from their taxanomic splitting which we consider insufficiently proved and unwarranted. Future application of new molecular methods could partly solve this issue, and thus provide a more exact enumeration of *Caspiohydrobia* species existing in the Aral Sea.

Seven ichthyofauna species were present at the division**.** From aboriginal species only stickleback (*Pungitius platygaster aralensis*) remained. Among intentionally introduced fishes only two species survived: Baltic herring (*Clupea harengus membras*) and plaice (*Platichthys flesus*). In accidentally introduced fishes only silverside (*Atherina mochon pontica*) and three species of gobies – bubyr (*Pomatoschistus caucasicus*), monkey goby (*Neogobius fluviatilis pallasi*) and round goby (*N. melanostomus officinus*) remained. Thus, the portion of recent invaders in ichthyofauna was 86%.

After division in 1989 the Small Aral Sea stabilized at +40 m asl and began to rise due to positive water balance (Aladin, 1995; Aladin, Potts, Plotnikov, 1995). As a result waters of the Small Sea began to flow southward into the Large Aral. This outflow did not occur over all the surface of the dried bottom of former Berg's strait but only in its central part, which was earlier dredged. This dredging had begun in 1980's when water level in Berg's strait has fallen so much as to cause troubles for shipping. At that time a navigation canal was cut between the northern and southern basins. In spring 1989, this canal was visible and a slow southward current was present in autumn. This flow was due to declining lake levels in the Large Aral. The flow sharply increased with continuing desiccation of the Large Aral and reached 100 m^3/sec as the Large Aral level fell to +37.1 m, a difference between the two lakes reaching 3 m. This strong stream eroded the bottom and threatened to almost completely drain the Small Aral Sea (Aladin et al., 1995). To prevent this, the canal between the Large and Small Aral was dammed in July-August 1992 and the flow stopped. In the next years this dam in Berg's strait was partly destroyed by floods and restored several times. The dam existence allowed to raise the Small Aral Sea level up to +42.8 m at April 1999 and to decrease salinity from 29.2 g/l (at division) to 18.2 g/l. Unfortunately, in late April 1999 the dam was completely destroyed by waves due to the rise of Small Aral level. After 7 years the level returned to the mark +40 m. Dam restoration has not been undertaken and waters of Small Aral are again flowing out to the south. They do not reach the Large Aral and are lost in sands and salt marshes north of past Barsakelmes Island. Now the Large Aral has dried so much that its modern shoreline here is far (many km) from the modern Small Aral Sea (Fig. 4).

After the dam was built in 1992 rising lake levels and declining salinity partially restored the Small Aral. Biodiversity increased, desiccated Bolshoy Sary-Cheganak gulf was filled with water again, and rehabilitation processes began in Syrdarya delta. Reeds (*Phragmites australis*) began to grow again, forming an environment for hydrobionts and amphibiotic animals (Aladin, 1995; Aladin, Plotnikov, Potts, 1995). Increasing depth of Syrdarya delta resulted from the Small Aral level raise and allowed for aboriginal and introduced freshwater fishes to forage in the estuary as before. The peak of such foraging was at the end of 1990's when the Small Aral level reached more than + 42 m. The foraging of fresh water fishes also was favored by the average salinity decrease to about 18 g/l. Before the dam in Berg's strait was built the Syrdarya estuary was poorly developed, and the zone of fresh and saline water mixing practically absent because most of the fresh water moved directly to the canal between Small and Large Seas. After construction of the dam, fresh water was retained in the Small Aral and its average salinity decreased down to 11 g/l.

In spite of the significant decrease in salinity which allowed fishes from Syrdarya to forage in the Small Aral, the number of fish species resident in the Small Aral remained at seven, the same ones present at the prior partitioning of the Aral Sea. Of these only plaice is of commercial value. Some fishes from Syrdarya, pike-perch (*Lucioperca lucioperca*) for example, that can now forage in a large part of the Small Aral cannot be considered as the salinity of the Small Aral is still high for reproduction of these fishes.

Level raise and salinity decrease were favorable not only for ichthyofauna of Small Aral, but for its zooplankton and zoobenthos as well. Thus, two species of Cladocera: *Moina mongolica* and *Evadne anonyx* reappeared, and the number of *Podonevadne camptonyx* increased. Appearance of *E. anonyx* could be explained by peculiarities if its life cycle. Cladocera from family Podonidae, to which *E. anonyx* belongs, have latent (resting) eggs, sinking in water and capable of surviving under unfavorable conditions for some years in a stage of diapausing embryos. Before the Aral Sea division *E. anonyx* was observed for the last time in the northern water area in summer 1988 when salinity exceeded 25 g/l. Later this species was not found in zooplankton during some years. But, when in 1993 salinity of Small Aral decreased below 25 g/l, *E. anonyx* probably hatched from resting eggs surviving on the sea bottom.

The re-appearance of *Moina mongolica* in the Small Aral also appears to be from resting eggs. Resting eggs of these crustaceans do not sink as in the case of *E. anonyx,* but can survive on the shoreline. Resting eggs of *M. mongolica* are capable of enduring extended periods of drying and freezing of up to tens of years (Makrushin, 1985). Resting eggs of *M. mongolica* would be brought into the Small Aral by wind from nearby saline ponds during dust-salt storms. *M. mongolica* probably did not become a permanent member of the zooplankton community of the recently isolated Small Aral as it was before extermination by Baltic herring in the beginning of 1960's. Prior to the 1960s *M. mongolica* was found in summer plankton of the Aral Sea (from spring till autumn), and latent eggs were always present in recently exposed sediments areas. This planktonic crustacean was widespread in all Aral Sea from estuaries to saline gulfs because it is widely euryhaline and endures salinity from fresh water up to 97 g/l. Presently, *M. mongolica* in the Small Aral Sea is only sporadically observed, and its resting eggs are not found on the shore. Obviously, spring dust/salt storms are bringing latent eggs, from which crustaceans later hatch. After parthenogenetic reproduction, herring and silverside exterminate them, without leaving resting eggs. In subsequent springs, this situation is repeated, as in nearby fishless salt lakes and ponds, *M. mongolica* is common and produces large quantities of resting eggs. Thus, zooplankton biodiversity in the Small Aral has increased by only one species to the present twelve which consists of the one recent invader (*Calanipeda aquaedulcis*), two ancient invaders (*Podonevadne camptonyx*, *Evadne anonyx*), and nine euryhaline species, part of which are widespread in Aral region and others could be considered aboriginal. Therefore, the portion of recent invaders in zooplankton has decreased to 8%.

New species also appeared in the Small Aral zoobenthos. Two species of Ostracoda – *Eucypris inflata* и *Heterocypris salina* were added to remaining *Cyprideis torosa*. They were never recorded in the Aral Sea before and were first noted in 1995 in Bolshoy Sary-Chaganak bay after refilling due to construction of the dam. Invasion of these species of Ostracoda, as in the case of *M. mongolica*, was evidently the result of their spreading by dust-salt storms. Both these euryhaline species have latent stages, enduring freezing and desiccation and are easily transported by wind. The frequency of dust-salt storms in the Aral region has increased following anthropogenic desiccation. Meteorological data from the Small Aral region indicate the annual frequency of dust storms has increased from about 60 in the mid-1960's to almost double that in the mid-1980's (The Aral Sea, 1990). Given their frequency and strength, we conclude that aeolian transfer is becoming a significant factor in maintaining and introducing new species into water bodies of Aral Sea region.

At the end of 1990's, when the average salinity of Small Aral decreased to 18 g/l, larvae of Chironomidae appeared in the benthos again. Before anthropogenic desiccation and increased salinity some species of Chironomidae were main components of the zoobenthos. Now, following more than 30 years absence, larvae of *Chironomus halophilus* have re-appeared (Aladin et al., 2002). In the near future, larvae of other Chironomidae may appear in the Small Aral, as the deltaic water bodies of Syrdarya and others saline water bodies of the Aral Sea region contain many species of Chironomidae, imagoes of which are able to actively (flight) or passively (aeolian transfer) reach the Small Aral area and lay eggs. Return of Chironomidae larvae into Small Aral (natural reintroduction) is a sign of increased benthic productivity. The >10 g/l salinity decrease that occurred during the period of dam in the Berg's strait, positively affected other components of the zoobenthos as well. Other species not only survived, but also increased in abundance and biomass despite active predation by plaice, providing further evidence of increased benthic productivity.

Thus, the zoobenthic community of the modern Small Aral rose to 10 species; three recent invaders (*Abra ovata*, *Nereis diversicolor* and *Palaemon elegans*), one ancient invader (*Cerastoderma isthmicum*), three euryhaline species, two new species of Ostracoda (*Eucypris inflata* and *Heterocypris salina*), and *Chironomus halophilus*. Thus, the portion of recent invaders in the zoobenthos has increased slightly to 60%.

The dam collapse in late April 1999 reestablished outflows from the Small Aral Sea and the Bolshoy Sarycheganak bay practically dried up and the straits connecting Shevchenko and Butakov bays with Small Aral became shallow. Nevertheless, there is no threat of the Syrdarya changing course to flow into the Large Aral, as in the early 1990's, because in the late 1990s the Syrdarya had its flow artificially channeled and it enters the Small Aral north of its former natural mouth. Meanwhile, quick restoration of the dam in Berg's strait is required to maintain and enhance biodiversity and productivity of the Small Aral.

After division in 1989, the Large Aral Sea level continued to decline due to a negative water balance and salinity rapidly increased. After the dam in Berg's strait was built in 1992, the Large Aral level declined slightly faster, because inflows from Small Aral ceased. Nevertheless, the increased rate of desiccation due to dam construction was small as indicated by comparative measures of Large and Small Aral levels by satellites. The increasing salinity is negatively impacting the biota and biodiversity is decreasing.

The recent salinity increase in the Large Aral has caused extinction of almost all marine and euryhaline fish and invertebrate species except a few remaining halophiles. Of seven fish species present at partition of the Aral Sea none were present in autumn 2002 when salinity exceeded 70 g/l. Along the shoreline there were a lot of dead decaying bodies of plaices and silversides. But there is a possibility that in Chernyshov and Tsche-Bas bays and near Aktumsyk cape, where there is increased outcome of freshened subterranean waters, adult plaices still may survive during some years. Unfortunately, the output of ground waters is so little that it has influence on the salinity only near the bottom; so, plaices will die sooner or later. However, it is possible to say with certainty there is no natural reproduction of fishes in the Large Aral.

Of eleven invertebrate zooplankton species only the widely euryhaline rotifer, *Brachionus plicatilis* has survived. However, three new halophylic species appeared apparently due to aeolian transfer; the cladoceran *Moina mongolica,* the brine shrimp *Artemia salina* and of the infusorium *Fabrea salina*. Thus only four species remain in the Large Aral Sea zooplankton. In contrast to the Small Aral, *Moina mongo-*

lica has became a permanent component of summer plankton in the Large Aral, but has not settled over the whole water area. *Artemia salina* has invaded the Large Aral Sea and in some areas reaches high abundance. There is no doubt that the Large Aral may become an important center of harvesting brine shrimp cysts for use in aquaculture and thus provide economic value.

The zooplankton of the modern Large Aral Sea includes four euryhaline species, widespread in the region. *Brachionus plicatilis* and reintroduced *Moina mongolica* cannot be considered invaders, as they were present before anthropogenic desiccation. However, *Artemia salina* and *Fabrea salina* are invaders and constitute 50% of the zooplankton species.

Of eight zoobenthic species only two species of widely euryhaline gastropods from the genus *Caspiohydrobia* and one euryhaline species of ostracods *Cyprideis torosa* remain. All other bottom inhabitants, present at partition of the Aral Sea, such as Gastropoda, Polychaeta and Decapoda, have disappeared due to increased salinity or are near extinction. As in the case of zooplankton, the Large Aral Sea zoobenthos was enriched by aeolian transfer of new halophylic invaders. Euryhaline ostracod *Eucypris inflata* and halophylic protozoans appeared in zoobenthos and along with larvae of halophylic Chironomidae. Thus, due to new invaders the number of dominating species has reached six.

Higher zoobenthic biodiversity in Tsche-Bas and Chernyshov bays deserves special note. Here and probably near Aktumsyk cape biodiversity is higher than in the rest of the Large Aral Sea. As mentioned above, near the bottom of these bays and at Aktumsyk cape, inflowing underground freshwaters from under cliffs of Ustjurt plateau occur and reduced salinity provides more favorable benthic conditions than in other areas of Large Aral. Field samples collected from these bays in August-September 2002 contained not only species of *Caspiohydrobia*, Chironomidae and euryhaline ostracod *Cyprideis torosa*, but also some recent (*Abra ovata*) and ancient (*Cerastoderma isthmicum*) invaders. Also in Tsche-Bas bay, where salinity was somewhat lower than in Chernyshov bay, adult *Cerastoderma isthmicum* and *Abra ovata* were present. Also, the presence of *A. ovata* juveniles suggests continuing reproduction of this species. However, *Nereis diversicolor* was not found on any stations in Tsche-Bas bay. As for more saline Chernyshov bay, no bivalves were present, but *Nereis diversicolor* was found.

We also have to note that not only high salinity is killing bottom animals and fishes. In many places near the bottom oxygen concentration is very low. In some other places H_2S makes bottom environment completely lifeless. So, not only salinity, but also anoxic conditions are controlling the bottom communities (Aladin et al., 2002).

These data indicate that after partition of the Aral Sea, the southern part was quickly transformed from a mesohaline to a hyperhaline water body. Biodiversity of Large Aral changed with typical hyperhaline species becoming dominant and most of its former inhabitants, including fishes, extinct. The phytoplankton of modern Large Aral is the halophylic alga, Dunaliella, which has become the dominate autotrophic organism of this hyperhaline water body. This alga came into Large Aral from neighboring hyperhaline water bodies. As in the case of Small Aral, the Large Aral fauna is enriched mainly by aeolian transfer of resting stages of hydrobionts from other water bodies of Aral region.

The rapid decline of the Large Aral level actually destroyed the delta of Amudarya. Unlike the delta of Syrdarya, where, natural rehabilitation processes began after the dam was built, rapid degradation of Amudarya delta continues. Moreover, deltaic water bodies of the Syrdarya are near the Small Aral and are regularly fed with fluvial waters, while those of Amudarya are far from the Large Aral and receive no regular flows. Thus the ecological situation in the south is more complicated than on the northern Aral Sea.

Restoration of the Small Aral is possible and depends on construction of a new dam with water locks. Increased biodiversity and productivity would accompany rising lake level and decreasing salinity. Apparently, natural migration of euryhaline species with fluvial waters from artificial and natural water bodies located in the delta and lower reaches of Syrdarya will also occur. It could be expedient to speed up this natural process by the introduction of food species of some valuable of invertebrates from lakes Kamyslybas, Zhalanash, Tuschibas etc., directly into the Small Aral. Many aboriginal and introduced species that perished in Aral survived in deltaic water bodies and, after the dam restoration, could be reintroduced into the Small Sea. However, one must stress that these actions could succeed only after the average salinity of Small Aral decreases to below 14 g/l. Reintroduction at higher salinity is of no avail.

Continued desiccation of the Large Aral is almost assured. In a few years its water area will inevitably be divided into at least 3 parts separate lakes (Fig. 1B). Tsche-Bas bay will soon be separated in the north, with a deep basin in the west and a shallow water body in the east basin. The latter could dry up completely by 2010 or even earlier. Separated Tsche-Bas bay will become saline slowly more, if underground fresh waters income noted by some authors (Radjabov, Tahirov, personal communication) are significant. Nevertheless, sooner (2020) or later (2025), Tsche-Bas bay will salinize anyway, because low mineralized underground waters in arid climate lakes couldn't compensate evaporation for the long time.

The deepwater basin of the north will obviously exist the longest, because it has the largest water volume and the lower area/volume ratio, and as with Tsche-Bas bay, has some subterranean inputs from Ustjurt plateau. Such inflows were found at Aktumsyk cape (Radjabov, Tahirov, personal communication). It is also probable that analogous underground inflows occur at other points along the steep shore of Large Aral, but as usual in arid climate lakes ground waters couldn't compensate evaporation for the long time. So, year after year the last part of the Large Aral will become smaller and more saline until the stability will be reached.

Before salinity increases to 200-300 g/l in all these water bodies, there will be only euryhaline halophylic species, and their number will decrease as salinity increases. As salinity reaches 300-350 g/l, only bacteria will survive. No introductions into the Large Aral are necessary or warranted. All hydrobionts able to survive in it are already present or could easily come into it naturally, as resting stages or by aeolian transfer or with migrating birds. It is well known that flamingos, eating zooplankton of hyperhaline lakes, often transfer cysts of euryhaline hydrobionts on its feathers and muddy feet.

Restoration and rehabilitation of Large Aral is practically impossible as it would require large amounts of both the Syrdarya and Amudarya waters which are diverted for irrigation. Syrdarya inflows to the Aral Sea have been greatly reduced and almost nothing remains of Amudarya inflows because all countries in the upper basin continue to divert almost all of its flows for irrigation. The withdrawal of river water during the next years will increase, as peace and economic development return to Afghanistan bringing further development of irrigated agriculture in this country.

Interest in restoration of Large Aral Sea is decreasing not only because of deficit of Amudarya's water, but also due to the discovery of large oil and gas deposits in this region. Extracting mineral resources is easier and cheaper from playas than from marine platforms. Economic benefits of oil development in Kazakhstan and Uzbekistan have reduced their interest in restoration and rehabilitation of the Large Aral.

Another evidence that interest to restore the Large Aral is low is coming from recently published documents on the project of river Ob' redirection to the Central Asia. In this project, strongly supported by Moscow major Yu. Luzhkov, all water is giving only for irrigation and social needs. Absolutely nothing left to the Large Aral Sea itself.

Finally, Large Aral reconstruction is complicated by political division stemming from belonging to two countries and intergovernmental accords require much time.

Fortunately, the situation at Small Aral lying entirely within Kazakhstan is not so despairing and there is a real possibility of rehabilitation. We hope that the dam in Berg's strait will be restored and that Small Aral will rise again. Rising water and decreasing salinity result in increased biodiversity due to natural and possibly intentional reintroduction of fishes and invertebrates from deltaic water bodies of Syrdarya. If these plans are realized, in some distant future the Small Aral could be a donor to any restoration of the Large Aral. Such a possibility is testified to by medieval desiccation. In 15-16th centuries the Large Aral was desiccated as now due to irrigation development, but by the 19th century had returned from +30 m to the +53 m. Let us hope that future generations could admire not only Small Aral but also Large Aral Sea.

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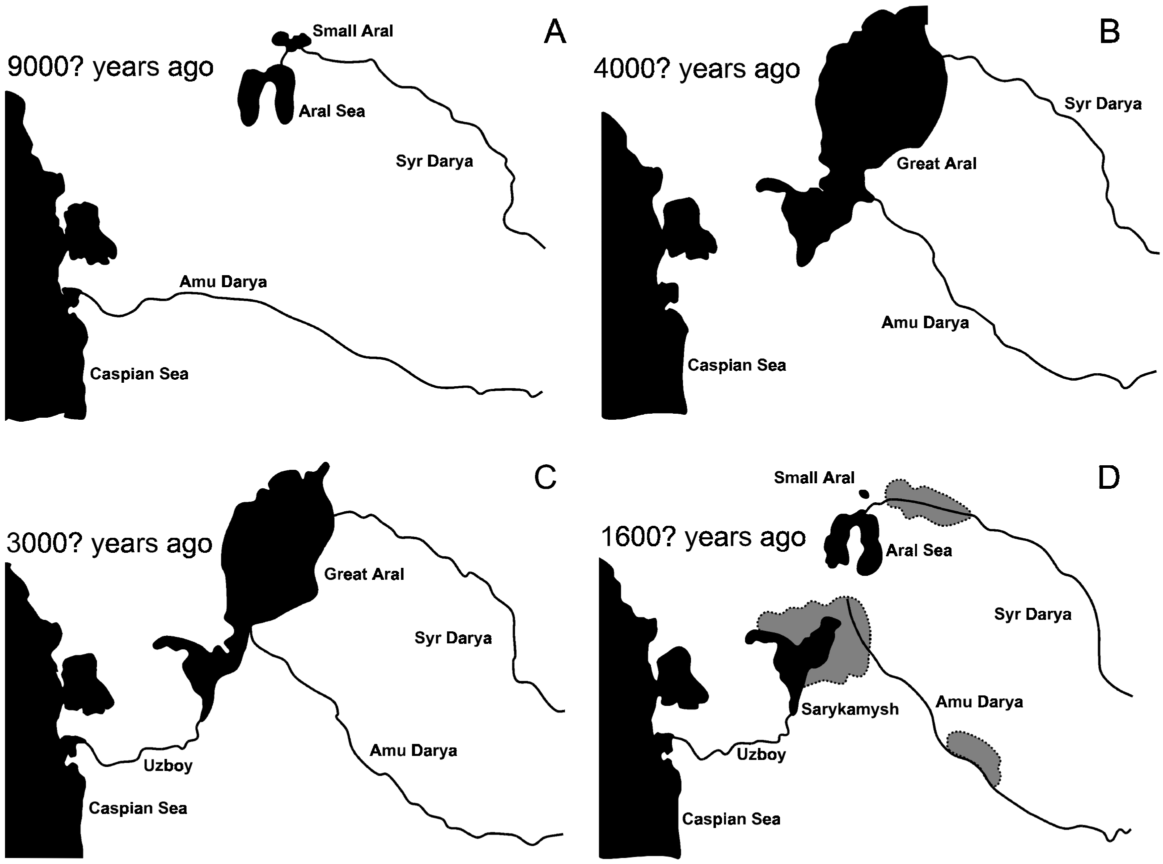

Fig. 1A. Early Holocene and late Holocene palaeohydrographical systems of Central Asia and Kazakhstan:

A — Paskevich stage; *B* —the Great Aral stage; *C* — stage of the first natural discharge throw Uzboy to the Caspian Sea; *D* — stage of the first anthropogenic desiccation.

Areas of irrigation are *shaded*.

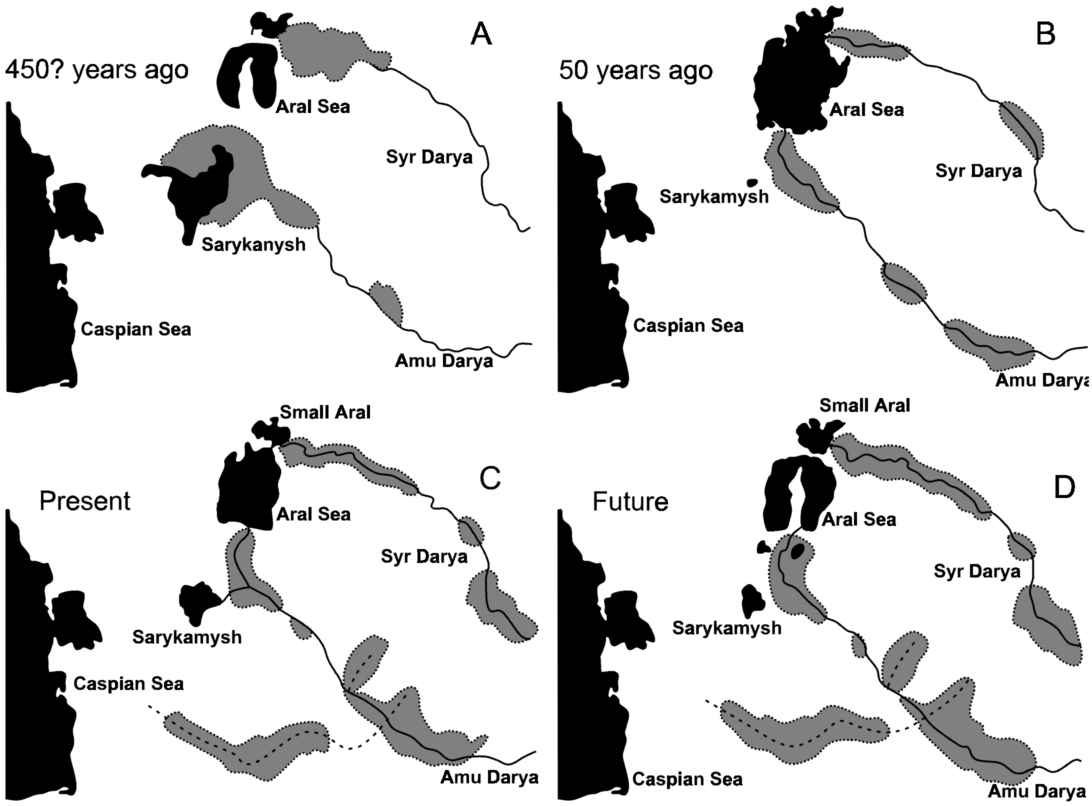

Fig. 1B. Medieval, in the middle of XX century, modern and possible future hydrographical systems in Central Asia and Kazakhstan:
A — stage of medieval anthropogenic desiccation; *B* — stage of the modern Aral before anthropogenic desiccation; *C* — stage of the present anthropogenic desiccation; *D* — stage of the Aral stabilisation in future.
areas of irrigation are *shadowed*

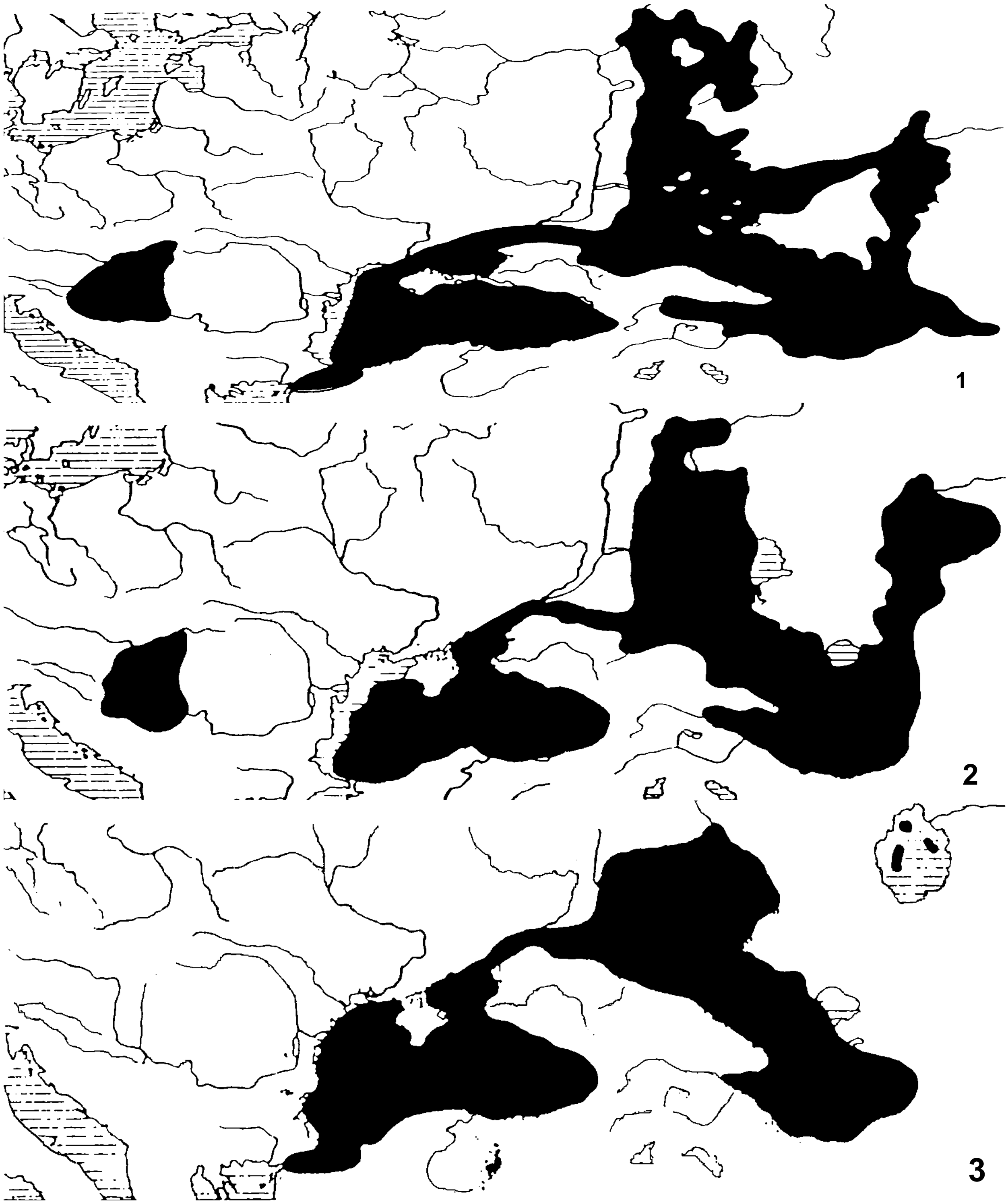

Fig. 2. Palaeohydrography of southeastern Europe and southwestern Central Asia in late Miocene-Pleistocene.:
1 — Akchagyl and Kuyalnik lake-seas (3 mln. years B.P.); *2* — Apsheronian and Gurian lake-seas; *3* — Anciant Euxinian and Hazarian lake-seas (0.4 mln. years B.P.)

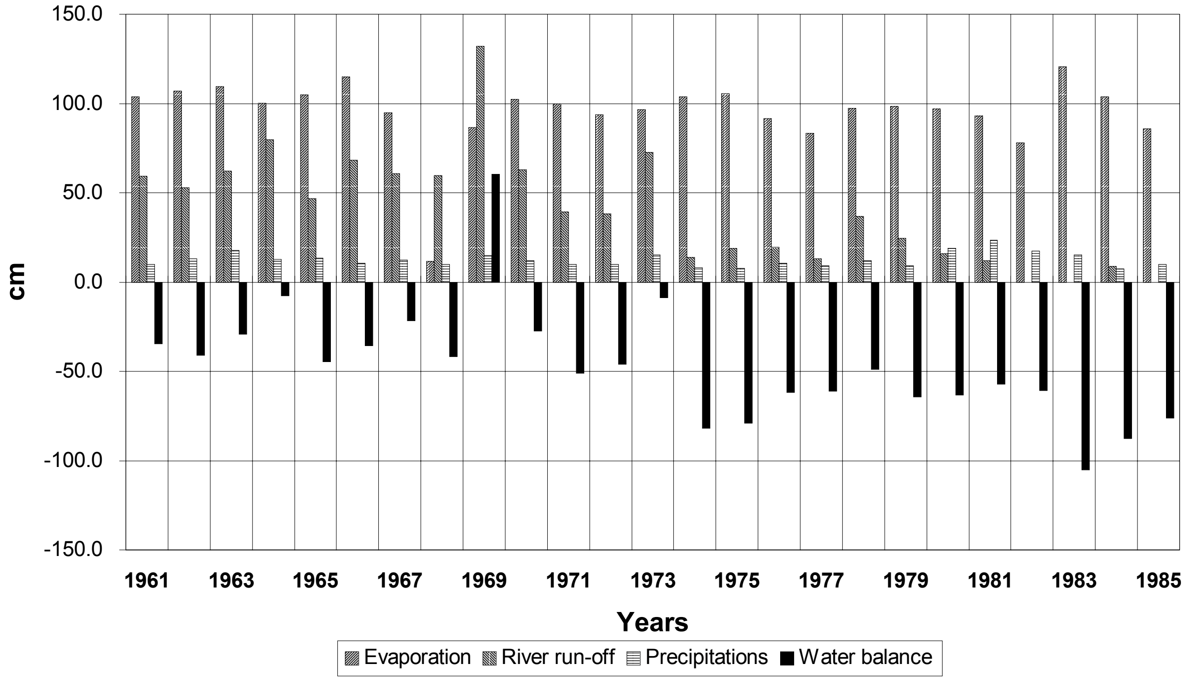

Fig. 3. Water balance of the Aral Sea in 1961-1985.

Fig. 4. The Aral Sea in 2000.

Table 1.

List of free-living invertebrates in the Aral Sea.

No.	Species
	Coelenterata
1.	*Protohydra leuckarti* Greef
	Turbellaria
1.	*Mecynostomum agile* (Beklemischev)
2.	*Macrostomum hystricinum* Beklemischev
3.	*M. minimum* (Luther)
4.	*Promonotus orientalis* Beklemischev
5.	*Kirgisella forcipata* Beklemischev
6.	*Gieysztoria bergi* (Beklemischev)
7.	*Byrsophlebs geniculata* Beklemischev
8.	*Beklemischeviella contorta* (Beklemischev)
9.	*Phonorhynchoides flagellatus* Beklemischev
10.	*Gyratrix hermaphroditus*
11.	*Pontaralia relicta* (Beklemischev)
12.	*Placorhynchus octaculeatus dimorphis* Karling
	Nematodes
1.	*Adoncolaimus aralensis* Filipjev
	Rotatoria
1.	*Eosphora ehrenbergi* Weber
2.	*Trichocerca* (*Diurella*) *heterodactyla* Tschugunoff
3.	*T.* (*D.*) *similis* (Wierzejski)
4.	*T.* (*D.*) *porcellus*
5.	*T. s. str. elongata* (Gosse)
6.	*T. s. str. pusilla* (Lauterborn)
7.	*T. s. str. longiseta* (Schrank)
8.	*T. caspica* Tschugunoff
9.	*Synchaeta stylata* Wierzejski
10.	*S. vorax* Rousselet
11.	*S. tremula* (Müller)
12.	*S. pectinata* Ehrenberg
13.	*Polyarthra euryptera* Wierzejski
14.	*P. luminosa* Kutikova
15.	*P. vulgaris* Carlin
16.	*P. longiremis* Carlin
17.	*Lindia torulosa* Dujardin
18.	*Encentrum limicola* Otto
19.	*Asplanchna priodonta* Gosse
20.	*A. girodi* Guerne
21.	*Brachionus angularis* Gosse
22.	*B. calyciflorus* Pallas
23.	*B. quadridentatus* Hermann
24.	*B. plicatilis* Müller
25.	*B. rubens* Ehrenberg
26.	*B. urceus* (Linnaeus)
27.	*Platyias quadricornis* (Ehrenberg)
28.	*P. palustris* (Müller)
29.	*Keratella cochlearis* (Gosse)

No.	Species
30.	*K. tropica* (Apstein)
31.	*K. quadrata* (Müller)
32.	*K. valga* (Ehrenberg)
33.	*Notholca squamala* (Müller)
34.	*N. acuminata* (Ehrenberg)
36.	*Kellicottia longispina* (Kellicott)
37.	*Euchlanis dilatata* Ehrenberg
38.	*E. triquerta* Ehrenberg
39.	*Trichotria pocillum* (Müller)
40.	*T. tetractis* (Ehrenberg)
41.	*Mytilina ventralis* (Ehrenberg)
42.	*Lecane* (*Lecane*) *luna* (Müller)
43.	*L.* (*L.*) *ungulata* (Gosse)
44.	*L.* (*Monostyla*) *lamellata* (Daday)
45.	*L.* (*M.*) *stenroosi* (Meissner)
46.	*L.* (*M.*) *bulla* (Gosse)
47.	*L.* (*M.*) *lunaris* (Ehrenberg)
48.	*Colurella obtusa* (Gosse)
49.	*C. adriatica* (Ehrenberg)
50.	*C. uncinata* (Müller)
51.	*C. colurus* (Ehrenberg)
52.	*Hexarthra fennica* (Levander)
53.	*H. oxyuris* (Zernov)
54.	*H. mira* ()
55.	*Testudinella patina* (Hermann)
56.	*T. bidentata* (Ternetz)
57.	*Filinia longiseta* (Ehrenberg)
58.	*Collotheca mutabilis* (Hudson)
	Olligochaeta
1.	*Aeolosoma hemprichi* Ehrenberg
2.	*Nais elingius* Müller
3.	*N. communis* Piguet
4.	*Paranais simplex* Hrabe
5.	*Amphichaeta sannio* Kallstenius
6.	*Chaetogaster* sp.
7.	*Limnodrilus helveticus* Piguet
8.	*Potamothrix bavaricus* (Oeschmann)
9.	*Psammorhyctides albicola* (Michaelsen)
10.	*Lumbriculus lineatus* (Müller)
	Cladocera
1.	*Diaphanosoma brachyurum* Lievin
2.	*Chydorus sphaericus* (O. F. Müller)
3.	*Alona rectangula* G. Sars
4.	*Bosmina longirostris* (O. F. Müller)
5.	*Daphnia longispina* (O. F. Müller)
6.	*Ceriodaphnia reticulata* (Jurine)
7.	*C. cornuta* G. Sars
8.	*C. pulchella* G. Sars
9.	*Moina mongolica* Daday

No.	Species
10.	*M. micrura* Kurz
11.	*Podonevadne camptonyx* (G. Sars)
12.	*P. angusta* (G. Sars)
13.	*Evadne anonyx* G. Sars
14.	*Cercopagis pengoi aralensis* M.-Boltovskoi
	Copepoda
1.	*Phyllodiaptomus blanci* (Guerne et Richard)
2.	*Arctodiaptomus salinus* (Daday)
3.	*Halicyclops rotundipes aralensis* Borutzky
4.	*Cyclops vicinus* Uljanin
5.	*Acanthocyclops viridis* Kiefer
6.	*Mesocyclops leuckarti* (Claus)
7.	*Thermocyclops crassus* (Fischer)
	Harpacticoida
1.	*Halectinsoma abrau* (Kritchagin)
2.	*Schizopera aralensis* Borutzky
3.	*S. jugurtha* (Blanchard et Rich.)
4.	*S. reducta* Borutzky
5.	*Nitocra lacustris* (Schmankewitsch)
6.	*N. hibernica* (Brady)
7.	*Mesochra aestuarii* Gurney
8.	*Onychocamptus mohammed* (Blanchard et Rich.)
9.	*Cletocamptus retrogressus* Schmankewitsch
10.	*C. confluens* (Schmeil.)
11.	*Limnocletodes behningi* Borutzky
12.	*Nannopus palustris* Brady
13.	*Enchydrosoma birstein* Borutzky
14.	*Leptocaris brevicornis* (Van Douwe)
15.	*Paraleptastacus spinicauda* Noodt
	Ostracoda
1.	*Darwinula stevensoni* (Brady et Robertson)
2.	*Candona marchica* Hartwig
3.	*Cyclicypris laevis* (O. F. Müller)
4.	*Plesiocypris newtoni* (Brady et Robertson)
5.	*Cyprideis torosa* (Jones)
6.	*Amnicythere cymbula* (Livental)
7.	*Tyrrenicythere amnicola donetziensis* (Dubowsky)
8.	*Limnocythere* (*Limnocythere*) *dubiosa* Daday
9.	*L.* (*L.*) *inopinata* (Baird)
10.	*L.* (*Galolimnocythere*) *aralensis* Schornikov
11.	*L.* (*Loxocaspia*) *immodulata* Stepanitys
	Malacostraca
1.	*Dikerogammarus aralensis* (Uljanin)
	Hydracarina
1.	*Eylais rimosa* Piersig
2.	*Hydriphantes s. str. crassipalpis* Könike
3.	*H.* (*Polyhydriphantes*) *flexuosus* Koenike
4.	*Hydrodroma despiciens* (O. Müller)
5.	*Limnesia undulata* (O. F. Müller)

No.	Species
6.	*Arrenurus s. str. tricuspidator* (O. F. Müller)
7.	*Copidognathus s. str. oxianus* Viets
	Bivalvia
1.	*Dreissena polymorpha* (Pall.)
2.	*D. p. aralensis* (Andr.)
3.	*D. p. obtusicarinata* (Andr.)
4.	*D. caspia* (Eichwald)
5.	*D. c. pallasi* (Andr.)
6.	*Cerastoderma lamarcki lamarcki* (Reeve)
7.	*C. umbonatum* (Wood)
8.	*Hypanis vitrea* (Eichw.)
9.	*H. v. bergi* Starobogatov
10.	*H. minima* (Ostr.)
11.	*H. m. sidorovi* Starobogatov
12.	*H. m. minima* (Ostr.)
	Gastropoda
1.	*Theodoxus pallasi* Ldh.
2.	*Caspiohydrobia conica* (Logv. et Star.)
3.	*C. husainovae* Starobogatov

Table 2. *Alien species in the Aral Sea*

N	Taxonomic Group	Species	Source	Year(s) of introduction	Year of first finding	Status after acclima-tization	Status in 1990s	Ecolo-gycal status	Way of intro-duction	Effect
1	Pisces	Alosa caspia	Caspian Sea	1929—1932	-	-	-	N	del	0
2		Acipenser stellatus	Caspian Sea	1927—1934 /1948-1963	1958	-	-	N	del	0
3		Acipenser nudiventris der-javini	Ural River Delta	1958	-	-	-	N	del	-
4		Acipenser guldenstadti	?	1978-1980	1981	Rare	-	N	del	0
5		Clupea harengus membras	Balthic Sea	1954-1959	1957	Rare	?	N	del	+
6		Mugil auratus	Caspian Sea	1954-1956	-	-	-	N	del	0
7		Mugil saliens	Caspian Sea	1954-1956	-	-	-	N	del	0
8		Ctenopharyngodon idella	China	1960-1961	1963	Commercial fish	-	N	del	+
9		Hypophtalmichthys molifrix	China	1960-1961	1963	Commercial fish	-	N	del	+
10		Aristichtys nobilis	China	1960-1961	?	Rare	-	N	del	+
11		Platichthys flesus	Azov Sea	1979-1987	1981	Commercial fish	Commercial fish	N	del	+
12		Mylopharyngodon piceus	China	1960—1961	1963	Commercial fish	-	N	assoc	0
13		Syngnathus abaster caspius	Caspian Sea	1954—1956	?	Rare	-	N	assoc	-
14		Atherina boyeri caspia	Caspian Sea	1954—1956	1959	Numerous	Limited num-ber	N	assoc	-
15		Pomatoschistus caucasicus	Caspian Sea	1954—1956	1958	Numerous	?	N	assoc	-
16		Neogobius fluviatilis	Caspian Sea	1954—1956	1958	Numerous	?	N	assoc	-
17		Neogobius melanostomus	Caspian Sea	1954—1956	1959	Numerous	-	N	assoc	-
18		Neogobius syrman	Caspian Sea	1954—1956	1959	Limited num-ber	-	N	assoc	-
19		Proterorchinus marmoratus	Caspian Sea	1954—1966	1959	Limited num-ber	?	N	assoc	-
20		Neogobius kessleri	Caspian Sea	1954—1956	1959	Limited num-ber	-	N	assoc	-
21		Ophicephalus(Channa) argus	Karakum canal	1960s	1965	Commercial fish	Commercial fish in river delta	N	assoc	+
22	Monogenea	Nitzschia sturionis	Caspian Sea	1927—1934	?	Common	-	Par	assoc	-
23	Coelenterata	Polipodium hydriforme Us-sov	Caspian Sea	1927—1934	?	Common	-	Par	assoc	-
24	Mysidacea	Paramysis baeri	River Don	1958—1960	-	?	-	N/B	del	0
25		Paramysis lacustris	River Don	1958—1960	1961	Numerous	In river deltas	N/B	del	+
26		Paramysis intermedia	River Don	1958—1960	1961	Numerous	-	N/B	del	+

27		Paramysis ullskyi	River Don	1958—1960	1963	Limited number	-	N/B	inc	+
28		Limnomysis benedeny	?	?	1975	Limited number	-	N/B	inc	+
29	Decapoda	Palaemon elegans (squilla)	Caspian Sea	1954—1966	1957	Numerous	Numerous	N/B	assoc	?
30		P. adspersus	Caspian Sea	1954—1966	-	?	-	N/B	assoc	?
31		Rhithropanopeus harrisii tridentata (Maitland)	Azov Sea	1965, 1966,	1976	Numerous	Numerous	B	assoc	+
32	Copepoda	Calanipeda aquaedulcis	Azov Sea	1965, 1966/1970	1970	Numerous	Numerous	P	del	+
33		Heterocope caspia Sars	?	1971	-	-	-	P	del	0
34		Acartia clausi	?	1985, 1986	-	-	-	P	del	0
35	Polychaeta	Nereis diversicolor	Azov Sea	1960—1961	1963	Numerous	Numerous	B	del	+
36	Bivalvia	Abra ovata	Azov Sea	1960, 1961,1963	1967	Numerous	Numerous	B	del	+
37		Monodacna colorata (Eichw.)	?	1964,1965	-	-	-	B	del	0
38		Mytilus galloprovincialis Lam	Azov Sea	1984-1986	-	-	-	B	del	0
39		Mya arenaria Linne	Azov Sea	1984-1986	-	-	-	B	del	0

Way of introduction: del, deliberately, inc, incidentally, assoc, in association with deliberate acclimatizants
Ecologycal status: N, necton, B, benthos, N/B, nectobenthos, P, plankton
Effect: -, negative, +, positive, 0, none, ?, unknown