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—Review Article—

Large saline lakes of Central Asia

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Abstract: In Central Asia, there are many saline lakes, both small and large. They range in salinity from <3 g/L to >100 g/L. The paper provides a summary review of their major physico-chemical and biological features of Caspian Sea, Aral Sea, lakes Balkhash, Issyk-Kul, Alakol and Tengiz. Several are threatened by human activities in their drainage basins, particularly diversion of inflowing waters.

Keywords: saline lakes, Central Asia, fauna, flora

1. Introduction

In Central Asia there are a lot of saline lakes. All of them are endorheic. They differ by their size and by salinity of their waters. Among them we can find nearly freshwater, brackish and hyperhaline. Most of them are small and shallow, with an area of less than 1 km^2, but six are large lakes, each with an area more than 1000 km^2: the Caspian Sea, the Aral Sea, lakes Balkhash, Issyk-Kul, Alakol and Tengiz (**Figure 1**). The total surface area of these 6 saline lakes is nearly 523000 km^2. **Table 1** gives their main characteristics at the highest recorded water-levels. Rather little information on some of these important lakes is available. The present paper aims to introduce these lakes by means of a summary review of their major features.

2. Caspian Sea

The Caspian Sea (**Figure 2**) is the largest lake in the world by area and volume. It is located between Europe and Asia. There are two states of Central Asia—Kazakhstan and

Fig. 1. Largest saline lakes of Central Asia.

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Table 1. Main physic-chemical features of the largest saline lakes of Central Asia.

Lake	Area, km^2	Volume, km^3	Elevation a.s.l., m	Max. depth, m	Salinity, g/L
Caspian Sea	422,000	79,000	-28	1,025	13
Aral Sea before 1960s	66,500	1,090	53	69	10
Balkhash	22,000	122	343	27	1.1-4.7
Issyk-Kul	6,200	1,738	1,608	668	6
Alakol	2,650	N/D	343	54	0.8-9.5
Tengiz	1,590	N/D	304	8	40.6-54.9

N/D—no data.

Fig. 2. The Caspian Sea.

Turkmenistan on its shore.

The Caspian Sea is an ancient lake. Originally, it was a part of the Paratethys Sea, which began splitting ~5.6 million years ago due to tectonic processes. Its age as endorheic water body is ~2.6 million years.

Its area, without Kara-Bogaz-Gol, is ~386,400 km^2, volume 78,200 km^3, maximal depth is 1025 m. The water level is below the ocean level. The Caspian waters are brackish, average salinity is ~13 g/L, except of hyperhaline bay Kara-Bogaz-Gol and some shallow gulfs. Water, due to isolation and the influence of river runoffs, is metamorphosed: portions of sodium and chlorine ions are lower when portions of calcium and sulfates ions are higher than in oceanic water (Kosarev and Yablonskaya, 1994; Leroy *et al.*, 2020).

As the Caspian is endorheic lake, its water balance depends on precipitation, river and ground water runoffs and evaporation. Its level is not stable. In the 20th century, it dropped from –25 m in 1896 to –29 m in 1977. The lake has shrunk. Then the level has begun to rise and, after 10 years, it reached –27.6 m, the area increased again. However, in the 21st century the level began to fall again. Since 2016, it stabilized at ~–28 m (Aladin *et al.*, 2001; Leroy *et al.*, 2020).

Four parts are distinguished within the Caspian Sea: the Northern, Middle, and Southern Caspian, and the bay Kara-Bogaz-Gol. The Northern Caspian makes ~29% of the total area, its volume is <1% because it is shallow—average depth 6 m, the maximum ~10 m. Its average water salinity is 5-10 g/L. At the mouths of Volga, Ural and Terek rivers salinity is 2-4 g/L. In the eastern shoals, salinity, due to strong evaporation in calm weather, reaches 15-20 g/L. In the shallow gulfs Mertvy Kultuk and Kaydak salinity can be up to 30 g/L or more (Zenkevich, 1963). The Middle Caspian makes up ~36% by area and ~35% by volume. Average depth is ~175 m, the maximum—~790 m, average salinity is 12.7 g/L. Salinity lower only in the delta-front of the Sulak River. The Southern Caspian makes up ~35% of total area and ~64% of total volume. It is the deepest—average depth 300 m, maximum 1025 m. Its salinity is 13 g/L. It is lower near deltas of the Kura and Sefidrud rivers. In the open sea, salinity slightly increases with depth (Zenkevich, 1963).

Kara-Bogaz-Gol is the smallest part of the Caspian Sea. A narrow strait connects it with the Middle Caspian. Its water level is lower than in the Caspian by several meters, and there is permanent water overflow into the bay. In it, water rapidly evaporates at shoals, and salinity can reach 300-350 g/L or more; huge amount of salts accumulates at the bottom. Kara-Bogaz-Gol is the major evaporator of the Caspian Sea, thus playing an important role of natural desalter in salt balance (Zenkevich, 1963; Aladin *et al.*, 2001).

The temperature regime of the Caspian Sea is characterized by considerable differences between its northern and southern areas in winter and equalizing of the temperature in summer. In winter in the Northern Caspian average air temperature is <0°C, and it is covered with ice. In the Middle and Southern Caspian, winter mean air temperature is always >0°C, and there is no ice. At depths, water temperature is low and stable: in the Southern Caspian –6°C at depths >500-600 m, in the Middle Caspian –4.5-5°C at depths >400-500 m. Seasonal thermocline exists at 20-50 m in summer (Zenkevich, 1963; Jamshidi, 2017).

In the Caspian Sea, there is high diversity of biotopes, biotic and abiotic conditions. Due to varying from fresh to hypersaline salinity, freshwater, brackish, euryhaline and hyperhaline hydrobionts can inhabit the Caspian.

The modern fauna and flora includes five main components: Caspian origin, freshwater origin, Mediterranean origin, Arctic marine origin and some recent Atlantic and freshwater invaders (Zenkevich, 1963; Kosarev and Yablonskaya, 1994).

The total biodiversity of the Caspian is lower than that of the Black Sea and he Barents Sea (Zenkevich, 1963). Probably the main reason for this, except for the benthos, is changing over time salinity. Only brackish-water species from both marine and continental water bodies are favored (Mordukhai-Boltovskoy, 1979). Aquatic biota is mostly euryhaline (Aladin and Plotnikov, 2004; Plotnikov *et al.*, 2006). Fishes and crustaceans (especially benthic) are good osmoregulators, can live in a very wide range of salinity and have the greatest diversity in the Caspian. They consist to 2/3 of the total number of free-living animal species (Zenkevich, 1963). Owing to long isolation, the Caspian Sea biota has high level of endemism (Dumont, 1998; Grigorovich *et al.*, 2003; Marret *et al.*, 2004). Nowadays, descendants of many ancient organisms, whose ancestors had penetrated into the Caspian some millions of years ago, inhabit it.

While in phytoplankton of the Northern Caspian there are >400 species (Aladin *et al.*, 2001), only a few species predominate. One of them is invader, marine diatom *Pseudosolenia calcar-avis* (Karpevich, 1975; Karpinsky, 2010). In periphyton there are ~200 species of algae. There are known 87 species of algal macrophytes (Zaberzhinskaya, 1968).

Up to 542 species of free-living Metazoa inhabit the Caspian Sea (Chesunov, 1978). Much of them are endemic species: 4 of Porifera, 2 of Coelenterata, 29 of Turbellaria, 3 of Nematoda, 2 of Rotifera, 2 of Oligochaeta, 4 of Polychaeta, 19 of Cladocera, 3 of Ostracoda, 23 of Copepoda, 20 of Mysidacea, 1 of Isopoda, 68 of Amphipoda, 19 of Cumacea, 1 of Decapoda, 2 of Hydracarina, 53 of Mollusca, 66 of fish and 1 mammal. Many species, particularly from Rotifera, Cladocera, Copepoda and Insecta, are of freshwater origin (Derzhavin, 1951; Mordukhai-Boltovskoy, 1960; Zenkevich, 1963; Leroy *et al.*, 2020).

In zooplankton, 315 species and subspecies are known, 135 species of them are ciliates (Kasimov, 1987, 1994; Agamaliev, 1983). Their main part is of Caspian origin. The most common crustaceans are: *Eurytemora grimmi*, *E. minor*, *Limnocalanus grimaldii*, *Acartia clausi*, *Heterocope caspia*, *Calanipeda aquaedulcis*, *Evadne anonyx*, *Podonevadne camptonyx*, *P. angusta*, *P. trigona*, *Polyphemus exiguus*, *Apagis* spp., *Cercopagis* spp., *Pleopis (Podon): polyphemoides*. Rotifers *Brachionus* spp., freshwater cladocerans *Moina* spp., *Diaphanosoma* spp., *Bosmina* spp. and others inhabit freshened areas. Larvae of benthic invertebrates—barnacles *Balanus* spp. and mollusks are numerous in spring and summer plankton of coastal zone (Bagirov, 1989).

According to Derzhavin (1951) and Zenkevich (1963), among Crustacea there are 114 autochthonous species from Mysidae, Pseudocumatidae, Isopoda, Amphipoda and Decapoda. From 57 to 70 endemic mollusk species of gastropods (from Neritidae, Hydrobiidae, Pyrgulidae and Planorbidae) and bivalves (from Dreissenidae and Cardiidae) are known from the Caspian (Leroy *et al.*, 2018, 2020).

Native ichthyofauna of the Caspian Sea together with deltas, freshened bays and lagoons includes 119 species and subspecies from 52 genera and 15 families. The richest by species are families Gobitidae, Cyprinidae and Clupeidae. Ichthyofauna of the Caspian has high endemism: 66 species and subspecies (mainly from Clupeidae and Gobiidae) are endemics. In it there are representatives of autochthonous, Mediterranean, Arctic and freshwater complexes (Kazancheev, 1981; Bogutskaya *et al.*, 2013).

Ichthyofauna is the most important biological resource of the Caspian Sea. The most valuable commercial fish are sturgeons—*Acipenser gueldenstaedtii*, *A. nudiventris*, *A. persicus*, *A. stellatus* and *Huso huso*. In the 1950s, the main dams blocking migratory routes of anadromous fish to the places of spawning were built on many rivers of the basin. The total area of the spawning grounds of sturgeons decreased by ~90%. In order to compensate this and to pro-

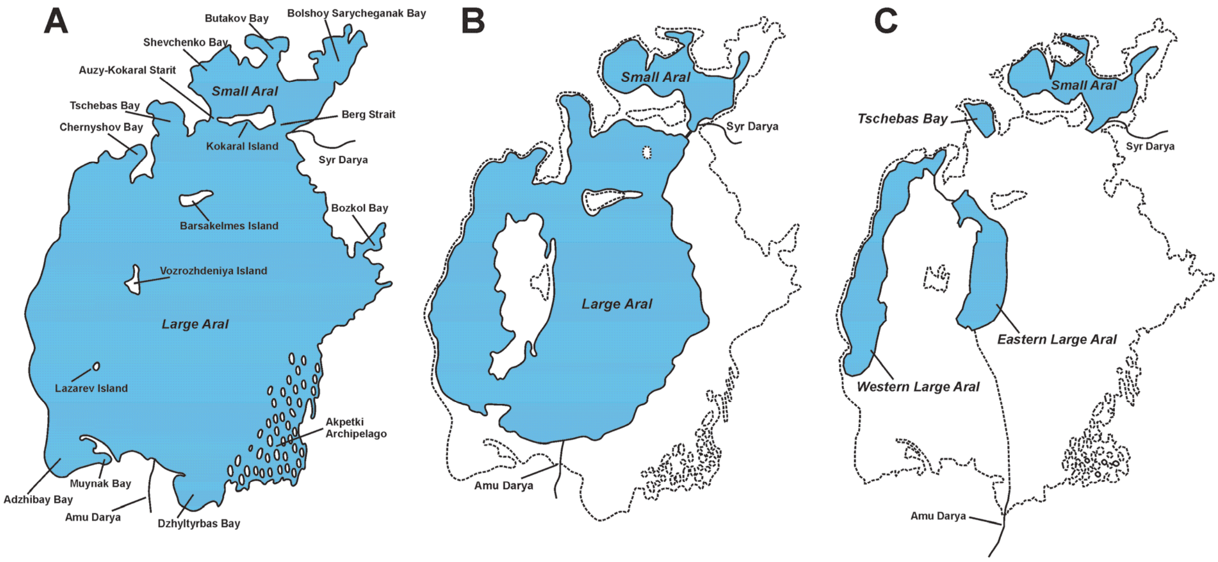

Fig. 3. The Aral Sea. A—before modern regression; B—in 1990; C—now.

tect sturgeon stocks, special sturgeon rearing stations were built. From the early 1960s, sturgeon catches increased for almost 20 years. After 1980, a sharp decline in catches took place. This was caused by the increased catch of previous years and by a decrease in the number of mature fish as a result of a decrease in natural reproduction due to loss of spawning grounds. Significantly increased poaching also influences on sturgeon stocks. By the early 1990s, the catches were almost halved and continued to decline (Aladin *et al.*, 2018).

The only aquatic mammal in the Caspian is endemic seal *Pusa caspica*. In winter, seals concentrate in the Northern Caspian at the edge of ice cover. Whelping, mating and molting occur on ice. In summer, the most of seals migrates for feeding to the Middle and Southern Caspian. During the 20th century population of seal declined (Aladin *et al.*, 2001, 2018).

In the 20th century, people both accidentally and specially introduced to the Caspian algal, invertebrate and fish species. The first were accidentally introduced diatom *Pseudosolenia calcar-avis* (in the 1920s), bivalve *Mytilaster lineatus*, and two shrimps—*Palaemon elegans* and *P. adspersus*. Later, intentionally were introduced mullets *Mugil auratus*, *M. saliens*, flounder *Pleuronectes flesus luscus* and, as food for fishes, polychaete worm *Hediste diversicolor* and bivalve mollusk *Abra segmentum* (Aladin *et al.*, 2002).

After the Volga-Don channel was built in the middle of the 20th century, a new group of species invaded the Caspian. Algae *Ceramium diaphanum*, *C. tenuissimum*, *Ectocarpus confervoides*, *Polysiphonia variegate*, planktonic crustaceans *Pleopis polyphemoides*, *Calanipeda aquaedulcis*, *Acartia clausi*, *A. tonsa*, crab *Rhithropanopeus harrisii*, jelly fish *Blackfordia virginica* and ctenophore *Mnemiopsis leidyi* were introduced with ballast waters. Barnacles *Balanus impovisus*, *B. eburneus* and briozoan *Membranipora crustulenta* were introduced with biofouling. The ctenophore has negative impact on the biota of the Caspian. Consuming zooplankton, it causes starvation for plankton-feeding fish, and thus blooms in phytoplankton (Aladin *et al.*, 2002; Ivanov *et al.*, 2000; Nasrollahzadeh *et al.*, 2014).

3. Aral Sea

The Aral Sea (**Figure 3**) is terminal closed lake amidst deserts of Central Asia in Kazakhstan and Uzbekistan. In it flow two rivers, Amu Darya at South and Syr Darya at Northeast. In the recent past (mid 20th century), the Aral Sea was a giant continental brackish water body. In 1960, prior to modern anthropogenic regression, the level was ~+53 m, area—67,499 km^2, volume—1,089 km^3, maximum depth—69 m, average depth—16 m. The Aral consisted of two main parts—the smaller northern basin (Small Aral) and the larger southern basin (Large Aral). They were divided by the elongate Kokaral Island and connected by two straits—the narrow Auzy-Kokaral and wide Berg straits. From the 1600s to the 1960s the Aral Sea remained relatively stable (Bortnik and Chistyaeva, 1990).

In winter in the Small Aral and northern part of Large Aral average air temperature is <0°C, and they are covered with ice. In the South of Large Aral, winter mean air temperature is always >0°C, and there is no ice (Bortnik and Chistyaeva, 1990).

The Aral Sea water level and salinity, as of other water bodies in arid zones, depend on water balance. It consists of inflow from the rivers (the most of water incomes from them), atmospheric precipitations on the surface, ground water runoffs and evaporation. Water balance of the Aral depends not only on climate change, but also on anthropogenic factor—withdrawals of water for irrigation (Bortnik and Chistyaeva, 1990; Micklin, 2014).

Before present anthropogenic regression, average salinity of the Aral Sea was 10.3 g/L. Salinity was lower near the deltas of rivers. Due to the intensive evaporation and slow water exchange, the salinity in shallow areas, in bays of the eastern shore, and in the southeast in the area of the Akpetki (Karabaily) Archipelago was increased reaching 50 g/L and more. Water of the Aral Sea is metamorphosed: ratio of divalent ions (bi-carbonate, calcium, magnesium, and sulfate) to monovalent ions (sodium and chlorine) is largely increased due to the salt composition of the slightly mineralized waters of inflowing rivers, where proportion of divalent ions is also higher (Dengina, 1959; Husainova, 1960; Bortnik and Chistyayeva, 1990).

The native fauna of the Aral Sea before the modern regression was represented by more than 200 species of free-living invertebrates (Mordukhai-Boltovskoi, 1974; Plotnikov, 2016) and 20 fish species (Nikolsky, 1940). Among the species of free-living invertebrates, the inhabitants of freshwater, brackish-water and saline continental water bodies composed 78%, Ponto-Caspian species 17% and marine species 5%. The highest biodiversity had rotifers and crustaceans (Mordukhai-Boltovskoi, 1974; Plotnikov, 2016).

To be compared with the Caspian Sea, the Aral Sea is young; its age does not exceed 20 thousand years (Micklin *et al.*, 2020). In contrast to the Caspian, only a few native endemic species are known in the fauna of the Aral Sea: 2 turbellarians—*Kirgisella forcipata*, *Gieysztoria bergi* and 3 harpacticoids—*Schizopera aralensis*, *S. reducta*, *Enhydrosoma birsteini* (Mordukhai-Boltovskoi, 1974; World Register of Marine Species).

In zooplankton, the most numerous copepod was *Arctodiaptomus salinus*, from fauna of continental saline waters. Ponto-Caspian cladocerans *Cercopagis pengoi aralensis*, *Evadne anonyx*, *Podonevadne camptonyx* and *P. angusta* were also numerous. Among the freshwater euryhaline Cyclopoida, the most common was *Mesocyclops leuckarti*. The highest diversity of zooplankton observed in the freshened water areas due to presence of many freshwater species (Kortunova, 1975; Andreev, 1989).

Freshwater and Caspian species prevailed in the aboriginal benthic fauna of the Aral Sea. Its basis was mollusks, oligochaetes, higher crustaceans and larval chironomids (Mordukhai-Boltovskoi, 1974). Bivalve mollusks *Dreissena* spp. and *Adacna* spp., oligochaetes *Nais elingius* and *Paranais simplex*, ostracod *Cyprideis torosa*, amphipod *Dikerogammarus aralensis*, larval chironomid *Chironomus behningi* and caddis flies *Oecetis intima* were numerous. Mollusks accounted for 63% of zoobenthos biomass, and chironomids—33% (Karpevich, 1975).

Almost all aboriginal ichthyofauna of the Aral Sea consisted of generatively freshwater (i.e. usually breeding in fresh water) species. In it, 60% were cyprinids (Nikolsky, 1940; Ermakhanov *et al.*, 2012). The best places for spawning were rivers with their deltas and deltaic lakes (Bervald, 1964). Almost all aboriginal fish were benthophages or predators (Nikolsky, 1940).

Flora of aquatic and coastal-aquatic plants was poor by species. Only two species and two plant communities dominated—reeds in coastal shallow waters and eelgrass on silty sands at depths of up to 11 m. In the central part charophytes were found on mud at depths of 11-22 m, and in the shallows—water milfoil *Myriophyllum* sp. and *Potamogeton perfoliatus*. By the 1960s in the Aral Sea flora 24 species of higher plants, 6 species of charophytes and about 40 other species of macroalgae were known. Aquatic vegetation formed zones of helophytes and zones of hydrophytes. Everywhere reed-beds of *Phragmites australis* dominated. In the northern part of the sea beyond the reed zone often was a zone of bulrush *Scirpus kasachstanicum*. Communities of hydrophytes presented diverse associations that formed vast underwater meadows. Eelgrass *Zostera noltii* dominated on sandy bottoms. Extensive deep-water thickets of Charophyta existed at the beginning of the 20th century but were absent by the 1950s. In their place algae *Vaucheria dichotoma* were found. In freshened bays, the basis of macrophytobenthos was higher flowering plants. In closed saline bays and inlets charophytes dominated (Plotnikov *et al.*, 2014a).

In 1954-1956 during unsuccessful acclimatization of the mullets from the Caspian Sea, unwanted fish—atherine *Atherina boyeri caspia*, pipefish *Syngnatus abaster caspius*, gobies *Knipowitschia caucasicus*, *Neogobius fluviatilis* and *N. melanostomus* were introduced. Together with them, shrimp *Palaemon elegans* was brought to the sea (Karpevich, 1975). This shrimp naturalized and became a competitor with the aboriginal amphipod *Dikerogammarus aralensis* and even ate it. This alien species, but not salinization later, caused extinction of the amphipod by 1973 (Mordukhai-Boltovskoi, 1972; Andreeva, 1989, Aladin and

Kotov, 1989, Aladin and Potts, 1992).

The most dramatic consequences were caused by the introduced in 1954-1956 planktophage Baltic herring *Clupea harengus membras* (Karpevich, 1975). Because of this alien species as well as atherine and gobies, the load on zooplankton increased (Kortunova, 1975). As a result, abundance and biomass of planktonic crustaceans sharply decreased and this led to the mass death of herring and atherine from starvation (Osmanov, 1961; Kortunova and Lukonina, 1970; Kortunova, 1975).

The first invertebrates introduced in the Aral Sea by plan (1958-1960) were Ponto-Caspian misyds from the delta of the Don (Karpevich, 1960). Of the three species—*Paramysis lacustris*, *P. intermedia* and *P. baeri*, only the first two naturalized. Fourth mysid, *P. ullskyi*, migrated independently from reservoirs upstream on the Syr Darya where it was introduced earlier (Kortunova, 1970). The next planned invertebrate species, euryhaline polychaete *Hediste diversicolor* from the Sea of Azov, was introduced in 1960-1961. This worm quickly naturalized and in 1973-1974 settled the whole Aral. Euryhaline bivalve *Abra segmentum* was introduced from the Sea of Azov in 1960-1963. By 1973, it settled all over the sea and became the main component of zoobenthos (Karpevich, 1975).

The euryhaline marine planktonic copepod *Calanipeda aquaedulcis* was introduced from the Sea of Azov in 1965 and again in 1970. By 1971 this crustacean became one of dominating species in zooplankton (Karpevich, 1975; Andreev, 1989) and by 1974 displaced *Arctodiaptomus salinus* (Mordukhai-Boltovskoi, 1972) and it disappeared.

In the deltaic areas of the Syr Darya and Amu Darya freshwater commercial fishes were acclimatized in 1958-1960: grass carp *Ctenopharyngodon idella*, silver carp *Hypophtalmichthys molifrix*, bighead carp *Aristichtys nobilis* and black carp *Mylopharyngodon piceus*. Except for bighead carp, all were successfully naturalized and became commercial (Karpevich, 1975).

Another and main cause of changes in the composition of the Aral Sea biota has been anthropogenic regression. It has begun in 1961, resulting from an increasing diversion of water from the Syr Darya and Amu Darya for irrigation, thereby considerably reducing riverine flows into the Aral Sea (Micklin, 2014). This broke the equilibrium of water balance, causing desiccation and salinization of the Aral Sea (Bortnik and Chistyaeva, 1990).

During the period 1961-1971 the Aral Sea desiccation and increase of its salinity occurred still slowly. Neverthelass this caused significant reduction in the total number of bivalves *Dreissena* spp. after 1964. This slight salinization was unfavorable only for *D. polymorpha aralensis* and *D. p obtusecarinata* but not for more resistant *D. caspia pallasi* (Andreeva, 1989).

In the 1970s, the rate of Aral Sea desiccation and salinity rise increased. Since that time, the main factor influencing the fauna of the Aral Sea has been continued salinity. In 1971-1976 invertebrate fauna of the Aral Sea passed through the first crisis period caused by salinization over 12–13 g/L (Plotnikov *et al.*, 1991). The most species-rich, freshwater component of fauna disappeared. Only 8 species of rotifers remained; from them only *Synchaeta* spp. were common and numerous. Cladocerans *Ceriodaphnia reticulata* and *Coronatella rectangula* disappeared by 1974. By 1975, of Cladocera only Ponto-Caspian *Evadne anonyx*, *Podonevadne camptonyx*, *P angusta* and *Cercopagis pengoi aralensis* remained. Instead of freshwater *Mesocyclops leuckarti* the most numerous copepod became euryhaline marine *Halicyclops rotundipes aralensis* (Andreev, 1989).

All mollusks from the genus *Adacna*—*A. vitrea* and *A. minima* disappeared after 1977. Further increases in salinity was unfavorable to *Dreissena polymorpha aralensis* and *D. p. obtusicarinata*, but favorable to *D. caspia pallasi*. Growing salinity led to the reduction in the area and number of the bivalve *Cerastoderma rhomboides*, and conversely was favorable for *C. glaucum*. After 1978 *C. rhomboides* was no longer found and *C. glaucum* took its place. Salinity above 12-14 g/L favored *Abra segmentum*. The abundance of the halophilic gastropod *Ecrobia grimmi* began to grow. Since 1973, when salinity reached 12 g/L, Oligochaeta are not found. By 1974, most of larval chironomids had disappeared; only *Chironomus salinarius* and *Ch. halophilus* remained. By 1980, the leading forms of zoobenthos were *A. segmentum*, *C. glaucum*, *Hediste diversicolor* and *E. grimmi*. After 1977 when the salinity had reached 15 g/L all mysids disappeared (Andreeva, 1989).

Because of this first crisis, freshwater and brackish water species of freshwater origin disappeared from the free-living invertebrate fauna of the Aral Sea. This provided an advantage to Caspian and marine euryhaline species and halophilic species (Andreev, 1989). Despite the continuing salinity growth, the first crisis period was followed by a period of relative stability in 1977-1985.

By 1987 salinity of the Aral Sea rose to 27 g/l. Crossing this boundary free-living invertebrate fauna of the Aral Sea entered the period of the second crisis during which occurred the next reduction of species diversity (Plotnikov *et al.*, 1991). All Ponto-Caspian cladocerans disappeared by 1990. After this crisis, of the native zooplankton species in the sea, remained only the rotifers *Synchaeta* spp., *Notholca squamula*, *N. acuminata*, *Keratella quadrata*, *Brachionus plicatilis*, *B. quadridentatus*, copepods *Calanipeda aquaedulcis* and *Halicyclops rotundipes aralensis*, as well as several species of Harpacticoida. Among benthic fauna only mollusks *Cerastoderma glaucum*, *Abra segmentum*, *Ecrobia grimmi*, ostracod *Cyprideis torosa*, polychaete *Hediste diversicolor*, crab *Rhithropanopeus harrisii tridentata* and the shrimp *Palaemon elegans* remained. After this crisis in the free-living invertebrate fauna of the Aral Sea there were marine species and euryhaline species of marine origin as well as representatives of euryhaline halophilic fauna of inland saline waters. This crisis was followed by a new period of relative stability (Plotnikov, 2016).

By 1988-1989, when the Aral Sea level declined from +53 m to +40 m, the Berg Strait dried up. The Auzy-Kokaral Strait had dried up earlier. The sea has divided into 2 residual water bodies—the Small and Large Aral. The total area and volume of the sea was reduced, the average salinity in both parts increased up to ~30 g/L (Aladin and Plotnikov, 2008; Plotnikov *et al.*, 2014b).

After the division of the Aral Sea, changes in the hydrological/hydrochemical regimes of these two new lakes occurred independently. The Syr Darya runoff was sufficient not only to stabilize the Small Aral. Since its separation, the Small Aral has positive water balance and its level has stabilized. Surplus water began to outflow towards the Large Aral through a channel formed on the Berg Strait bottom. The Small Aral salinity began to decrease. Soon after this, cladoceran *Podonevadne camptonyx* reappeared from dormant eggs. In 1999, chironomids were found in the benthos again (Aladin *et al.*, 2000). In contrast, the water balance of the Large Aral Sea has remained negative; desiccation and salinization are continuing. Consequently, the biotic characteristics these residual water bodies began to diverge (Aladin and Plotnikov, 2008).

The first Kokaral Dam was built across dried-up Berg Strait in 1992 in order to retain water in the Small Aral. This made possible to stabilize the Small Aral's water level and to decrease its salinity (Aladin *et al.*, 1995). This dam was destroyed by a storm in the spring of 1999. In 2004-2005, new soundly-engineered Kokaral Dam in the Berg Strait was built. It has a spillway for the discharge of excess water and for maintaining the level of the regulated Small Sea at a safe and stable level +42 m (Aladin and Plotnikov, 2008). After some years, Small Sea has again become brackish water.

A significant decrease in salinity and the formation of a highly freshened zone near the Syr Darya delta opened a possibility of a natural reintroduction of many freshwater and brackish water invertebrate species associated with the Syr Darya, its lower reaches and associated lakes, or invertebrate species with resting eggs that retain their viability for a longtime (Plotnikov *et al.*, 2014b, 2016).

The decrease in salinity has led to the reappearance of freshwater rotifers such as *Filinia longiseta*, *Asplanchna priodonta* and *Brachionus calyciflorus* in the Small Aral. The biodiversity of planktonic crustaceans has increased due to the reappearance of *Bosmina longirostris*, *Chydorus sphaericus*, *Diaphanosoma brachyurum*, *Ceriodaphnia reticulata*, *Podonevadne angusta*, *Evadne anonyx*, and copepods *Phyllodiaptomus blanci*, *Cyclops vicinus*, *Mesocyclops leuckarti*, and *Acanthocyclops viridis*. Mysid *Paramys isintermedia* has returned from the lower reaches of the Syr Darya. Moreover, bivalve *Dreissena polymorpha aralensis* and gastropod *Theodoxus pallasi* returned into the freshened zones. At least eight species of larval chironomids were identified. At the same time, the sharp decrease in salinity became unfavorable for the species of marine fauna and fauna of saline continental water bodies, for example, the density mollusks *Cerastoderma glaucum* and *Ecrobia grimmi*, decreased due to the lowered salinity (Plotnikov *et al.*, 2016).

Unlike the Small Aral, the water balance of the Large Aral remains negative. Water from the Amu Darya reaches it irregularly, and the water level continues to decline and the salinity to increase. The Large Sea had turned into a hyperhaline water body by the end of the 1990s. By 2003, it had become divided into a group of residual water bodies—the Eastern Large Aral, Western Large Aral and Tschebas Bay (Aladin and Plotnikov, 2008).

In the mid-1990s when salinity of Large Aral exceeded 47-52 g/L, fast changes in its biota occurred. By 2004, when salinity became 100-105 g/L, most invertebrates disappeared. Only rotifers *Hexarthra fennica* and *Brachionus plicatilis*, ostracod *Cyprideis torosa*, Turbellaria *Mecynostomum agile*, some species of Foraminifera, Nematoda and Harpacticoida remained. This time appeared some halophilic invertebrates such as ciliates *Fabrea salina* and *Frontonia marina*, copepod *Apocyclops dengizicus*, ostracod *Eucypris insflata*, brine shrimp *Artemia parthenogenetica*, larval chironomids *Beotendipes noctivaga* (Aladin and Plotnikov, 2008; Mokievsky and Miljutina, 2011).

Decline in the Aral Sea water level, salinization and drying of deltas significantly altered the living conditions

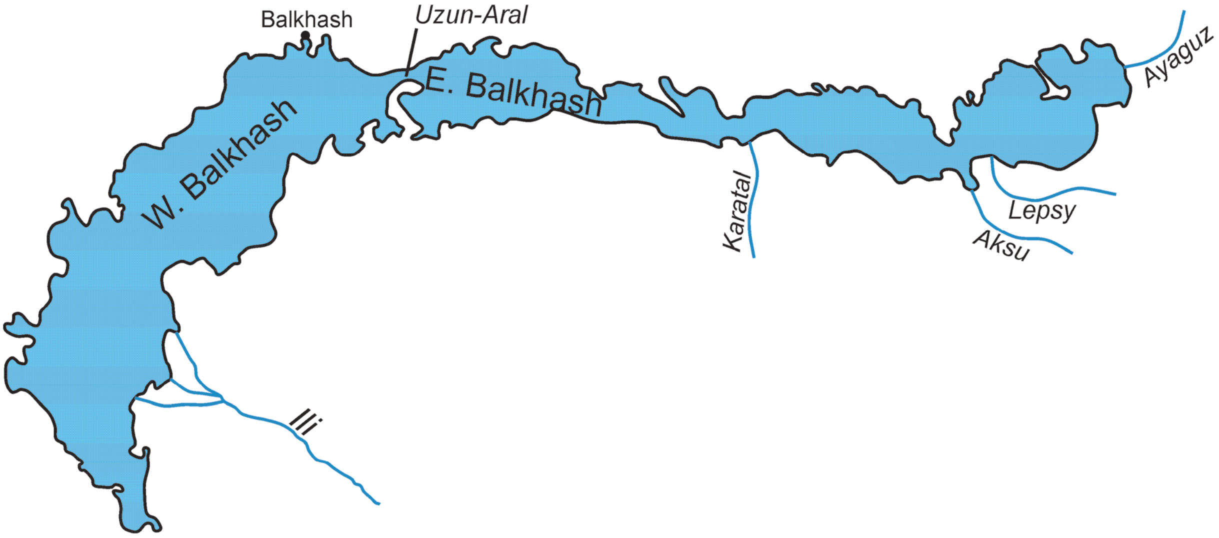

Fig. 4. Lake Balkhash.

for fishes, especially for their reproduction. This sharply affected the state of commercial fish populations. At the end of the 1960s, spawning conditions for semi-anadromous fishes significantly worsened. Beginning in 1971, negative effects of salinity on adult fishes appeared. By the middle of the 1970s, the natural reproduction of Aral fishes was destroyed. By 1981the Aral Sea had completely lost its fishery. The remaining ichthyofauna consisted of nine-spined stickle-back *Pungitius platygaster aralensis*, as well as gobies, atherine and Baltic herring. Aboriginal commercial fishes survived only in the Syr Darya and Amu Darya rivers and deltaic lakes. To restore the Aral Sea fishery, the flounder-gloss *Platichthys flesus luscus* was successfully introduced in 1979-1987. This marine fish can reproduce at salinities from 17-60 g/L and remained the only commercial fish from 1991 to 2000. The Large Aral by the end of the 1990s lost all ichthyofauna (Ermakhanov *et al.*, 2012).

After construction of the Kok-Aral dam, with freshening of the Small Aral Sea, aboriginal fish began to be found again. The fish fauna expanded spawning and feeding zones to almost the entire Small Aral (Ermakhanov *et al.*, 2012).

Regression and salinization of the Aral Sea caused the destruction of the majority of vegetational complexes. During the 1970s, the species composition was depleted and a few euryhaline species became dominant. Reed-beds in the 1980s disappeared completely. By the end of the 1980s there was only *Ruppia* spp. tolerating salinity of 50 g/L (Plotnikov *et al.*, 2014b).

In the Small Aral in the 1990s, the bulk of macrophytobenthos production belonged to the macroalgae *Chaetomorpha linum*, *Cladophora glomerata* and *Cl. fracta*. Macrophyte communities were formed of flowering plants *Phragmites australis*, *Ruppia cirrhosa*, *R. maritima*, *Zostera noltii*, and charophytes *Lamprothamnium papulosum* and *Chara aculeolata*. Near the Syr Darya delta reed-beds began to form. At present, this water body is settled widely by species of hydrophytes and helophytes coming from other continental brackish water bodies. In the hypersaline Large Aral microphytobenthos (diatoms and blue-green algae) dominates. Among macrophytobenthos only *Cladophora* and *Vaucheria* were found. From higher plants, sterile specimens of *Ruppia* sp. were found (Zavialov *et al.*, 2012; Plotnikov *et al.*, 2014b).

4. Lake Balkhash

Large endorheic Lake Balkhash (**Figure 4**) is located in the desert territory of eastern Kazakhstan in the western part of Balkhash-Alakol Depression at ~340 m asl. Its length is ~600 km, width is ~74 km in the western part and 9-19 km in the eastern part. The water surface area of the lake is variable depending on its level and ranges 17,000-22,000 km^2. In the 1960s, the maximum depth was 27 m. The average depth of the lake is 5.8 m, the total water volume is about 106 km^3 (Alekin, 1984; Domrachev, 1933; Semenov and Kurdin, 1970).

Lake Balkhash has two distinct parts divided by Saryesik peninsula. The western part is larger by area (>10,000 km^2) and shallow (up to 11 m). The eastern part has a lower area (>7,000 km^2) but is deeper (up to 26 m). Narrow (width ~3.5 km) and shallow (~3 m); strait Uzun-Aral connects them. The water exchange between these two parts is limited.

Rivers give ~80% of water flowing into the lake. The losses consist of evaporation from the lake surface (in arid climate, it consumes almost all the incoming water) and water infiltration into the lakebed (Yunusov, 1950; Zhirkevich, 1972).

The catchment area of the Lake Balkhash is ~413,000 km^2. All five rivers flowing into the Lake Balkhash are formed in the mountains. The only river flowing into the Western Balkhash is Ili. This largest tributary supplies up to 80% of the total riverine run-off to the lake. Rivers Karatal, Aksu, Lepsy and Ayaguz flow into the Eastern Balkhash (Alekin, 1984).

The Lake Balkhash level is unstable and is highly dependent on climate change. In the history the lake oscillated between high and low levels (Endo *et al.*, 2012). From 1911 to 1946 the level dropped by 3 m (from 344 to 341 m asl) followed by 15 years of increase up to 343 m asl (Petr, 1992). Until 1970, the lake level kept stable, but the construction of the Kapshagay reservoir on the Ili River and the development of irrigation along it changed the situation. A drastic change of the riverine runoff caused between 1970 and 1987 a drop of the lake level by ~2 m (Kezer and Matsuyama, 2006). Then, from 1987 to 2005, the lake water level rose again up to 343 m due to increasing moisture in the region and income of additional water to Ili River by melting of mountain glaciers.

In winter, Lake Balkhash is covered with ice (Abrosov, 1973).

Average salinity of the Lake Balkhash is 2.2-2.94 g/L. Western Balkhash is freshened, average salinity is 1.1-1.6 g/L, while in the eastern part it is up to 3.3-4.7 g/L, reaching 6-7 g/L in shallows (Sechnoy, 1974; Tarasov, 1961). Changes in the lake water level influence on its salinity (Aladin, Plotnikov, 1993).

Waters of the Lake Balkhash are strongly metamorphosed. The proportion of chloride ions is by 2-3 times lower than in the oceanic water. Proportions of potassium, calcium and magnesium, sulfate, and carbonate/bicarbonate ions are much higher (Alekin, 1984; Panov, 1933). This ionic composition (high concentrations of potassium and magnesium): is unfavorable for biota (Karpevich, 1975).

Over 350 species and varieties of algae are known in Balkhash. The most of them are diatoms, green algae and blue-green algae. Most of algae are freshwater or euryhaline, also there are several halophiles, halobionts and mezohalobionts. Benthic algae are mainly diatoms and charophyceans (Abrosov, 1973; Alekin, 1984; Karpevich, 1975).

Due to the geographical isolation, fauna of Balkhash was originally qualitatively and quantitatively poor.

In the past, rotifers played the leading role in zooplankton, and *Keratella quadrata* predominated. Among copepods, *Arctodiaptomus salinus* and sometimes *Thermocyclops crassus* and *Mesocyclops leuckarti* were the leading forms (Rylov, 1933; Abrosov, 1973). In 1978-1980, the water level fall and salinity increase led to significant changes in the development of zooplankton. Many species of rotifers and crustaceans disappeared almost completely. The most common were *A. salinus* and *Diaphanosoma lacustris*. In 1983-1985 with continuous water level fall and salinity increase, the total number of species has declined by more than half compared to the end of the 1960s. Small forms completely fell from the zooplankton. The number of freshwater cyclopids, cladocerans and rotifers was low. By the end of 1990s, zooplankton stabilized in quality. The role of rotifers is negligible, although in the 1970s they predominated over crustaceans (Isbekov *et al.*, 2019).

Initially, zoobenthos species composition in Balkhash was very poor. It was represented mainly by larvae of insects, especially chironomids. Numerous were larvae of dragonflies, mayflies, stoneflies and caddisflies, aquatic hemipterans and beetles (Abrosov, 1973; Karpevich, 1975; Isbekov *et al.*, 2019). Oligochaetes are widespread, 9 species of them are known. Only 6 species of Ostracoda are found (Abrosov, 1973). In the native crustacean fauna of Balkhash, there are only three species of Malacostraca. Aboriginal fauna of mollusks consisted only of freshwater species. The most numerous in the past were gastropods *Valvata piscinalis*, *Planorbis* spp. and bivalve *Pisidium henslowanum* (Isbekov *et al.*, 2019).

In 1953-1966, in order to strengthen food base for commercial fish several species of benthic invertebrates were acclimatized from Ponto-Caspian: polychaetes *Hypania invalida*, *Hypaniola kowalevskii*, amphipod *Corophium curvispinum*, mysids *Paramysis lacustris*, *P. intermedia*, *P. ullskyi* and *P. baeri* and bivalve mollusc *Monodacna colorata*. Freshwater bivalves *Anodonta cygnea* and *A. cellensis* appeared in the lake incidentally because their glochidia were on the gills of introduced zander (Karpevich, 1975).

Currently, 93 native and introduced invertebrate species are recorded in the macrozoobenthos of Balkhash. In 2009-2013, the main taxonomic group in the benthic fauna is native larval and adult insects. However, in zoobenthos the dominant by biomass are the introduced representatives of the Ponto-Caspian complex (Isbekov *et al.*, 2019).

Present fish fauna of Balkhash includes 26 species, but only 6 are native: Ili marinka *Schizothorax pseudaksaiensis pseudaksaiensis*, Balkhash perch *Perca schrenkii*, spotted stone loach *Triplophysa strauchi*—endemics of

Fig. 5. Lake Issyk-Kul.

Balkhash-Alakol basin, Balkhash marinka *Sch. argentatus*, plain thicklip loach *Barbatula labiata* and Balkhash minnow *Lagowskiella poljakowi*. Othes were introduced intentionally or are auto-acclimatizants. Both marinkas perch now disappeared in the lake (Abrosov, 1973; Karpevich, 1975; Isbekov *et al.*, 2019).

5. Issyk-Kul

Issyk-Kul (**Figure 5**) is a terminal, endorheic, lake located in north-eastern Kirghizia in mountains of northern Tien Shan (elevation 1606 m asl). The lake area ~6200 km^2, length 178 km, width 60 km, maximum depth 668 m, average depth, 278 m, volume 1738 km^3. More than 50 rivers flow into Issyk-Kul. The largest of them are the Dzhergalan and Tyup. Rivers are snow-fed. Water from underground sources is of great significance in the water balance (Podrezov *et al.*, 2020).

The water level of Issyk-Kul fluctuates. Thousand years ago the water level was lower than at present. In the 17-18th centuries, it was higher than now (Rosenwinkel *et al.*, 2017), and an outflow into the Chu River existed. Then, the level has decreased (Alekin, 1984).

The regional climate is warm, temperate and dry. The lake is not covered with ice in winter, but in cold winters, ice can appear in some bays (Alekin, 1984; Aladin and Plotnikov, 1993).

At present water salinity is 6 g/L, while in 1930 it was some lower, 5.8 g/L. Compared to ocean water, sulphate concentrations are higher (44 equiv. percent), chlorides are lower (45 equiv. percent), and there is more magnesium, calcium and bicarbonate/carbonate but less sodium and potassium (68.5 equiv. percent) (Alekin, 1984)

In phytoplankton of Issyk-Kul 346 algal species are known. Cyanobacteria, diatoms and green algae predominate. There are many periphytic diatoms (Kulumbaeva, 1982; Podrezov *et al.*, 2020).

Angiosperms occur down to 2 m, and charophytes are present. The latter form an unbroken carpet down to depths of 30-40 m, and dominate the aquatic plant communities of the lake. The highest production of charophytes occurs at depths from 15 to 20 m. Of the angiosperms, common reed *Phragmites australis* is most common but various species of pondweeds *Potamogeton* spp. are widespread (Alekin, 1984).

In zooplankton 154 species are recorded: 76 protozoans, 59 rotifers, 11 cladocerans, and 8 copepods. In the open lake, there are numerous only 9 species of rotifers, 2 species of cladocerans, and 2 species of copepods. The dominant of zooplankton, amounting up to 75-95% of abundance and 95-99% of the total biomass, is low productive copepod *Arctodiaptomus salinus*. The total zooplankton biomass is low (Alekin, 1984; Foliyan, 1973, 1981; Savvaitova and Petr, 1992; Podrezov *et al.*, 2020).

In zoobenthos 224 species and subspecies are known (Pavlova, 1964): 3 of mollusks, 35 chironomid larvae, 2 other larval dipterous, 2 aquatic beetles, 5 aquatic hemipterans, 7 caddisfly larvae, 1 stonefly larva, 4 dragonfly larvae, 5 acarians, 5 amphipods, 12 ostracods, 5 leeches, 5 oligochaetes, and 35 protozoans. Turbellarians and nematodes occur also. Chironomids, mollusks, amphipods and mysids are predominating. Oligochaetes *Enchytraeus przewalskii*, *E. issykulensis* and amphipod *Issykogammarus hamatus* are endemics of Issyk-Kul and only those occur in profundal. Among molluscs, *Radix auricularia* is the most widespread, occurs down to ~60 m (Pavlova, 1964, 1983), and is the main food source of fish in the lake. Also widespread are the amphipods *Gammarus negri* and *G. ocellatus* (Podrezov *et al.*, 2020).

In the 1960s, the Ponto-Caspian mysids *Paramysis lacustris*, *P. baeri* and *P. intermedia* were introduced from Lake Balkhash. These crustaceans have settled during the 1970s over shallow areas, particularly in bays and fresher localities near the rivers mouths.

The fish fauna consists of 27 taxa from five families. Schmidt's dace *Leuciscus schmidti*, Issyk-Kul dace *L. bergi*, gudgeon *Gobio gobio latus*, Issyk-Kul marinka *Schizothorax issykkuli*, spotted stone loachs *Nemachilus strauchi ulacholicus* and *N. strauchi dorsaloides* and the scaleless osman *Dyptychus dybovskii* are endemics. Since the 1930s, many alien species have been successfully introduced. The first was the Sevan trout *Salmo ischan gegarkuni*; it was followed by the oriental bream *Abramis brama aralensis*, carp *Cyprinus carpio*, sander *Lucioperca lucioperca* and by many others. The main fish in the catches are daces, sander and trout (Alekin, 1984).

Because of appearance of alien predatory fish such as the rainbow trout *Oncorhynchus mykiss*, the endemic fish fauna of Issyk-Kul is endangered now (Alamanov and Mikkola, 2011). Today the alien fishes represent 73% of the total ichthyofauna of the lake (Podrezov *et al.*, 2020).

In the bays of Issyk-Kul nearly 20,000-50,000 individuals of aquatic birds spend the winter. To protect them, in 1958 a reserve was established. It also protects pheasants and the mountain fauna of Kirghizia. In 1944, the muskrat *Ondatra zibethicus* was introduced and has spread in marsh vegetation in some localities along the shores (Aladin and Plotnikov, 1993).

6. Lake Alakol

Lake Alakol (**Figure 6**) is located in the semi-desert zone of Kazakhstan within the Balkhash-Alakol depression at an altitude of 343 m asl. Stretching from northwest to southeast, it is 104 km long, 52 km wide and has an area of 2,650 km^2. The maximum depth of the lake is 54 m, the average is 22.1 m. In 1952-1962, the water level rose by 4.25 m. The average annual fluctuations in the water level are 1.2 m. More than 15 rivers flow into the lake, of which the main rivers are Urzhar, Katynsu, and Emel.

Salinity of lake water varies from 0.8 to 9.5 g/L. According to long-term data, water salinity was the lowest in the northern and eastern parts of the lake. The duration of freeze-up is about 2 months (February-March). The largest thickness of ice is 0.8 m (in February). Melting ice is in a period of April-early May (Krupa *et al.*, 2010).

In total in Lake Alakol, 208 species and infraspecies of algae and cyanobacteria from 5 taxonomic divisions were

Fig. 6. Lake Alakol.

identified (Jiyenbekov *et al.*, 2018). Among algae, Bacillariophyta was distinguished by the greatest taxonomic diversity—134 species. Blue-green algae in the lake are represented by 21 species, charophytes by 20 species. Green algae and euglenids are represented by 15 and 6 species, respectively (Jiyenbekov *et al.*, 2019).

Macrophytes are represented by 25 plant species. Genus *Potamogeton* is one of the most rich genera in terms of species composition; it contains 5 species, with the most frequently recorded two species—*P. natans* and *P. perfoliatus*. *Nymphaea candida* and *Nuphar luteum*, *Myriophyllum spicatum* and *M. verticillatum*, *Hydrocharis* sp., *Najas* sp., *Ceratophyllum demersum*, *Spirodela polyrhiza* are often found in the lake (Jashenko *et al.*, 2019). Macrophytes are found throughout the lake, but are most developed in the northwest.

In the composition of zooplankton, 135 species of invertebrates have been identified. Crustaceans *Ceriodaphnia reticulata*, *Coronatella rectangula*, *Mesocyclops leuckarti*, *Arctodiaptomus salinus*, rotifers *Keratella quadrata*, *Filinia longiseta* are a constant component of zooplankton. In the zooplankton of the pelagic zone, there are 8-12 species, while in the estuarine areas the diversity of plankton increases to 16-22 species. At lake depth below 16 m, the dominant forms are *A. salinus* and *K. quadrata* (Krupa *et al.*, 2010).

The zoobenthos of Lake Alakol contains 43 taxa (Jashenko *et al.*, 2019). All these species are widespread in the water bodies of the Palearctic, with the exception of the endemic species of mollusks *Bithynia caerulans*, which currently lives in Lake Balkhash and the lakes of the Alakol Biosphere Reserve (Koshkarkol, Sasykkol and Alakol lakes). The zoobenthos is dominated by chironomids. The species composition of the open parts of the Alakol lake is relatively poor; only their separate shallow areas are distinguished by biodiversity. The open areas of Lake Alakol are characterized by presence of chironomids *Chironomus behningi*, *Polypedilum. scalaenum*, *Stictochironomus* gr. *histrio*. In the western parts of Lake Alakol, the identified biodiversity of benthic organisms in autumn is relatively low. There is a significant difference in the populations of silts and silty-sandy grounds. In the first, the chironomids *Ch. behningi* and *Cryptochironomus defectus* (up to 60 ind./m^2.): prevailed, in the second—*St.* gr. *histrio*. Only a few species were common to both types of sites (Lopatin *et al.*, 2007).

Common minnow *Phoxinus phoxinus*, Balkhash marinka *Schizothorax argentatus*, *Gymnodiptychus dybowskii*, Tibetan stone loach *Triplophysa stoliczkai*, gray stone loach *Nemachilus dorzalis*, spotted stone loach *N. labiatus*, Severtzov's stone loach *N. sewerzowi* and Balkhash perch *Perca schrenki* were found in the lake before the start of acclimatizations (Jashenko *et al.*, 2019). As a result of acclimatizations, the species composition of Alakol fish fauna has been significantly enriched by many species: Chinese false gudgeon *Abbotina rivularis*, bream *Abramis brama*, Prussian carp *Carassius auratus gibelio*, grass carp *Ctenopharyngodon idella*, carp *Cyprinus carpio*, sander *Stizostedion lucioperca*, Chinese freshwater sleeper *Micropercups cinctus*, Amur goby *Rhinogobius brunneus* and sharpbelly *Hemiculter leucisculus* (Strelnikov *et al.*, 2016). Some introduced species, such as grass carp, silver carp, could not create a self-reproducing population. If the introduction of pike perch in Balkhash had catastrophic consequences for aboriginal fish species, then the situation in Alakol was another. High salinity became an obstacle to the increase in the number of pike perch in the lake. However, the pike perch has settled the water areas where the rivers flow into the lake. At first, the basis of its food was Balkhash perch and spotted stone loach, later, due to the disappearance of

Fig. 7. Lake Tengiz.

native species from these areas, pike perch began to feed mainly on alien species. The saline part of the lake remains the habitat of the native species. Since the pike perch has settled the estuarine areas of rivers spawning for Balkhash perch, marinka and spotted stone loach, a further decrease in the number of native species should be expected as far as their extinction.

In 1998, the Alakol Nature Reserve was created here. Part of its territory (3300 hectares): is located on three large islands in the center of the water area of Lake Alakol (Berezovikov, 2006).

7. Lake Tengiz

The bitter-salty Lake Tengiz (**Figure 7**) is located in Central Kazakhstan on the elevated Tengiz plain in the Kazakh Upland, in closed depression. The lake is a terminal water body in the Tengiz-Kurgaldzhi lake system. It is a part of the Korgalzhinsky Nature Reserve and is included in the list of wetlands of international importance that fall under the Ramsar Convention. Its area, in some years, reaches 1590 km^2; length up to 74 km, width up to 40.2 km.

Tengiz-Kurgaldzhi system is fed by the waters of the Nura River, and during the spring flood, which accounts for 70-90% of the annual flow, by the water of rivers Kulanutpes, Kona and small steppe rivers. The system of the Kurgaldzhi stretches is not stagnant, and the lake Tengiz is the terminal water body (Shitnikov, 1968). Teniz-Kurgaldzhi lakes are characterized by an unstable hydrological regime, which causes significant inter-annual fluctuations in their morphometric, hydrochemical and hydrobiological parameters. The total area of the lakes in the system (2330-2600 km^2): depends on the volume of the incoming river runoff and the total moisture content of the basin territory. In dry years, there is a shallowing and partial drying of many lakes in the region, including Lake Tengiz (Krupa and Slivinsky, 2013). The reservoir is completely devoid of emergent vegetation. Its coastline is very winding and forms many promontories and branching shallow bays that jut deep into the land. The shores of the lake are low-lying, turning into an extremely flat bottom. Almost everywhere, the lake is surrounded for 2-3 km (and in some places up to 5 km) by drying salt licks (Andrusenko and Zhuliy, 1978). The maximum depth of the lake is about 8 m in high-water years.

The total mineralization of Lake Tengiz water varies considerably from year to year. So, for example, in the high-water 2005, it ranged from 40.6-54.9 g/L (Global'no ..., 2007), and in the low-water 2012, the salinity of the lake Tengiz has almost tripled—154.7 g/L.

The ionic composition of water is characterized by the predominance of chlorides and sodium ions; the water in Lake Tengiz is very hard (43.6 meq/L): (Krupa and Slivinsky, 2013).

The aquatic fauna of the lake is practically not studied. One species of ostracods *Eucypris inflata* (Gvozdev and Maksimova, 1978), branchiopods *Artemia salina* (Maximova, 1977; Maksimova, 1988) and *Branchinella spinosa* (Maksimova, 1990) were found in the lake. All of the above mentioned species are food for numerous birds nesting on the lake (Maksimova, 1977; Gvozdev and Maksimova, 1978; Maksimova, 1988).

The basis of the abundance (2274 ind./m^3): and biomass (2518 mg/m^3) of zooplankton was formed by the branchiopod crustacean *Artemia* (Krupa and Slivinsky, 2013). *Branchinella spinosa* in mass are found only during the period of strong freshening of the lake during the spring high water. Later, in the summer and autumn months, as the water salinity in the lake increases, the number of crustaceans rapidly decreases until their active forms completely disappear (Maksimova, 1990).

The identification of *Artemia* inhabiting the lake as *A. salina*, made at the end of the 20th century, raises doubts. It is known that *A. parthenogenetica* was found in the lakes of northern Kazakhstan and the Large Aral (Sharapova *et al.*, 2016; Shalgimbaeva and Volkov, 2017).

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