BIODIVERSITY OF THE ARAL SEA AND ITS IMPORTANCE TO THE POSSIBLE WAYS OF REHABILITATING AND CONSERVING ITS REMNANT WATER BODIES

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Abstract. The Aral Sea, despite being the 4th largest lake in the world up to 1960, has now split into six separate water bodies. This break-up and desiccation resulted overwhelmingly from upstream irrigation withdrawals from the two main influent rivers, the Syr Darya and the Amu Darya. The negative effects on both the lake's ecosystem due to declining water level and increasing salinity, as well as the profound socioeconomic and human impacts to the riparian populations are well documented. This paper focuses on the conservation and rehabilitation efforts of the remnant water bodies with a focus on four key areas: the Northern (Small) Aral and its ecosystem; the Southern (Large) Aral and its ecosystem; the delta and deltaic water bodies of the Syr Darya; and the delta and deltaic water bodies of the Amu Darya. It is encouraging to note the reversal of degradation in the Northern Aral after the creation of a dike at Berg's Strait in 1992. The dike washed out in 1999 but has been replaced with a new structurally sound dike. The water level in the Northern Aral has increased several meters and salinity is returning to levels that can sustain the pre-1960 ecosystem. However, much less success has been seen regarding the Southern Aral, which continues its retreat and hypersalinization. There have been recent efforts also in the

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deltas and deltaic regions of the Syr Darya and Amu Darya, with the rehabilitation of Sudochie Lake perhaps being the best known. All of these restoration projects are critiqued in this paper and recommendations for future actions are made.

Keywords: Aral Sea, deltaic water bodies, lake basin management, rehabilitation, saline lakes, salinity, osmoregulation

1. The Aral Sea and its biodiversity

The Aral Sea was the 4th largest lake in the world by water surface area in 1960. At that time its area was 67,499 km^2 (Large Aral 61,381 km^2, Small Aral 6,118 km^2) and volume was 1,089 km^3 (Large Aral 1,007 km^3, Small Aral 82 km^3). The Aral Sea was +53.4 m above ocean level with maximum depth 69 m. It was a slightly saline lake with average salinity about 10 g/L.

The Aral Sea was inhabited by about 12 species of fishes and about 160 species of free-living invertebrates excluding Protozoa and small-size Metazoa as listed in Table 1 (Atlas of the Aral Sea invertebrates, 1974).

TABLE 1. Aboriginal fishes and free-living invertebrates in the Aral Sea (Atlas of the Aral Sea invertebrates, 1974).

Species	Type of osmoregulation
Coelenterata	
Protohydra leuckarti Greef, 1970	A3
Turbellaria	
Mecynostomum agile (Beklemischev, 1927)	A3
Macrostomum hystricinum Beklemischev, 1927	A3
M. minimum (Luther, 1947)	A3
Promonotus orientalis Beklemischev, 1927	A3
Kirgisella forcipata Beklemischev, 1927	A3
Gieysztoria bergi (Beklemischev, 1927)	A3
Byrsophlebs geniculata Beklemischev, 1927	A3
Beklemischeviella contorta (Beklemischev, 1927)	A3
Phonorhynchoides flagellatus Beklemischev, 1927	A3
Gyratrix hermaphroditus Ehrenberg, 1831	A3
Pontaralia relicta (Beklemischev, 1927)	A3
Placorhynchus octaculeatus ssp. *dimorphis* (Karling, 1931)	A3
Nematodes	
Adoncolaimus aralensis Filipjev, 1923	C1
Rotatoria	

Species	Type of osmoregulation
Eosphora ehrenbergi Weber, 1918	C1
Trichocerca (*Diurella*) *heterodactyla* Tschugunoff, 1921	C1
T. (*D*.) *similis* (Wierzejski, 1893)	C1
T. (*D*.) *porcellus* (Gosse, 1851)	C1
T. (s. str.) *elongata* (Gosse, 1896)	C1
T. (s. str.) *pusilla* (Lauterborn, 1898)	C1
T. (s. str.) *longiseta* (Schrank, 1802)	C1
T. (s. str.) *caspica* Tschugunoff, 1921	C1
Synchaeta stylata Wierzejski, 1893	C1
S. vorax Rousselet, 1902	C2
S. tremula (Müller, 1786)	C2
S. pectinata Ehrenberg, 1832	C1
Polyarthra euryptera Wierzejski, 1891	C1
P. luminosa Kutikova, 1962	C1
P. vulgaris Carlin, 1943	C1
P. longiremis Carlin, 1943	C1
Lindia torulosa Dujardin, 1841	C2
Encentrum limicola Otto, 1963	C2
Asplanchna priodonta Gosse, 1850	C1
A. girodi Guerne, 1888	C1
Brachionus angularis Gosse, 1851	C1
B. calyciflorus Pallas, 1776	C1
B. quadridentatus Hermann, 1783	C2
B. plicatilis Müller, 1786	C2
B. rubens Ehrenberg, 1838	C1
B. urceus (Linnaeus, 1758)	C1
Platyias quadricornis (Ehrenberg, 1832)	C1
P. palustris (Müller, 1786)	C1
Keratella cochlearis (Gosse, 1851)	C2
K. tropica (Apstein, 1907)	C2
K. quadrata (Müller, 1786)	C2
K. valga (Ehrenberg, 1834)	C2
Notholca squamula (Müller, 1786)	C2
N. acuminata (Ehrenberg, 1832)	C2
Kellicottia longispina (Kellicott, 1879)	C1
Euchlanis dilatata Ehrenberg, 1832	C1
E. triquerta Ehrenberg, 1838	C1
Trichotria pocillum (Müller, 1776)	C1
T. tetractis (Ehrenberg, 1830)	C1
Mytilina ventralis (Ehrenberg, 1832)	C1
Lecane (*Lecane*) *luna* (Müller, 1776)	C1

Species	Type of osmoregulation
L. (*L*.) *ungulata* (Gosse, 1887)	C1
L. (*Monostyla*) *lamellata* (Daday, 1893)	C1
L. (*M*.) *stenroosi* (Meissner, 1908)	C1
L. (*M*.) *bulla* (Gosse, 1851)	C1
L. (*M*.) *lunaris* (Ehrenberg, 1832)	C1
Colurella obtusa (Gosse, 1886)	C1
C. adriatica Ehrenberg, 1831	C2
C. uncinata (Müller, 1773)	C1
C. colurus (Ehrenberg, 1830)	C2
Hexarthra fennica (Levander, 1892)	C2
H. oxyuris (Zernov, 1903)	C2
H. mira (Hudson, 1871)	C1
Testudinella patina (Hermann, 1783)	C2
T. bidentata (Ternetz, 1892)	C1
Filinia longiseta (Ehrenberg, 1834)	C1
Collotheca mutabilis (Hudson, 1885)	C1
Oligochaeta	
Aeolosoma hemprichi Ehrenberg, 1828	C1
Nais elingius Müller, 1773	C1
N. communis Piguet, 1906	C1
Paranais simplex Hrabe, 1936	C1
Amphichaeta sannio Kallstenius, 1892	C1
Chaetogaster sp.	C1
Limnodrilus helveticus Piguet, 1923	C1
Potamothrix bavaricus (Oeschmann, 1913)	C1
Psammorhyctides albicola (Michaelsen, 1901)	C1
Lumbriculus lineatus (Müller, 1771)	C1
Cladocera	
Diaphanosoma brachyurum Lievin, 1848	C1
Chydorus sphaericus (O. F. Müller, 1785)	C2
Alona rectangula G. Sars, 1861	C2
Bosmina longirostris (O. F. Müller, 1785)	C2
Daphnia longispina (O. F. Müller, 1776)	C2
Ceriodaphnia reticulata (Jurine, 1820)	C2
C. cornuta G. Sars, 1885	C2
C. pulchella G. Sars, 1862	C2
Moina mongolica Daday, 1901	D4
M. micrura Kurz, 1874	C2
Podonevadne camptonyx (G. Sars, 1897)	D3
P. angusta (G. Sars, 1897)	D1
Evadne anonyx G. Sars, 1897	D1

Species	Type of osmoregulation
Cercopagis pengoi aralensis M.-Boltovskoi, 1971	C2
Copepoda	
Phyllodiaptomus blanci (Guerne et Richard, 1896)	C1
Arctodiaptomus salinus (Daday, 1885)	B1
Halicyclops rotundipes aralensis Borutzky, 1971	B1
Cyclops vicinus Uljanin, 1875	C1
Acanthocyclops viridis (Jurine, 1820)	C1
Mesocyclops leuckarti (Claus, 1857)	C1
Thermocyclops crassus (Fischer, 1853)	C1
Harpacticoida	
Halectinosoma abrau (Kritchagin, 1873)	B2
Schizopera aralensis Borutzky, 1971	B2
S. jugurtha (Blanchard et Richard, 1891)	B2
S. reducta Borutzky, 1971	B2
Nitocra lacustris (Schmankewitsch, 1875)	A3
N. hibernica (Brady, 1880)	C1
Mesochra aestuarii Gurney, 1921	B2
Onychocamptus mohammed (Blanchard et Richard, 1891)	B2
Cletocamptus retrogressus Schmankewitsch, 1875	A3
C. confluens (Schmeil, 1894)	A3
Limnocletodes behningi Borutzky, 1926	C2
Nannopus palustris Brady, 1880	B2
Enchydrosoma birsteini Borutzky, 1971	A3
Leptocaris brevicornis (Van Douwe, 1905)	B2
Paraleptastacus spinicauda Noodt, 1954	A3
Ostracoda	
Darwinula stevensoni (Brady et Robertson, 1870)	C2
Candona marchica Hartwig, 1899	C1
Cyclocypris laevis (O. F. Müller, 1776)	C2
Plesiocypris newtoni (Brady et Robertson, 1870)	C1
Cyprideis torosa (Jones, 1850)	D4
Amnicythere cymbula (Livental, 1929)	D1
Tyrrhenocythere amnicola donetziensis (Dubowsky, 1926)	D1
Limnocythere (*Limnocythere*) *dubiosa* Daday, 1903	
L. (*L.*) *inopinata* (Baird, 1850)	C2
L. (*Galolimnocythere*) *aralensis* Schornikov, 1973	D1
Loxoconchissa (*Loxocaspia*) *immodulata* (Stepanaitys, 1958)	
Malacostraca	
Dikerogammarus aralensis (Uljanin, 1875)	B1
Hydracarina	
Eylais rimosa Piersig, 1899	C1

Species	Type of osmoregulation
Hydriphantes s. str. *Crassipalpis* Könike, 1914	C1
H. (*Polyhydriphantes*) *flexuosus* (Köenike, 1885)	C1
Hydrodroma despiciens (O. Müller, 1776)	C1
Limnesia undulata (O. F. Müller, 1776)	C1
Arrenurus s. Str. *Tricuspidator* (O. F. Müller, 1776)	C1
Copidognathus (s. str.) *oxianus* Viets, 1928	C1
Bivalvia	
D. polymorpha aralensis (Andrusov, 1897)	C2
D. p. obtusicarinata (Andrusov, 1897)	C2
D. caspia caspia Eichwald, 1829	C2
D. c. pallasi (Andrusov, 1897)	C2
Cerastoderma rhomboides rhomboides (Lamarck, 1819)	A3
C. isthmicum Issel, 1869	A3
H. vitrea bergi Starobogatov, 1971	A3
H. minima sidorovi Starobogatov, 1971	A3
H. m. minima (Ostroumoff, 1907)	A3
Gastropoda	
Theodoxus pallasi Lindholm, 1924	A3
Caspiohydrobia conica (Logvinenko et Starobogatov, 1968)	A3
C. husainovae Starobogatov, 1971	A3
Pisces	
Cyprinus carpio Linnaeus, 1758	C1
Rutilus rutilus aralensis Berg, 1916	C1
Abramis brama orientalis Berg, 1949	C1
Abramis sapa bergi natio *aralensis* Tjapkin, 1939	C1
Aspius aspius taeniatus (Eichwald, 1831)	C1
Barbus brachycephalus brachycephalus Kessler, 1872	C1
Capoetobrama kuschakewitschi (Kessler, 1872)	C1
Pelecus cultratus (Linnaeus, 1758)	C1
Scardinius erythrophthalmus (Linnaeus, 1758)	C1
Esox lucius Linnaeus, 1758	C1
Silurus glanis Linnaeus, 1758	C1
Gymnocephalus cernuus (Linnaeus, 1758)	C1
Perca fluviatilis Linnaeus, 1758	C1
Zander lucioperca (Linnaeus, 1758)	C1
Chalcalburnus chalcoides aralensis (Berg, 1923)	C1
Salmo trutta aralensis	D3
Pungitius platygaster aralensis (Kessler, 1877)	D3
Acipenser nudiventris (Lovetzky, 1828)	D3

Since 1960 the Aral Sea has steadily become shallower, owing overwhelmingly to water withdrawals upstream for irrigation. By 2007 the Aral was around 13,958 km^2 (21% of 1960), volume – 102 km^3 (9% of 1960). The Large Aral was 10,700 km^2 (17% of 1960) and had a volume of 75 km^3 (8% of 1960). Salinity of the Large Aral ranged from 100 g/L to well above that figure. Similar values for the Small Aral are 3,258 km^2 (53% of 1960), 27 km^3 (33% of 1960) with average salinity at about 10 g/L.

Prior to introduction of fishes and free-living invertebrates to the Aral Sea that started in the 1920s, the following aboriginal free-living animals were present: Fishes – 12, Coelenterata – 1, Turbellaria – 12, Rotatoria – 58, Oligohaeta – 10, Cladocera – 14, Copepoda – 7, Harpacticoida – 15, Ostracoda – 11, Malacostraca – 1, Hydracarina – 7, Bivalvia – 9, Gastropoda – 3. Total – 160. Protozoa and some other small-size Metazoa are not included.

Between the middle of the nineteenth century and 1961 the shape and salinity of the Aral Sea remained practically unchanged. We must note, however, that due to intended and accidental introductions that started in the 1920s the number of free-living animals grew substantially. In the Aral Sea appeared: Fishes – 21, Mysidacea – 5, Decapoda – 3, Copepoda – 3, Polychaeta – 1, Bivalvia – 4 for a total of 37 species (Table 2).

Originally in the Aral Sea there were freshwater, transitional freshwater-brackish water, brackish water and transitional brackish water-marine ecosystems. Brackish water ecosystems occupied the largest area (Figure 1). By the end of 1980s, due to salinity growth, marine ecosystems appeared in the Aral Sea and occupied the largest area instead of brackish water ecosystems (Figure 2). Now all parts of the Large Aral are occupied by hyperhaline ecosystems. In the Small Aral transitional brackish water-marine ecosystems are prevailing due to salinity decrease (Figures 3 and 4).

Abra ovata and *Nereis diversicolor* introduced by man are of great importance for fish nutrition. *Rhithropanopeus harrisii tridentata* was introduced accidentally and disturbs lake sediments.

Since the end of the 1980s, when the level dropped by about 13 m and reached about +40 m, the Aral Sea divided into the Large and Small Aral with area 40,000 km^2 (60% from 1960); volume 333 km^3 (33% from 1960); salinity 30 g/L (three times higher than in 1960).

In both newly created lakes salinity increased (Table 3) and under these new conditions the following free-living animals could survive: Fishes – 10; Rotatoria – 3; Cladocera – 2; Copepoda – 2; Ostracoda – 1; Decapoda – 2; Bivalvia – 2; Gastropoda – >2; Polychaeta – 1 for a total of >25 (Figures 5–8).

After the Aral Sea division, its volume has decreased from 1,000 km^3 to 400 km^3 by 2001 and to 108 km^3 by 2005 with the Large Aral Sea volume (2005) at 85 km^3 and the Small Aral Sea volume (2005) at 23 km^3 (Figure 9).

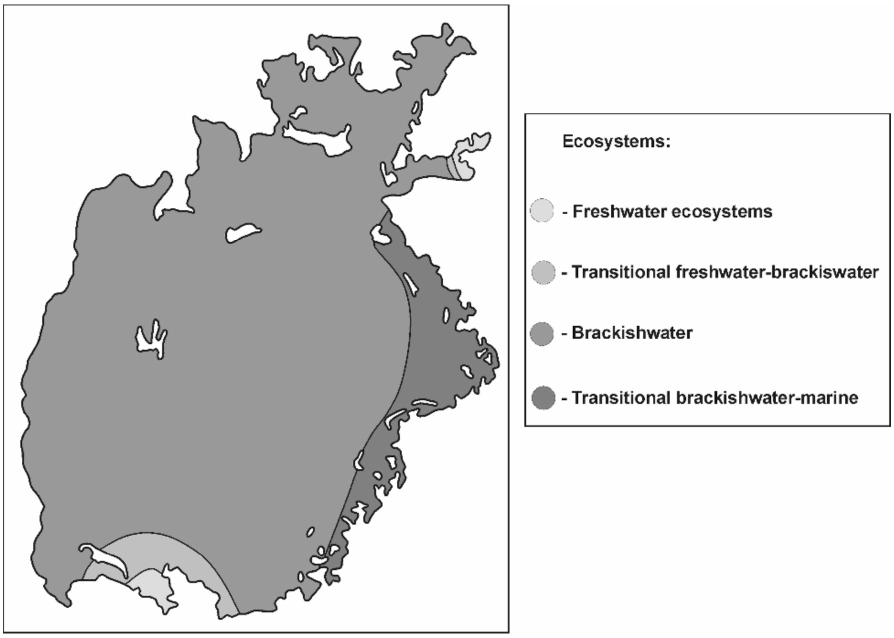

Figure 1. Ecosystems in relation to salinity before Aral Sea salinization.

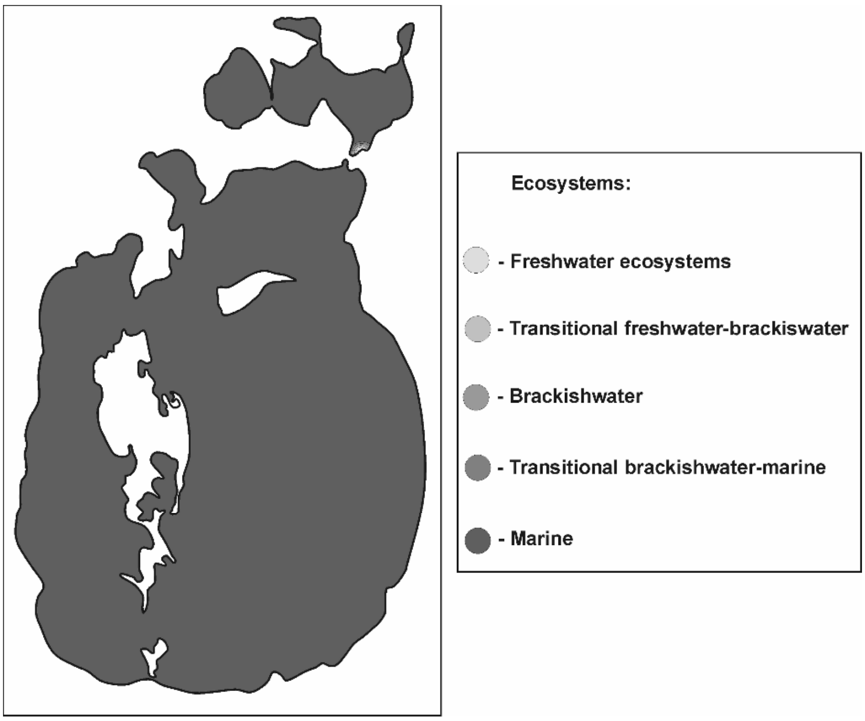

Figure 2. Ecosystems in relation to salinity at Aral Sea division.

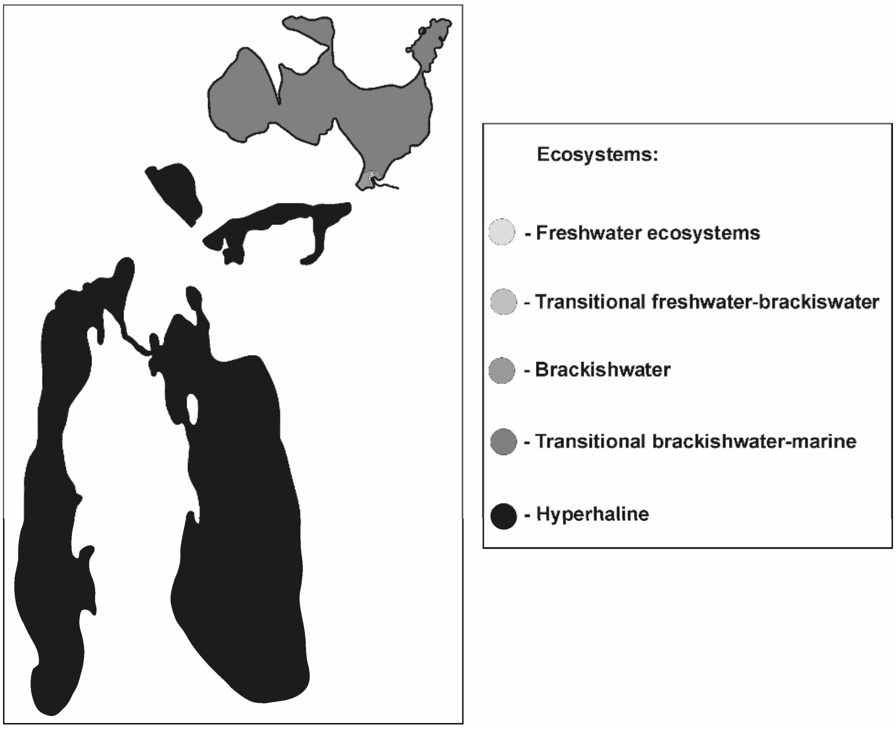

Figure 3. Ecosystems in relation to salinity now.

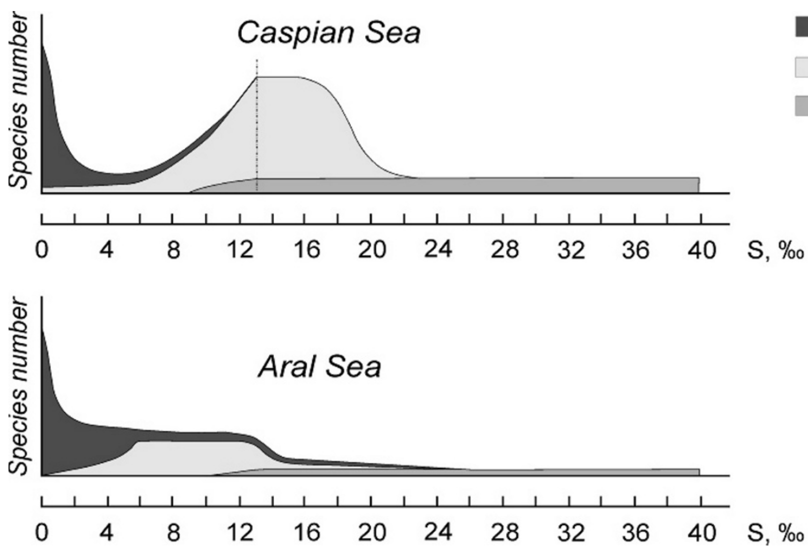

Figure 4. Scheme of aquatic fauna pattern change in the Caspian and Aral seas (by: Zenkevich, 1977; Andreeva and Andreev, 2001 with additions and corrections) 1 – freshwater, 2 – brackish-water, 3 – marine species.

TABLE 2. Alien fishes and free-living invertebrates in the Aral Sea (by: Aladin et al., 2004).

Taxon	Source	Year	Status	Status in the 1990s–2000s	Way	Impact	Type of osmo-regulation
Pisces							
Alosa caspia (Eichwald, 1838)	Caspian	1929–1932	–	–	A	0	D3
Acipenser stellatus Pallas, 1771	Caspian	1927–1934; 1948–1963	–	–	A	0	D3
Acipenser nudiventris derjavini Borzenko, 1950	Ural River	1958	–	–	A	–	D3
Acipenser guldenstadti Brandt et Ratzeburg, 1833	?	1978–1980	R	–	A	0	D3
Clupea harengus membras (Linnaeus, 1758)	Baltic Sea	1954–1959	R	?	A	+	D3
Liza auratus (Risso, 1810)	Caspian	1954–1956	–	–	A	0	E
Liza saliens (Risso, 1810)	Caspian	1954–1956	–	–	A	0	E
Ctenopharyngodon idella (Valenciennes, 1844)	China	1960–1961	C	–	A	+	C1
Hypophtalmichthys molifrix (Valenciennes, 1844)	China	1960–1961	C	–	A	+	C1
Aristichtys nobilis (Richardson, 1844)	China	1960–1961	R	–	A	+	C1
Platichthys flesus (Linnaeus, 1758)	Sea of Azov	1979–1987	C	C	A	+	E

Taxon	Source	Year	Status	Status in the 1990s–2000s	Way	Impact	Type of osmo-regulation
Mylopharyng-odon piceus (Richardson, 1845)	China	1960–1961	C	–	A+	0	C1
Syngnatus abaster caspius Eichwald	Caspian	1954–1956	R	–	A+	–	E
Atherina boyeri caspia Eichwald, 1838	Caspian	1954–1956	N	R	A+	–	E
Knipowitschia caucasicus (Berg, 1916)	Caspian	1954–1956	N	?	A+	–	D3
Neogobius fluviatilis (Pallas, 1811)	Caspian	1954–1956	N	?	A+	–	D3
Neogobius melanostomus (Pallas, 1811)	Caspian	1954–1956	N	–	A+	–	D3
Neogobius syrman (Nordmann, 1840)	Caspian	1954–1956	R	–	A+	–	D3
Proterorchinus marmoratus (Pallas, 1811)	Caspian	1954–1966	R	?	A+	–	D3
Neogobius kessleri (Gunter, 1861)	Caspian	1954–1956	R	–	A+	–	D3
Ophicephalus (*Channa*) *argus* Cantor, 1842	Kara–Kum canal	1960s	C	C	A+	+	C1
Branchiopada							
Artemia salina (Linnaeus, 1758)*	Aral region	1990s–2000s	N	N	N	+	D4
Ostracoda							
Eucypris inflata G.O. Sars, 1903*	Aral region	1990s–2000s	N	N	N	+	D4

Taxon	Source	Year	Status	Status in the 1990s–2000s	Way	Impact	Type of osmo-regulation
Mysidacea							
Paramysis baeri (Czerniavsky, 1882)	Don River	1958–1960	?	–	A	0	C2
Paramysis lacustris (Czerniavsky, 1882)	Don River	1958–1960	N	In deltas	A	+	C2
Paramysis intermedia (Czerniavsky, 1882)	Don River	1958–1960	N	–	A	+	C2
Paramysis ullskyi (Czerniavsky, 1882)	Don River	1958–1960	R	–	AC	+	C2
Limnomysis benedeni (Czerniavsky, 1882)	?	?	R	–	AC	+	C2
Decapoda							
Palaemon elegans Rathke, 1837	Caspian	1954–1966	N	N	A+	?	B1
P. adspersus Rathke, 1837	Caspian	1954–1966	?	–	A+	?	B1
Rhithropanopeus harrisii tridentata (Maitland, 1874)	Sea of Azov	1965, 1966,	N	N	A+	+	B2
Copepoda							
Calanipeda aquaedulcis Kritschagin, 1873	Sea of Azov	1965, 1966–1970	N	N	A	+	B1
Heterocope caspia Sars, 1897	?	1971	–	–	A	0	?
Acartia clausi Giesbrecht, 1889	?	1985, 1986	–	–	A	0	B1
Polychaeta							

Taxon	Source	Year	Status	Status in the 1990s–2000s	Way	Impact	Type of osmo-regulation
Hediste diversicolor (Müller, 1776)	Sea of Azov	1960–1961	N	N	A	+	A3
Bivalvia							
Abra ovata (Philippi, 1893)	Sea of Azov	1960, 1961, 1963	N	N	A	+	A3
Monodacna colorata (Eichwald, 1839)	?	1964, 1965	–	–	A	0	A3
Mytilus galloprovincialis Lamarck, 1819	Sea of Azov	1984–1986	–	–	A	0	A3
Mya arenaria Linnaeus, 1758	Sea of Azov	1984–1986	–	–	A	0	A3

Way of introduction: A – acclimatization, AC – by accident, A+ – incidentally at planned introduction, N – naturally.

Status: R – rare, N – numerous, C – commercial.

Impact: – negative, + positive, 0 no effect, ? unknown.

[*]Only in the Large Aral.

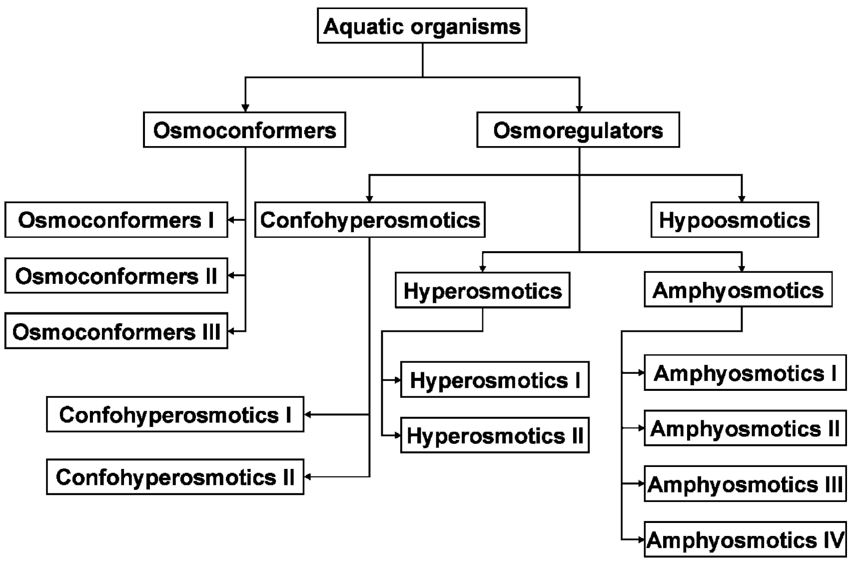

Figure 5. Classification of osmoconformers and osmoregulators.

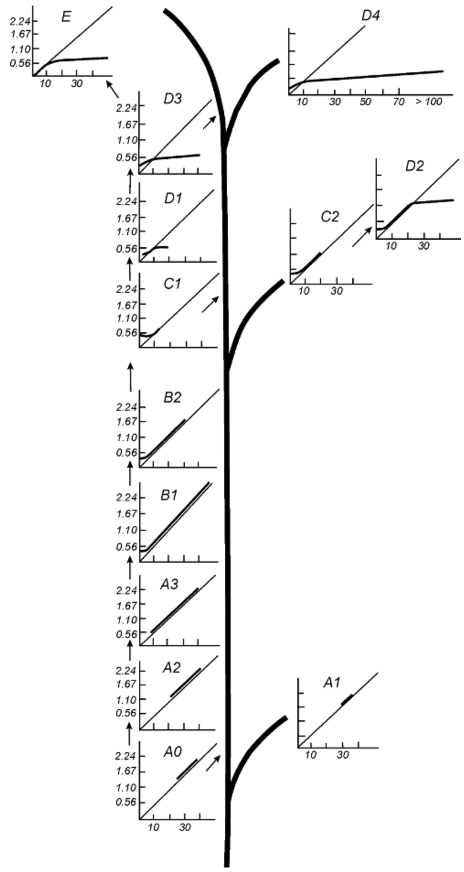

Figure 6. Evolution of all known types of osmoregulation (by: Aladin, 1996):

A0 – Hypothetic ancestral osmoconformer; A1 – Stenohaline marine hydrobionts (osmoconformers I) – 30–36‰; A2 – Marine hydrobionts (osmoconformers II) – 20–40‰; A3 – Euryhaline marine hydrobionts (osmoconformers III) – 8–40‰; B1 – Widely euryhaline marine hydrobionts (confohyperosmotics I) – 3–50‰ B2 – Brackish water hydrobionts of marine origin (confohyperosmotics II) – 0–30‰; C1 – Freshwater hydrobionts (hyperosmotics I) – 0–8‰; C2 – Brackish water hydrobionts of freshwater origin (hyperosmotics II or secondary confohyperosmotics) – 0–20‰; D1 – Some Caspian Brackish water hydrobionts (amphiosmotics I) – 0–20‰; D2 – Some euryhaline Australian hydrobionts of freshwater origin (amphiosmotics II) – 0–50‰; D3 – Euryhaline hydrobionts of freshwater origin (amphiosmotics III) – 0–50‰; D4 – Widely euryhaline hydrobionts of freshwater origin (amphiosmotics IV) – 0–300‰; E – Euryhaline marine hydrobionts of freshwater origin (hypoosmotics) – 8–50‰.

After the Aral Sea division salinity in the Large Aral continued to rise and reached 90 g/L (western part) and 160 g/L (eastern part) in 2005, while in the Small Aral it decreased and reached 17 g/L in 2005.

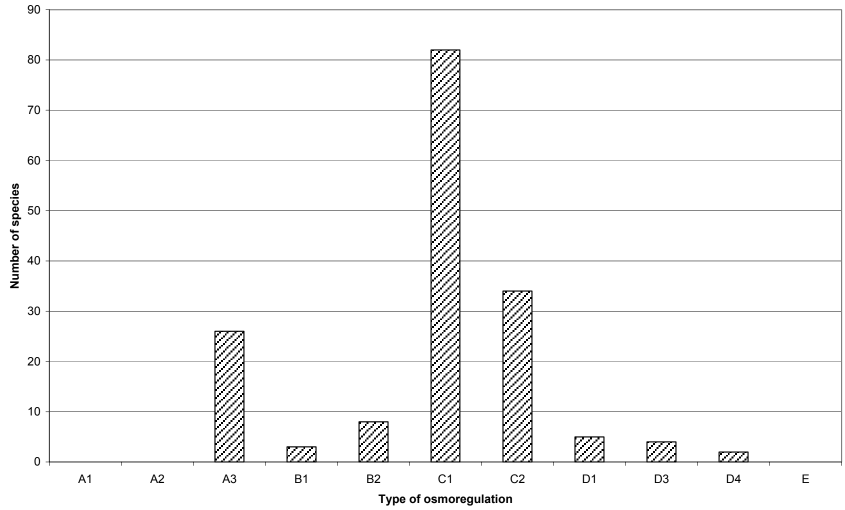

Figure 7. Number of different types of osmoregulation in aboriginal fishes and free-living invertebrates in the Aral Sea.

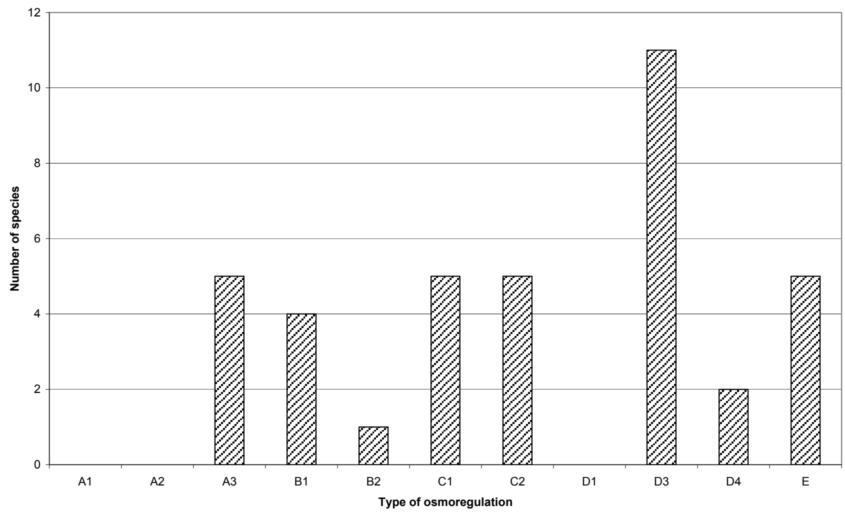

Figure 8. Number of different types of osmoregulation in alien fishes and free-living invertebrates in the Aral Sea.

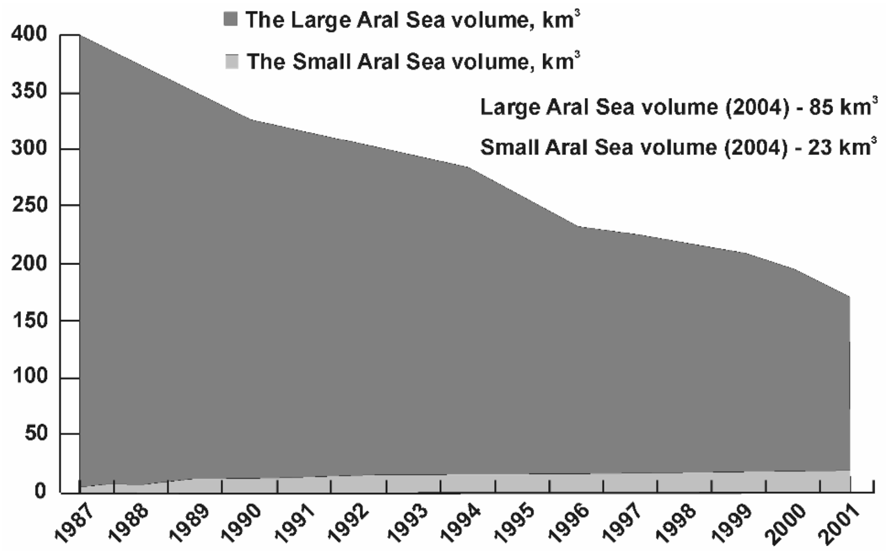

Figure 9. Changes in the Aral Sea volume.

TABLE 3. Hydrologic and salinity characteristics of the Aral Sea.

Year	Level (m asl)	Area (km^2)	% of 1960 area	Volume (km^3)	% of 1960 volume	Average salinity(g/L)	% 1960 salinity
1960 (whole sea)	53.4	67,499	100	1,089	100	10	100
Large Sea	53.4	61,381	100	1,007	100	10	100
Small Sea	53.4	6,118	100	82	100	10	100
1971 (whole sea)	51.1	60,200	89	925	85	10	100
1976 (whole sea)	48.3	55,700	83	763	70	14	140
1989 (whole sea)		39,734	59	365	33		
Large Sea	39.32	36,307	60	341	34	30	300
Small Sea	40.2	2,804	46	23	28	30	300
2007 (whole sea)		13,958	21	102	9		
Large Sea	29.4	10,700	17	75	8	East >100 West 100	>1,000 1,000
Small Sea	42.0	3,258	53	27	33	12?	120
2025 (whole sea)		9,058	14	68	6		
Large Sea[a]	21–28	6,400	10	41	4	>100 to 200	>1,000 to >2,000
Small Sea	42.0	3,258	53	27	33	5?	100

[a]The sea will consist of a western and eastern part with the west basin at 21 m with and the east at 28.3.

Sources: Compiled by P. Micklin from Asarin and Bortnik, 1987 and Bortnik and Chistyaevaya, 1990, Table 8.4, p. 72; Uzglavgidromet, 1994–2003; Water balance models, 1990–2006; Final Report, 2004; Ptichnikov, 2000, 2002; and Expedition, 2005 and 2007.

The zooplankton of the Aral Sea just after its separation (1989) under average salinity about 30 g/L was composed of the following invertebrates: Rotatoria – *Synchaeta vorax*, *S. cecilia*, *S. gyrina*; Cladocera – *Podonevadne camptonyx*, *Evadne anonyx*; Copepoda – *Calanipeda aquaedulcis*, *Halicyclops rotundipes aralensis*; larvae of Bivalvia – In zoobenthos there were Bivalvia – *Abra ovata*, *Cerastoderma isthmicum*; Gastropoda – *Caspiohydrobia* spp.; Polychaeta – *Nereis diversicolor*; Ostracoda – *Cyprideis torosa*; Decapoda – *Palaemon elegans*, *Rhithropanopeus harrisii tridentatus*. Fishes were represented by *Pungitius platygaster*, *Clupea harengus membras*, *Platichthys flesus*, *Atherina boyeri caspia*, *Knipowitschia caucasicus*, *Neogobius fluviatilis*, *N. melanostomus*, *N. syrman*, *N. kessleri*, *Proterorchinus marmoratus*.

2. Conservation and rehabilitation of Aral Sea and its ecosystems

There are four main ways of conservation and rehabilitation of Aral Sea and its ecosystems that were first discussed in Geneva (September 1992 – UNEP meeting):

1. Conservation and rehabilitation of Small Aral
2. Conservation and rehabilitation of Large Aral
3. Conservation and rehabilitation of delta and deltaic water bodies of Syr Darya
4. Conservation and rehabilitation of delta and deltaic water bodies of Amu Darya

Another option would be to give more water to the Eastern Large Aral from Small Aral via Berg Strait and from Amu Darya river via Ak Darya river bed. Level of Western Large Aral Sea might be maintainable using ground water flow from Amu Darya delta and Ustjurt plateau. Realization of this project will help biodiversity conservation.

2.1. WAY 1. CONSERVATION AND REHABILITATION OF SMALL ARAL AND ITS ECOSYSTEMS

Discharge of water from Small Aral occurs primarily in the spring-early summer high flow period on Syr Darya. Since August 2005 outflow has been controlled by a discharge structure (gates) in the dike (Figure 10).

The dike in Berg Strait is preserving the Small (Northern) Aral and rehabilitating its biodiversity. The old dike was built by our proposal in August 1992 (Aladin et al., 1995). It existed, with periodic partial breaches,

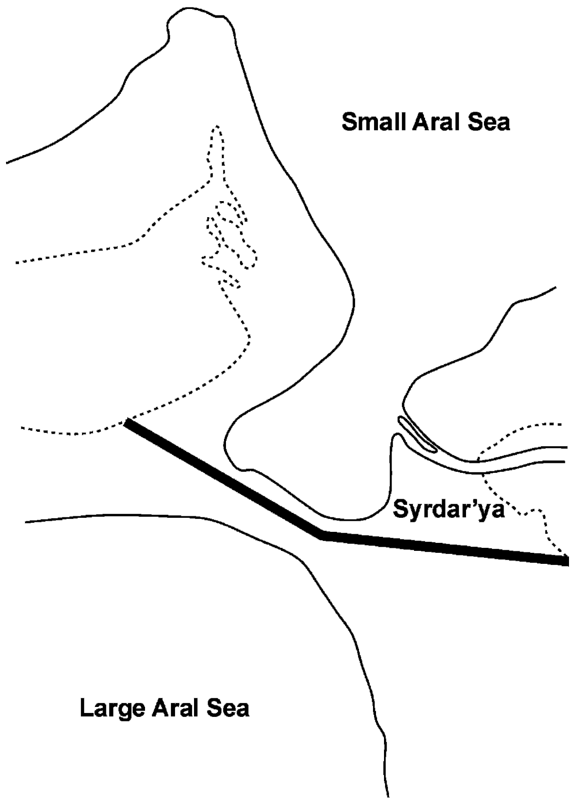

Figure 10. Dike in Berg Strait (by: Aladin et al., 1995).

until April 1999, when after the water level rose to +43.5 m, a catastrophic breach occurred that destroyed the dike. The number of free-living animals increased. Even such a short period allowed partial rehabilitation of biodiversity in Small Aral.

Since separation of the Small Aral Sea from Large Aral at the end of the 1980s, the number of free-living animals increased because salinity in this lake was cut nearly in half and in 2005 reached about 17 g/L. At that time, the Small Aral's area was 2,804 km^2 (47% from 1960), volume 23 km^3 (28% from 1960), and level +40.4 m asl.

Our survey in September 2007 showed the following number of species: Fishes – 12; Rotatoria – 3; Cladocera – 2; Copepoda – 2; Ostracoda – 2; Decapoda – 2; Bivalvia – 2; Gastropoda – >1; Polychaeta – 1. Total: >27.

Zoobenthos of the Small Aral Sea today consist of the following: Bivalvia – *Abra ovata*, *Cerastoderma isthmicum*; Gastropoda – *Caspiohydrobia* spp.; Polychaeta – *Nereis diversicolor*; Ostracoda – *Cyprideis torosa*, *Eucypris inflata*; Decapoda – *Palaemon elegans*; Insecta: Chironomidae larvae. Fishes of the Small Aral: *Clupea harengus membras*, *Platichthys flesus*, *Atherina boyeri caspia*, *Knipowitschia caucasicus*, *Neogobius fluviatilis*, *N. melanostomus*, *N. syrman*, *N. kessleri*, *Pungitius platygaster*, *Proterorchinus marmoratus*, *Ctenopharyngodon idella*, *Sander lucioperca*. When a dike in the Berg Strait was built in 1992, fishing on the Small Aral was recommenced. According to reports of fishermen in 2004 silver carp (*Ctenopharyngodon idella*) reappeared in Small Aral.

The Russian company "Zarubezhvodstroy" built the new dike in the Berg Strait. It was completed in autumn 2005. In spring 2006 the level of Small Aral reached the design level of 42 m, well ahead of schedule. The Small Aral area in 2007 is about 3,258 km^2, with a volume of 27 km^3.

2.2. WAY 2. CONSERVATION AND REHABILITATION OF THE LARGE ARAL AND ITS ECOSYSTEMS

Since the Aral Sea divided into two lakes at the end of the 1980s, the level of Large Aral Sea has steadily declined. Since the beginning of 2003, when the level in the Large Aral Sea dropped by 23 m and reached about +30 m, the Large Aral Sea has been practically divided into the Eastern Large and Western Large Aral and Tschebas Bay. Salinity in the Western part in September 2007 was 100 g/L; it no doubt is considerably higher in Tschebas Bay and the Eastern Large Aral where it may reach 150–160 g/L.

In both the eastern and western Large Aral salinity has increased so much that most inhabitants are gone. At the end of the twentieth century brine shrimp *Artemia salina* (*A. parthenogenetica*) appeared in the Large Aral Sea. Industrial harvesting by the international company INVE Aquaculture is being considered, but in 2005 the company postponed activities until salinity increases to levels more favorable for brine shrimp.

Zooplankton of the Western Large Aral Sea (2007 average salinity around 100 g/L): Infusoria – *Fabraea salina*; Rotatoria – *Brachionus plicatilis*, *Hexarthra fennica*; Branchiopoda – *Artemia salina*. Possibly could be found Cladocera – *Moina mongolica* and Copepoda – *Halicyclops rotundipes aralensis*. Zoobenthos: Infusoria – *Frontonia* sp.; Turbellaria – *Mecynostomum agile*; Polychaeta – *Nereis diversicolor*; Ostracoda – *Cyprideis torosa*, *Eucypris inflata*; also there is some possibility that Gastropoda – *Caspiohydrobia* spp. and Bivalvia – *Abra ovata* could still survive. In Tschebas Bay zooplankton and zoobenthos resembles those of the Western Large Aral Sea.

It appears that by 2005 all fishes of Western Large Aral Sea had disappeared. Nevertheless there is a chance that in some places, where salinity is lower due to inflow of underground waters, some very salinity tolerant fish species still could survive: *Pungitius platygaster*, *Platichthys flesus*, *Atherina boyeri caspia*, *Neogobius melanostomus*. There is suspect oral information that in Tschebas bay flounder (*Platichthys flesus*) was observed in water with salinity 80–90 g/L. Also there is unofficial information that in the remnants of the strait between Small and Eastern Large Aral *Atherina boyeri caspia* was found in water with salinity 60–80 g/L.

Only a few free-living invertebrates could survive such high salinity conditions: Infusoria – 2; Rotatoria – 3; Cladocera – 2; Copepoda – 2; Ostracoda – 2; Branchiopoda – 1; Decapoda – 2; Bivalvia – 2; Gastropoda – >2; Polychaeta – 1 for a possible total of fewer than 18.

Zooplankton and zoobenthos of the Eastern Aral Sea (2007 average salinity probably 150–160 g/L): Zooplankton – only *Artemia salina*; zoobenthos – no live macro- and mezo-Metazoa are found. Fishes are not found in the Eastern Large Aral; they are completely gone.

In 2005 a special water discharge facility (dike, water way and water discharge gates) was constructed in order to supply the Eastern depression of Large Aral with Amu Darya water from the Mezhdurechensky reservoir via the Ak Darya river bed. Unfortunately the completed spillway and water gates failed and were destroyed in October 2005 when the coffer dam holding back the water of the reservoir was removed. The cause was probably poor engineering design or construction. Now this complex is under restoration.

It may be desirable to provide more water to the Eastern Large Aral from Small Aral via the Berg Strait dike and water discharge from Mezhdurechensky reservoir via Ak Darya river bed. Western Large Aral Sea could, perhaps, maintain its level using ground water flow from Amu Darya delta and Ustjurt plateau. Realization of this project will help protect biodiversity of salt tolerant species of hydrobionts.

2.3. WAY 3. CONSERVATION AND REHABILITATION OF DELTA AND DELTAIC WATER BODIES OF SYR DARYA

After the collapse of the USSR, discharge of Syr Darya slightly increased and reached about 5 km^3 per year. After making a first dike in the Berg Strait in summer 1992 some other rehabilitation projects were initiated. Syr Darya delta shifted slightly northwards and some fresh water reservoirs were built. Along lower Syr Darya near the Small Aral several fresh water lakes have been rehabilitated: Tuschibas, Kamyslybas, Zhalanashkol, Karasholan, etc. These small projects allow the restoration of freshwater fisheries, hunting, and trapping. Fish farms were also renewed and more young fish are released to the local water bodies. Fish farms are also planned for use in reintroduction of sturgeon to the Small Aral.

2.4. WAY 4. CONSERVATION AND REHABILITATION OF DELTA AND DELTAIC WATER BODIES OF AMU DARYA

Uzbekistan branch of IFAS in cooperation with other national institutions prepared a plan of Amu Darya delta rehabilitation. In the lower reaches of the Amu Darya several freshwater and brackish water reservoirs and lakes were established. One of the most successful projects is Sudochie Lake. Sudochie Lake has been filled and via underground flow is giving some water to the Western Large Aral Sea. Reeds, aquatic birds and hydrobionts are almost recovered in Sudochie Lake. Other former Aral Sea bays have or could be rehabilitated, including Sarbas, Muynak, Adjibay and Zhiltyrbas. Fisheries and hunting activities have recovered in the areas that have been rehabilitated.

3. Some evidences of Medieval desiccation of the Aral Sea

As the Aral dried (Figures 11–15), remnants of saxauls were found on its former bottom. Some stumps were also found under water close to the modern shoreline. Radiocarbon analysis dated these to Medieval times. For more paleo-environmental reconstruction of Medieval desiccation special corings in the Aral Sea were made under the CLIMAN project (INTAS).

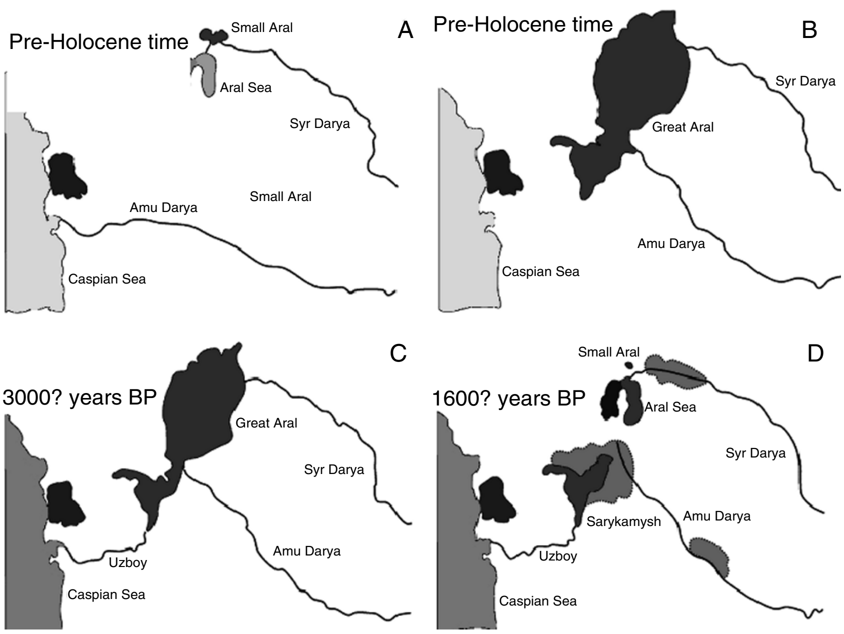

Figure 11. Aral Sea: from 9,000 to 1,600 years BP (by: Aladin and Plotnikov, 1995).

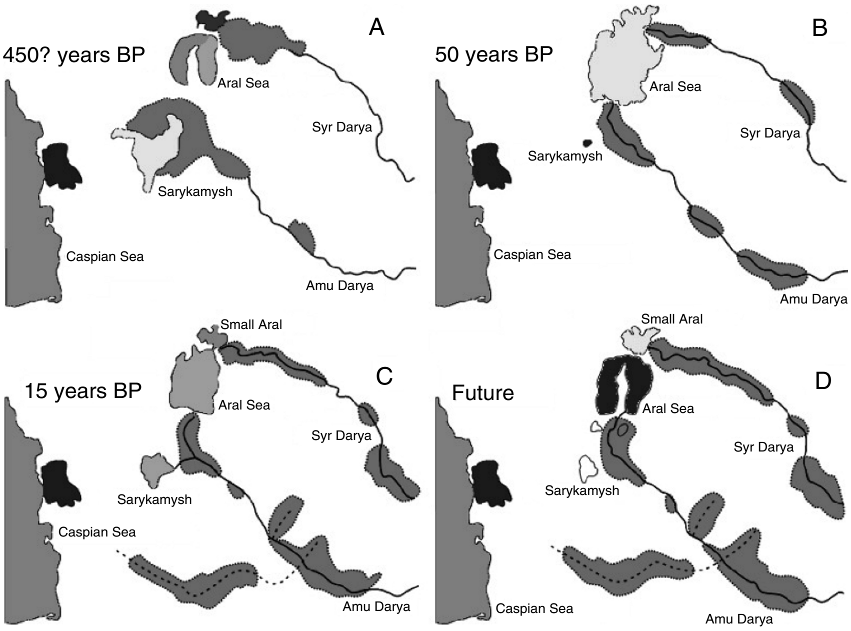

Figure 12. Aral Sea: from 450 years BP to present and in the future (by: Aladin and Plotnikov, 1995).

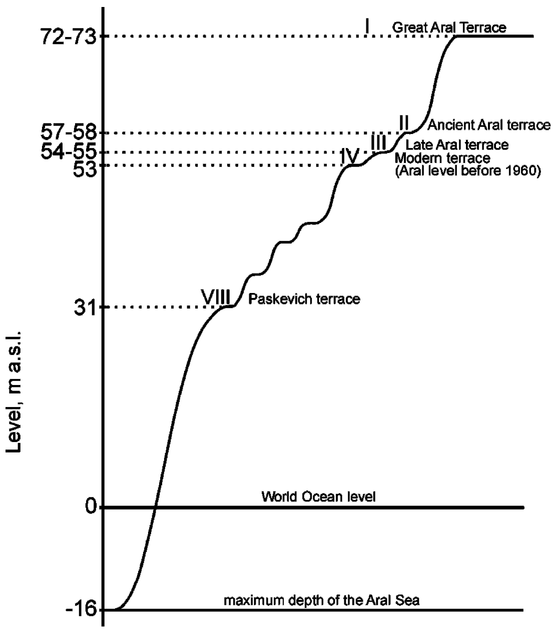

Figure 13. Main Aral Sea terraces (by: Aladin and Plotnikov, 1995).

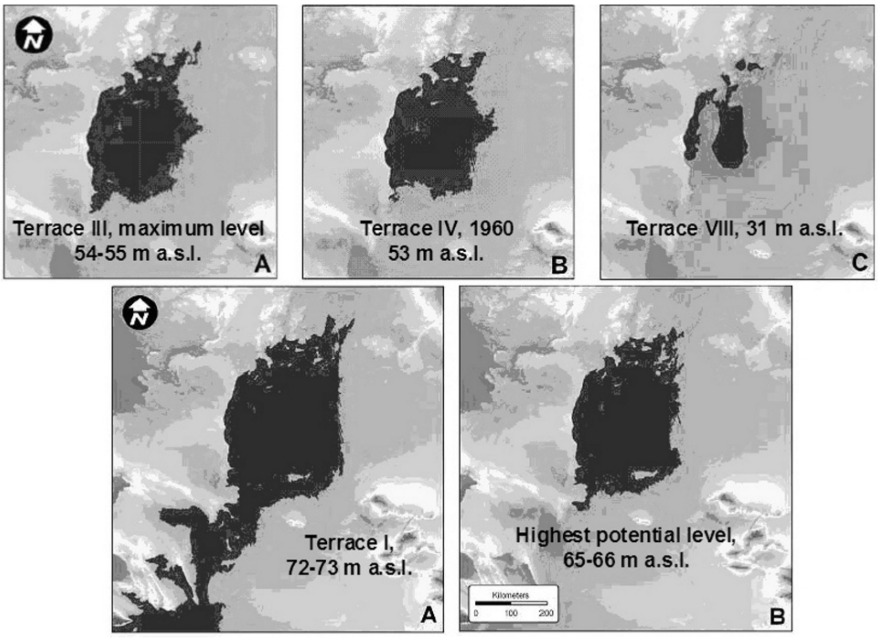

Figure 14. Surface areas of the Aral Sea at different levels (From: C. Reinhardt, 2007).

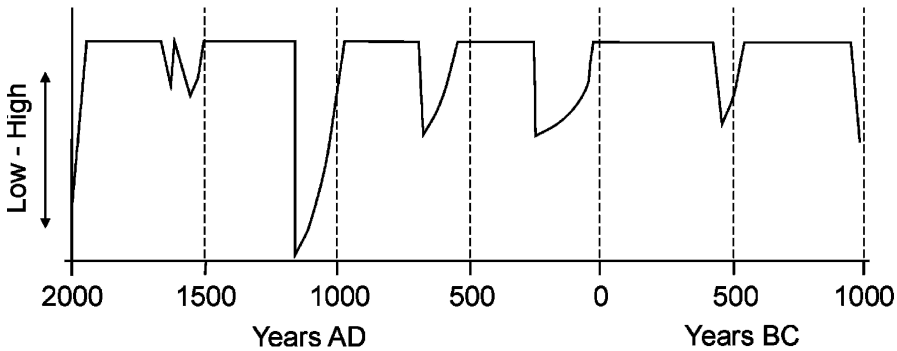

Figure 15. Aral Sea water level change during last 3,000 years (based on archeological data). Boomer et al., 2008 [Chapter by Boroffka].

At the end of twentieth century, Kazakh hunters found ruins of a Medieval mausoleum (Kerdery) on the dried bottom. In 1960, the area was under about 20 m of water. Bones of *Homo sapiens* and domestic animals, millstones, elements of ceramics, and other artifacts were found near the mausoleum. All these findings were studied by an international team of archeologists also under the CLIMAN project (Boroffka et al., 2005).

Recently remnants of Medieval river beds on the former Aral Sea bottom were also detected on satellite images. Preliminary investigations on this matter were made by D. Piriulin (personal communication, 2007).

4. Alternative 2nd phase of the small Aral rehabilitation project

In our opinion, the future of the Aral Sea is connected with oil and gas extraction. Oil and gas drilling rigs are now wide spread on the former Aral Sea bottom. A gas condensate plant was built not far from Muynak. Local decision-makers even permanently closed the channel that formally gave water to Muynak reservoir. The gate was closed in order to decrease the groundwater level in the area. A high water table level promotes softening of the ground that endangers drill towers, possibly causing them to fall over or start to lean.

The authors would like to note that citizens of Kazakhstan like to call Small (Northern) Aral Sea "Kazaral" that means "Kazakh Aral". People in Uzbekistan also sometimes instead of Large (Southern) Aral Sea like to use

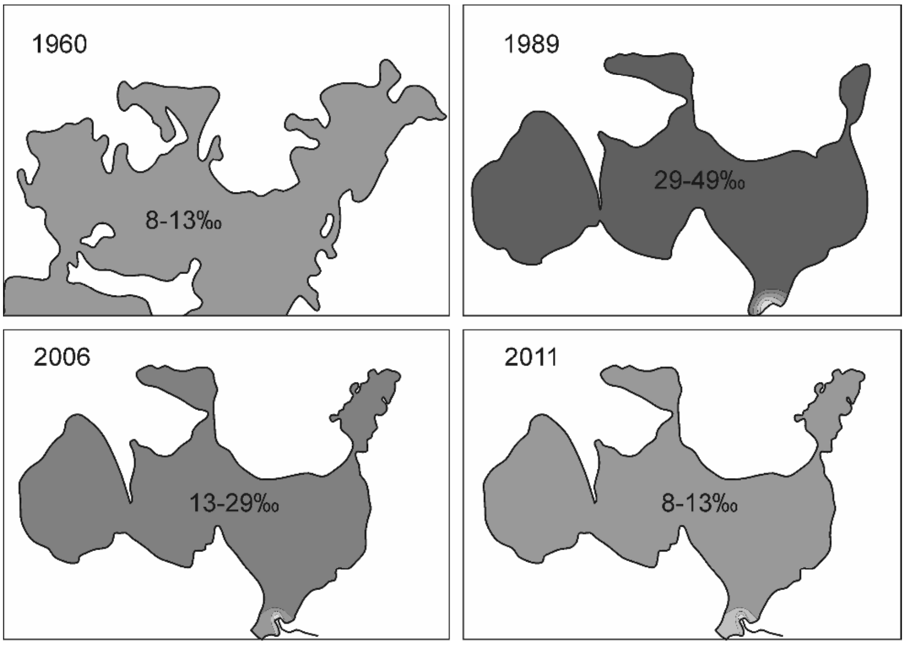

Figure 16. Dike in the Berg Strait funded by World Bank and Kazakhstan government allowed to improve brackish water environment of Small (Northern) Aral Sea.

name “Uzaral” that means “Uzbek Aral”. We believe that on future maps will be four main water bodies in what was formerly the Aral Sea: Kazaral, Western Uzaral, Eastern Uzaral, and remnant of Tshebas bay.

The dike in the Berg Strait allowed the level in the Small (Northern) Aral Sea to increase to +42 m asl. Present average salinity in Small (Northern) Aral Sea is about 10 g/L. For further improvement of this situation improvements in irrigation efficiency are needed to improve water balance. It is possible to make the present dike a bit higher and raise the level up to +45 m asl. This will allow enlarging the volume and area of Small (Northern) Aral Sea (Figure 16).

Another possible variant of the second phase of the “Kazaral” rehabilitation project is shown in Figure 17. It would involve construction of a new dike at the mouth of the Saryshaganak Gulf to raise the level of it to +46 or 47 m. Part of the flow of the Syr Darya would be diverted northward to fill the reservoir.

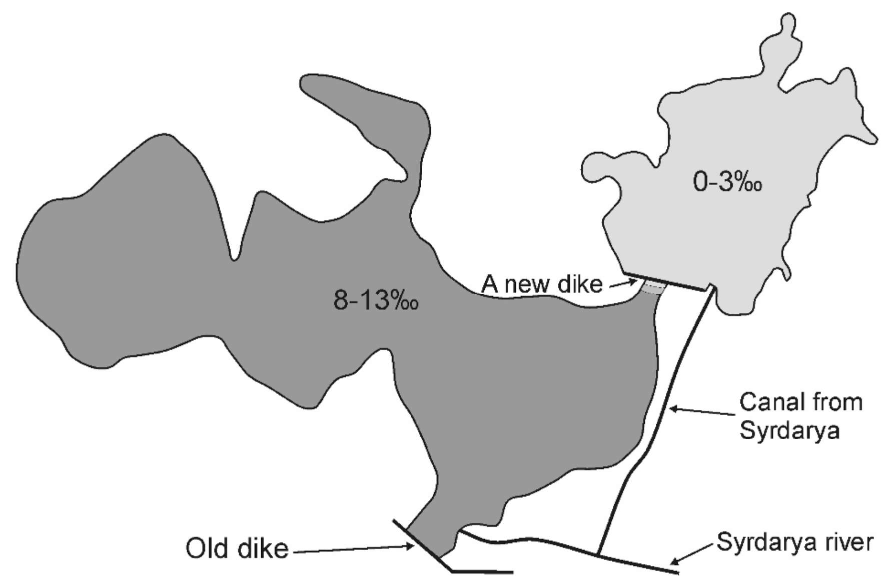

Figure 17. A variant of the second phase of Small Aral Sea rehabilitation project.

The second phase of the project will allow further improvement of the health of the local people, decreased unemployment and increased living standards, as well as income to local families. The local economy also will be improved (fishery, shipping, etc.). Local microclimate around Small (Northern) Aral Sea will be much better than now.

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