Changes in the Aral Sea ichthyofauna and fishery during the period of ecological crisis

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Abstract

Aboriginal ichthyofauna of the Aral Sea consisted of 20 generative-freshwater species from seven families. After acclimatization in 1927–1963, the number of species increased to 34. The regulation of Syr Dar'ya and Amu Dar'ya river water flows, and increasing water withdrawals, primarily for irrigation, resulted in a declining lake water level, increasing salinization and changing habitat conditions, especially for reproduction. As a result, the spawning areas were greatly reduced, and because of worsening conditions for natural reproduction, fish catches in 1961–1976 decreased more than 4-fold. The first signs of the negative impacts of salinization on fishes appeared in the mid-1960s. Natural reproduction ceased by the mid-1970s, and indigenous commercial fish fauna were lost by the end of the 1970s. Flounder-gloss was introduced from the Black Sea in 1979–1987 to preserve the fishery, and it was the only commercial fish left by 1991–2000. Because of the water level decline, the Aral Sea became divided in 1989 into the Large and Small Seas. By the end of the 1990s, flounder became extinct in the Large Aral because of high salinity, as did other fishes. Decreasing agriculture activity has resulted in stabilized run-off of the Syr Dar'ya to the Small Aral since 1988, creating a freshened water zone where indigenous ichthyofauna returned from lacustrine systems and the river. The ecological state of the Small Aral is improving, with some aboriginal valuable commercial fishes having reached numbers making their commercial catch possible once again.

Key words

Aral Sea, ecological crisis, fishery, fishes.

INTRODUCTION

Located in the arid zone of Central Asia, until the 2nd half of the 20th Century, the Aral Sea was a single terminal water body – a huge closed lake into which two rivers – Syr Dar'ya in the northeast and Amu Dar'ya in the south flowed. The island Kokaral divided the Aral Sea in two parts, including the smaller northern (Small Aral) and larger southern (Large Aral). The depression filled with the Aral Sea consists of several smaller ones. Because of such a structure, the Aral Sea became divided into separate waterbodies as the water levels dropped over the decades.

The average salinity of most of the Aral Sea was 10 g L^{-1}, so-called brackish conditions. The Aral Sea, over several centuries prior to the 1960s, preserved its quasi-stable state. For the period of more recent observations (from the middle of the 19th Century), its water level fluctuated a few metres, primarily because of natural climatic factors (Micklin 2010).

The aboriginal ichthyofauna of the Aral Sea, except for species found only in completely freshwater areas, consisted of 20 species from seven families (Table 1; Nikolsky 1940). The richest in species was the family Cyprinidae (12 species), accounting for 60% of all fish fauna. Based on species diversity, the second was the family Percidae (three species). Each of the other families – Acipenseridae, Salmonidae, Siluridae, Esocidae and Gasterosteidae – were represented by only one species. There were no endemic fish genera and species in the Aral Sea, with endemism only on the sub-species level. It is possible to explain this situation as a function of the youth of the Aral Sea as an isolated waterbody (Nikolsky 1940).

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Table 1. Species composition of Aral Sea aboriginal ichthyofauna

Fish species	Years				Status
	1950	1960–1979	1980–1990	1991–2004	
Acipenseridae					
Ship sturgeon *Acipenser nudiventris* Lovetsky	+	+	–	–	C–, E
Salmonidae					
Aral trout *Salmo trutta aralensis* Berg	+	+	–	–	C–, E
Esocidae					
Pike *Esox lucius* Linnaeus	+	+	–	+	C–
Cyprinidae					
Aral roach *Rutilus rutilus aralensis* Berg	+	+	–	+	C
Orfe *Leuciscus idus oxianus* (Kessler)	+	+	–	+	C–
Asp, zherekh *Aspius aspius iblioides* (Kessler)	+	+	–	+	C
Rudd *Scardinius erythropthalmus* (Linnaeus)	+	+	–	+	C–
Turkestan barbel *Barbus capito conocephalus* Kessler	+	+	–	–	C–, RB
Aral barbel *Barbus brachycephalus brachycephalus* Kessler	+	+	–	+	C–, RB
Bream *Abramis brama orientalis* Berg	+	+	–	+	C
White-eye bream *Abramis sapa aralensis* Tjapkin	+	+	–	+	C–
Aral shemaya *Chalcalburnus chalcoides aralensis* (Berg)	+	+	–	+	C–
Sabrefish *Pelecus cultratus* (Linnaeus)	+	+	–	+	C–
Crucian carp *Carassius carassius gibelio* Bloch	+	+	–	+	C–
Carp *Cyprinus carpio aralensis* Spitshakow	+	+	–	+	C
Siluridae					
Wels *Silurus glanis* Linnaeus	+	+	–	+	C–
Gasterostidae					
Nine-spined stickleback *Pungitius platygaster aralensis* (Kessler)	+	+	+	+	NC
Percidae					
Pike perch, zander *Stizostedion lucioperca* (Linnaeus)	+	+	–	+	C
Perch *Perca fluviatilis* Linnaeus	+	+	–	+	C–
Ruff *Gymnocephalus cernuus* (Linnaeus)	+	+	–	–	NC

Explanation: +, present; –, absent; C, commercial; C–, commercial, but low stocks; NC, not commercial; RB, in Red Book; E, extinct.

Most aboriginal fishes were benthophages, with only some being predators (pike, zander, wels, zherekh, trout). In regard to planktophages, the only common one was the nine-spined stickleback. Almost all the Aral Sea aboriginal fishes (except ruff and nine-spined stickleback) had commercial value, with the main objects of commercial fishery being bream, carp, roach and zander.

Aboriginal ichthyofauna of the Aral Sea was represented by generatively freshwater species. Their reproduction typically occurs in fresh water, although they also can spawn in brackish water. For their reproduction, all aboriginal fishes in the Aral Sea migrated into the coastal zone or into the rivers. Two species were anadromous: Aral trout and ship sturgeon. The best places for spawning were freshwater bays near deltas, deltaic lakes and the rivers, in which about 2/3 of the main commercial fishes spawned. There also were spawning areas in the Aral Sea itself, although no aboriginal fishes spawned in pelagic areas (Nikolsky 1940; Bervald 1964).

The role of marine spawning areas in the reproduction of commercial fishes was not originally clearly determined. Bervald (1964), while confirming that nearly 100% of Aral roach, 90% of carp and 50% of bream of the northeast part of the sea adapted to spawning in seawater, still could not determine the effectiveness of spawning of these fishes under marine conditions. Gosteeva (1956, 1957, 1959) observed normal development of roe and larvae of Aral roach, bream and carp at salinities of 11.6, 10.5 and 10.6 g L^{-1}, respectively.

Changes in the conditions of natural reproduction were the main factor affecting the fluctuations in the abundance of commercial fishes (Nikolsky 1940; Bervald 1964).

INTRODUCTION OF NEW FISH SPECIES

The first changes in the Aral Sea ichthyofauna occurred before the modern ecological crisis. There were some attempts during 1927–1963 to introduce new commercially important fish species into the Aral Sea for the purpose of enriching its ichthyofauna (Table 2). Not all these introductions were successful. Further, together with planned commercial fishes, non-commercial fish species were accidentally introduced, most being undesirable. During 1954–1956, during the unsuccessful introduction of two species of mullets from the Caspian Sea to the Aral Sea, six species of gobies (eeurybiontic euryphages) and plankton-eaters (atherine) and pipefish were coincidentally introduced. These alien species became competitors for aboriginal fishes, while they were only a supplementary food source for predators (Karpevich 1975).

During 1958–1960, commercial freshwater fishes of the China complex were successfully acclimatized into deltaic area, including the macrophytophage grass carp, phytoplanktophage silver carp and zooplanktophage spotted silver carp. The black carp, a benthophage and the

Table 2. Introduced fish species in Aral Sea (adapted from Aladin *et al.* 2004)

Fish species	Years of introduction	Source	Way	Status	Impact	Status in the 2000s
Acipenseridae						
Stellate sturgeon *Acipenser stellatus* Pallas	1927–1934	Caspian Sea	A	–	–	–
	1948–1963	Caspian Sea	A	C–	0	–
Clupeidae						
Caspian shad *Alosa caspia* (Eichwald)	1929–1932	Caspian Sea	A	–	0	–
Baltic herring *Clupea harengus membras* (Linnaeus)	1954–1959	Baltic Sea	A	N, C–	–	R
Mugilidae						
Golden grey mullet *Liza aurata* (Risso)	1954–1956	Caspian Sea	A	–	0	–
Leaping mullet *Liza saliens* (Risso)	1954–1956	Caspian Sea	A	–	0	–
Cyprinidae						
Grass carp *Ctenopharyngodon idella* (Valenciennes)	1960–1961	China	A	C	+	C–
Silver carp *Hypophtalmichthys molitrix* (Valenciennes)	1960–1961	China	A	C	+	C–
Spotted silver carp *Aristichtys nobilis* (Richardson)	1960–1961	China	A	R	+	C–
Black carp *Mylopharyngodon piceus* (Richardson)	1960–1961	China	A+	C	0	C–
Syngnathidae						
Black-striped pipefish *Syngnathus abaster caspius* Eichwald	1954–1956	Caspian Sea	A+	N, NC	–	?
Atherinidae						
Caspian atherine *Atherina boyeri caspia* Eichwald	1954–1956	Caspian Sea	A+	N, NC	–	R, NC
Gobiidae						
Bubyr goby, transcaucasian goby *Pomatoschistus caucasicus* Berg [=*Knipowitschia caucasica* (Berg)]	1954–1956	Caspian Sea	A+	N, NC	–	NC
Sand goby *Neogobius fluviatilis pallasi* (Berg)	1954–1956	Caspian Sea	A+	N, NC	–	NC
Round goby *Neogobius melanostomus affinis* (Eichwald)	1954–1956	Caspian Sea	A+	N, NC	–	NC
Syrman goby *Neogobius syrman eurystomus* (Kessler)	1954–1956	Caspian Sea	A+	R, NC	–	NC
Tubenose goby *Proterorhinus marmoratus* (Pallas)	1954–1966	Caspian Sea	A+	R, NC	–	NC
Bighead goby *Neogobius kessleri gorlap* Iljin	1954–1956	Caspian Sea	A+	R, NC	–	NC
Channidae						
Snakehead *Channa argus warpachowskii* Berg	1960s	Kara-Kum canal	A+	C	0	C
Pleuronectidae						
Black Sea flounder *Platichthys flesus* (Linnaeus)	1979–1987	Sea of Azov	A	N, C	+	N, C

Mode of introduction: A, acclimatization; A+, incidentally at planned introduction; R, rare; N, numerous; C, commercial; C–, commercial, but low stocks; NC, not commercial; Impact: –, negative; +, positive; 0, no effect.

predatory snakehead (Table 2) also were accidentally introduced at the same time, both also being commercial fishes (Karpevich 1975). These fishes inhabited the deltas of the Syr Dar'ya and Amu Dar'ya and also settled in the near deltaic zones of the Aral Sea. While this acclimatization had no negative consequences, the growth of catches resulting from it was insignificant.

After these planned and incidental acclimatizations, the number of fish species increased considerably from 20 up to 34, although the number of commercially important species only increased by six. As a result, 14 new fish species were naturalized in the Aral Sea (Table 2).

IMPACTS ON ICHTHOFAUNA OF THE ARAL SEAWATER LEVEL DECLINE

Freshened deltaic bays and lakes were considered in the early 1990s to be the best places for spawning (Bervald 1964), being the location for reproduction of 65–70% of the main commercial fishes. Human activities became the main factor influencing the hydrological regime of the Aral Sea since the 1960s. Regulation of the Syr Dar'ya and Amu Dar'ya, and increasing withdrawal of their flows to irrigate expanding agricultural lands caused the gradual, but steady, decline in the Aral Seawater level, salinization of its water and drying of its deltas. All these changes significantly altered the historically formed living conditions of the Aral Sea fishes, especially the conditions for their reproduction. In the case of semi-anadromous fishes, it was manifested in the shallowing or even full disappearance of spawning areas in the deltas of the rivers. For anadromous fishes, it was the decline of migration routes upstream to places of natural reproduction.

The Aral Seawater level decline of 1.5–2 m to the mid-1960s was responsible for perceptible decreases in the spawning area, with the reproduction of bream, zander, roach and shemaya – the main fish species – decreasing accordingly. Northern Aral fishes began to spawn in mass in locations earlier considered unusual for this activity. In years with heavy and average water flows, when the Syr Dar'ya was connected with lakes, reproduction of fishes occurred in these lakes. Grown-up juveniles then migrated down to the sea. In low-water years, such as 1974–1975, when the connection of the river with lakes was interrupted, the spawning occurred directly in the river. In this case, the fate of larvae migrating down to the sea was not propitious because there was a sharp shift of water salinity in the mouth of the Syr Dar'ya.

In the late 1970s and early 1980s, discharge of fresh water to the sea ceased as a result of the blocking of the Syr Dar'ya by a dam located near the settlement of Aklak (20 km from the mouth). Freshened bays disappeared, with the most important of these (Karashalan and Karateren) separating from the sea and subsequently drying up.

Since 1975, because of the Aral Sea level decline, marine spawning areas, as such, are not absent. The ichthyofauna of coastal zone, as indicated by studies on the juveniles' yield count in 1971–1975, consisted only of atherine, gobies and, sometimes, of non-commercial nine-spined stickle-back.

IMPACTS OF ARAL SEA SALINIZATION ON ICHTHYOFAUNA

Catastrophic deterioration of natural reproduction conditions in the Aral Sea also sharply impacted the state of commercial fish populations. The first signs of the negative impacts of salinization on the ichthyofauna occurred in the mid-1960s, as salinity reached 12–14 g L^{-1}. Salinity increased faster in shallow spawning areas than in the open sea, exceeding 14 g L^{-1} in 1965–1967. This level harmfully affected development of roe of fishes of freshwater origin. At the end of the 1960s, spawning grown conditions for semi-anadromous fishes significantly worsened.

Beginning in 1971, when average salinity in the open sea reached 12 g L^{-1}, the first signs of negative effects of salinity on adult fishes appeared. The rate of growth slowed for many fish species, with their numbers falling sharply. By the middle of the 1970s, when the average salinity of the sea exceeded 14 g L^{-1}, the natural reproduction of Aral fishes was completely destroyed. As a result, in the second half of the 1970s, recruitment of new members was absent for the populations of many fish species. Further, from 1961 until 1976, commercial fish catches across the Aral Sea decreased more than by four times (Table 3).

By 1981, when salinity exceeded 18 g L^{-1}, the Aral Sea had completely lost its fishery. The ichthyofauna consisted of nine-spined stickle-back from the aboriginal species, as well as gobies, atherine and Baltic herring from species introduced and subsequently acclimatized. Aboriginal commercial fishes survived only in the Syr Dar'ya and Amu Dar'ya rivers and floodplain deltaic lakes. Single cases of the catching of older commercial fishes occurred only in the mouths of these rivers.

ACCLIMATIZATION OF FLOUNDER-GLOSS

Based on forecasts of the hydrological and hydrochemical regimes of the Aral Sea, researchers of the Aral branch of KazNIIRKH (Kazakh Research Institute of Fish

Table 3. Dynamics of fish catches in Aral Sea, 1961–1980 (tons; Ermakhanov Z., unpublished data)

	Year										
Fish	1961	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Bream	8920	600	640	790	1100	1608	1975	1381	528.9	66.8	6
Carp	9940	1390	1000	990	1050	1346	328	219.5	100.9	–	373.5
Roach	6950	2360	1350	1380	1980	2277	1423	418.6	213.9	242.8	68.6
Shemaya	440	10	11	2	5	–	–	–	–	–	–
Barbel	1220	330	344	260	316	361.2	306	134.6	27.8	0.4	–
Zander	2740	8290	12	10680	6630	5351	4474	3500	2696	1689	2479
Pike	650	120	10	40	360	128.8	30	9.5	44.9	–	–
Wells	920	430	110	320	450	248.5	61	20.6	30.1	–	2.2
Asp	900	1010	1000	1460	2740	554.3	207	195.4	7.9	–	–
Snakehead	–	–	50	180	500	72.5	38	34.8	158.8	–	–
Grass carp	–	40	10	20	50	306.9	101	58.8	148.1	–	–
Silver carp	–	10	13	–	10	485.8	14	29.1	48.6	–	–
Others	1480	370	200	850	210	422.9	68	4	39	9.3	5.5
Total	34160	14960	16730	16970	15500	13462	9027	6007	4045	2009	2935

Table 4. Dynamics of flounder–gloss catches in Small Aral Sea after separation of the Small and Large Aral Seas (tons; Ermakhanov Z., unpublished data)

Years											
1991	1992	1993	1996	1997	1998	1999	2000	2001	2002	2003	2004
50	100	85	650	720	945	1050	1155	1225	1260	1350	1230

Industry) carried out experiments with euryhaline and halophilic fish species since the mid-1970s, including Caspian sturgeon, Kura salmon *Salmo trutta caspius* Kessler, Far East coho *Oncorhynchus kisutch* (Walbaum), Azov-Black Sea flounder-gloss *Platichthys flesus luscus* (Pallas) and flounder-turbot *Psetta maeotica* (Pallas). The most promising were experiments with flounder-gloss, characterized by remarkably large ecological flexibility, and the ability to reproduce at salinities from 17 to 60 g L^{-1}.

To preserve the Aral Sea fishery under conditions of increasing salinization and consistent with the biological substantiation that developed from 1979 to 1987 14, 280 flounder-gloss were introduced to the Aral Sea from the Sea of Azov (Lim 1986). Flounder-gloss has acclimatized successfully in the Aral Sea. This fishery was established across the entire sea by the early 1990s, producing commercially useful numbers in water with salinities ranging from 15–20 to 50 g L^{-1}. Acclimatized flounder-gloss was the only commercial fish species in the Aral Sea from 1991 to 2000 (Table 4).

ICHTHYOFAUNA OF THE ARAL SEA AFTER ITS DIVISION INTO TWO SEAS

At the end of 1989, as a result of its continuing water level decline, the Aral Sea separated into two parts; namely, the southern Large Sea and the northern Small Sea. After partition of the Aral Sea into the Large and Small Seas, changes in their hydrological–hydrochemical regime occurred independently of each other.

Salinity in the Large Aral Sea continued increase, with this waterbody becoming hyperhaline in the second half of the 1990s. By the end of the 1990s, the salinity of the Large Aral reached 60–70 g L^{-1}, resulting in the complete loss of acclimatized flounder in this part of the sea. The Large Aral Sea has become a lake without fishes since that time.

Beginning in 1988, the flow of the Syr Dar'ya again reached the Small Aral Sea after a long interval. As a result, a freshened water zone appeared in the river-mouth area, where aboriginal commercial fish fauna migrated from lacustrine systems and the Syr Dar'ya.

Decreasing water withdrawals for irrigated agriculture resulted in a relatively stable annual run-off of 6–8 km^3 to the Small Aral Sea. Construction of the first Kokaral earthen dike in 1992, for the purpose of blocking the water flow from the Small to Large Aral seas allowed most of the Syr Dar'ya flow to accumulate in the Small Sea. Freshening of the Small Aral Sea began, and the zone with salinity ranging from 1 to 10 g L^{-1} increasing to 60 000 hectares. Representatives of aboriginal ichthyofauna, including Aral roach, bream, carp, zander, asp, began to be found again in the Small Aral Sea for the first time in many years.

However, because of a lack of discharge facilities in the body of the dyke for discharging excess water, the dam was destroyed by strong winds in April 1999 that drove water against the dike. As a result, the water level of the Small Sea fell by 3 m during 1999–2001, with a significant volume of water flowing from the Small Sea through Berg strait to the Large Sea. The water flowing from the freshened water areas contained many aboriginal commercial fishes, which subsequently died in mass during the summer in the shoals and pits between the Small and Large Aral Seas.

The project titled 'Regulation of the Bed of the Syr Dar'ya River and the Northern Part of the Aral Sea', which was carried out within the framework of the programme, 'Concrete Actions for the Improvement of the Ecological Situation in the Aral Sea basin', is being implemented. This project is exceptionally important for the economy and improvement of ecological conditions in the Kazakhstan part of the Aral Sea – Syr Dar'ya basin. The channel connecting the Small and Large Aral Sea was closed in August 2005 with the completion of the new Kokaral dike and dam. The water level in the Small Sea at that time was 40 m.a.s.l. The Small Seawater level increased significantly as a result of unusually high winter flows on the Syr Dar'ya, reaching the design elevation of 42.0 m.a.s.l. in March 2006. The area of the freshened water zone increased considerably, as did the area inhabited by aboriginal commercial fish species. The fish fauna expanded their spawning and feeding zones to almost the entire area of the Small Aral Sea, with the exception of Butakov Bay, where the salinity remained too high.

The relative stabilization of the hydrological regime and, above all, freshening of the water of the Small Aral Sea promoted achievement of commercial numbers of a number of valuable food fishes, including carp, bream, zander, asp. (Table 5).

CONCLUSIONS

The Aral Sea ichthyofauna has changed as a result of the modern anthropogenic regression that began in the 1960s. Both aboriginal and acclimatized generative-freshwater species disappeared completely. Being the only commercial fish species, the Aral Sea completely lost its fishery value. Only the acclimatization of flounder-gloss allowed the partial recommencing of the fishery of the Small Aral Sea.

The ecological condition of the Small Aral Sea was considerably improved during the period 1989–2010, because of increasing water inflows from the Syr Dar'ya, and the construction of a dike in the former Berg Strait. Water level stabilization and a gradual decrease in salinity have allowed the return of generative-freshwater commercial fish fauna to the Small Aral Sea, via migration from the lacustrine system of the lower Syr Dar'ya. In the second half of the first decade of the new millennium, these fish species, along with the flounder-gloss, are being commercially caught in the Small Aral Sea. At the same time, however, the commercial importance of flounder-gloss is decreasing.

As the salinity decrease in the Small Aral Sea continues, the environmental conditions will be more and more favourable for generative-freshwater ichthyofauna, and these species will replace flounder-gloss. It is possible to

Table 5. Dynamics of fish catches in Small Aral Sea after construction of new Kokaral dam (tons; Ermakhanov Z., unpublished data)

		Fish species							
Year	Total	Flounder	Bream	Zander	Carp	Roach	Asp	Sabrefish	Others
2005	695	303	57	30	181	–	–	–	124
2006	1360	700	120	70	190	250	30	–	–
2007	1910	640	410	260	260	370	80	40	–
2008	1490	410	360	170	170	340	90	–	–
2009	1885	615	470	185	125	410	80	–	–
2010	2810	715	835	245	115	765	70	65	–

expect the full extinction of flounder-gloss in the future, when the water salinity will be insufficient for this marine species. Because the Large Aral Sea became hyperhaline in the second half of the 1990s, all fishes in it are now extinct.

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