THE INFLUENCE OF CHANGES IN THE HYDROLOGICAL REGIME OF THE URAL RIVER IN THE WEST KAZAKHSTAN REGION ON FISH RESOURCES

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Abstract. The Ural River is one of the main fisheries reservoirs of Kazakhstan. Its hydrological regime has been unstable over the past 10 years, which has affected the formation of fish resources. The present study has shown that commercial fish populations decrease from year to year due to the deterioration of spawning conditions in low-water years, when spawning grounds are not fully watered. In these years, the spawning efficiency decreased from 11% to 70%.
Keywords: hydrological regime; Ural River; fish resources; spawning conditions

The Ural River is the third longest river in Europe flowing through the territory of Kazakhstan and Russia and one of the main fisheries reservoirs in Kazakhstan. It is the only river with non-regulated low and middle water course for more than 1000 km upstream the delta, which is of great importance for the natural spawning grounds of valuable sturgeons (Chibilev, 2008; Lagutov & Lagutov, 2008). Average annual runoff of the Ural River is subject to significant intra-annual and long-term fluctuations (Kurmangaliyev et al., 2006; Chibilev, 2008; Sivokhip, 2014). In recent decades, there has been a decrease in the average annual runoff of the Ural River, which is explained by both anthropogenic influence and climatic changes (Kurmangaliev, 2001; Chibilev et al., 2012; Sivokhip, 2014).

The western part of the middle course and the northern part of the lower course of the Ural River are located in the West Kazakhstan oblast (administrative unit). The total length of this section of the river is 761 km. It plays an important role in reproduction of fish resources of the Ural-Caspian basin. Here are more than 1000 hectares of the main spawning grounds of sturgeons, as well as about 5000 hectares of floodplain spawning areas of phytophilic fish. Both non-anadromous and semi-anadromous species spawn here. The Ural River has commercial reserves of such fish species as common carp (sazan), pike perch (zander), asp, bream, catfish, white bream, blue bream, sabre carp, Volga pikeperch.

According to the monitoring data of the Western Branch of the Kazakh Research Institute of Fisheries[1)] the fish resources of the Ural River have been dynamically decreasing in the past eight years. The main possible reason for this can be the deterioration of the water content of the river (Assylbekova et al., 2017). This is due to the fact that most of the fish species of the Ural River are phytophilic and spawn in the spring on floodplain and coastal spawning grounds. The juveniles yield, and consequently the efficiency of reproduction, largely depends on the degree and duration of flooding of the spawning areas with the spring floods. In low-water years, spawning areas of the flooded floodplain banks are watered insufficiently, that leads to a decrease in the fish reproduction efficiency.

The first attempts to assess the relation of the decrease in the spawning efficiency and fish productivity from the water content fluctuations were presented only in local journals in Russian (Murzashev, 2009; Murzashev et al., 2013; Kim et al., 2015). The present study has a broader coverage with the combined data expanded to the last years.

Our goal was to study the influence of the deterioration of the hydrological regime on fish resources in the Ural River within the West Kazakhstan oblast. We attempted to assess the dependence of the juveniles yield and the biomass of the fish species of the Ural River on the hydrological conditions in this region.

Materials and methods

Hydrological measurements of the water runoff were made by specialists of the National Hydrometeorological Service of the Republic of Kazakhstan for the West Kazakhstan oblast. Annually, the runoff volume, water discharge in the riverbed and the water level were measured. The depth measurements at the sampling stations were carried out independently by the echo sounder "EHO 150" at the points of installation of a fishing tool. Water temperature and the dissolved oxygen content during the spawning period were measured by the thermo-oxymeter "Samara 2".

The degree of flooding of the spawning grounds was calculated as follows. The constant area of 12 flooded spawning grounds was known to us, which we considered to be the model ones. It was not possible to cover by research all the floodplain water bodies, because their number exceeded 100. The sizes of the individual spawning grounds were from 1 to 70 hectares – at a high flood they merge into common water area. In spring, at the peak of the flood, the flood area of the model spawning grounds was determined by setting the reference points on the shoreline by the GPS navigator. From these points, the average length and the average width were determined, and by their multiplying the value of the flooded area was calculated. Its ratio with the constant area is the value of the degree of flooding in the year of research.

Duration of flooding of the spawning grounds was recorded calendarly, as a period of time since the beginning of their covering with the rising flood water, till their disconnection from the river when the flood is low. The duration of spawning is directly related to the duration of flooding of the spawning grounds, and generally coincides with it.

Adult and juvenile fish were collected in the spring, summer and autumn periods of 2007–2016 at 5 stations, evenly scattered along the entire length of the riverbed of the Ural River in the West Kazakhstan oblast (Fig. 1). The geographical coordinates of the sampling stations are presented in Table 1.

Table 1. Coordinates of sampling stations

Numbers and names of stations at the Ural River	Latitude	Longitude
Station № 1 Burlin	51◦27’22”	52◦ 40’ 38”
Station № 2 Kabyl Tobe	51◦ 18’ 43”	51◦ 52’ 33”
Station № 3 Kruglozernoye	51◦ 04’ 12”	52◦ 40’ 38”
Station № 4 Chapayev	50◦ 11’ 24”	51◦ 10’ 49”
Station № 5 Taipak	49◦ 02’ 51”	51◦ 53’41”

Each year, up to 500 adult specimens and up to 100 juvenile fish were taken for study. Adult fish were caught by a river tailing net. Juveniles were caught by standard fishing tools (ichthyoplankton trap, Rass circle, fry trap), and patent tools of in-house development.

To catch the juvenile specimens downstream the river, the fishing tool was exposed in the transit stream for 5, 10 or 15 minutes, depending on the abundance of fry. The catch was carried out on three horizons: at the bottom, in the water column and at the surface. Active late juveniles were caught with the fry trap made of a net cloth with a mesh of 5 mm. The catch was carried out twice, on an even, pre-selected place, at a distance of 10 m along the shore. For catching along the coastal strip, the traps with a vertical lift were also used. They make it possible to determine the concentration of the juveniles on a fixed unit of the water area (accurate to 10 cm^2), without the active deterrent movement of the fishing tool.

Figure 1. The study area and the sampling stations at the Ural River

Fish species were identified and the total number and weight of each species in a catch was calculated. The entire catch was subjected to the mass measurements of the standard body length (without caudal fin).

The biomass of the adult fish was calculated by the area method. To do this, the number of fish was determined by formula:

$$N = \frac{S \cdot n}{s \cdot k},$$

where N – the number of fish in a reservoir; S – area of a reservoir; n – number of fish in a catch; s – area of a catch; k – coefficient of the net fishing efficiency.

Multiplying the number of fish by the average weight, the values of the ichthyomass for each species are obtained.

Results

Analysis of the water content of the Ural River in 2007 – 2016 showed a negative trend in the values of the annual runoff (Table 2, Fig. 2). Average annual volume of the water runoff for the previous 20 years at the Kushumsky gauging station was 10.6 km^3. After the optimal full-water content in 2007, the annual runoff volumes were below the average level and significantly fluctuated, dropping in 2008–2010, 2012 and 2015, down to the level of 4.45 km^3.

Hydrological conditions during the spring spawning season in 2007 – 2016 years influenced the duration of the spring flood, as well as the degree and duration of flooding of the spawning grounds (Table 2, Ffig. 2). After the 100% degree of flooding of the spawning grounds in 2007, in 2008 – 2016, it fluctuated between 39 – 78% reaching the lowest values in the most law-water years 2009, 2010 and 2015. Duration of flooding of the spawning grounds was also 100% in 2007, and then, in the period of 2008 – 2016, fluctuated within 53 – 87%, reaching the lowest values in the most law-water years 2009, 2010 and 2015.

Table 2. Hydrological and spawning conditions during the spring spawning seasons in 2007 – 2016

Years	Annual runoff volume, km^3	Degree of flooding of spawning grounds, %	Duration of flooding of spawning grounds, %
2007	11,60	100	100
2008	7,49	65	67
2009	5,30	46	58
2010	5,20	45	54
2011	6,40	56	65
2012	5,75	51	59
2013	7,89	68	71

2014	8,96	78	74
2015	4,45	39	53
2016	6,20	54	87

A correlation coefficient (r) between the fluctuations of the annual water runoff and the duration of flooding of the spawning grounds is equal to 1, whereas between the degree and duration of flooding of the spawning grounds $r = 0.8$ (Fig.2).

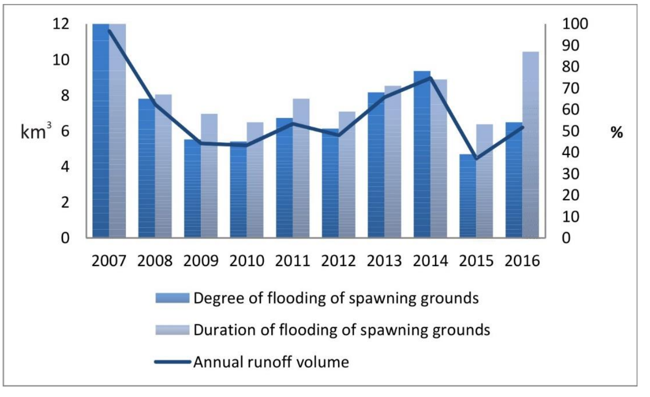

Figure 2. Hydrological and spawning conditions during the spring spawning seasons in 2007 – 2016

Deterioration of the spawning conditions markedly affected the juveniles yield. The results of studies on spawning efficiency, expressed in the dynamics of the downstream migration and juveniles yield for 2007 – 2016 years, are presented in Table 3.

Table 3. Dynamics of yield and downstream migration of the juvenile fish of the Ural River in the West Kazakhstan oblast in 2007 – 2016

Species of juvenile fish	specimen/100 m3									
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Asp	7	5	4	4	5	4	3	7	3	5
Blue bream	18	7	3	7	17	9	7	14	5	17
Bream	28	15	7	10	25	15	10	15	8	23
Catfish	3	2	1	2	2	1	-	1	1	3
Common carp	5	2	-	1	5	1	-	2	1	3
Common nase	-	-	-	2	1	1	3	1	1	1
European chub	-	-	-	2	1	1	2	1	1	1
Ide	-	-	-	1	1	2	2	2	1	1
Pike perch	8	7	5	1	1	1	1	1	1	7
Roach	17	7	4	6	16	8	8	10	7	12

Sabre carp	15	9	6	8	10	10	17	19	15	15
Silver carp	-	-	-	2	1	1	-	-	1	1
Sterlet	-	-	-	1	1	1	-	-	-	-
Volga pikeperch	2	2	1	7	8	8	4	7	5	4
White bream	16	8	5	7	14	9	20	24	18	17
Total:	119	64	36	61	108	72	77	104	68	110

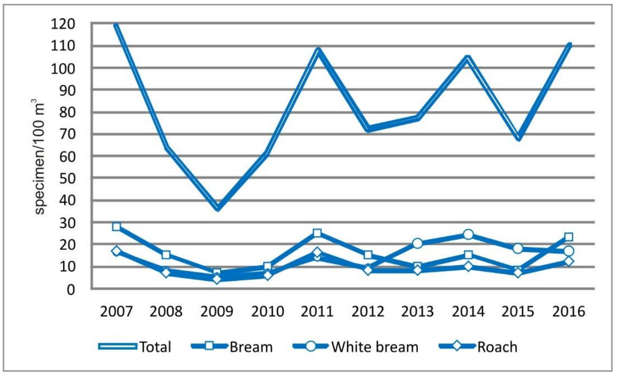

Figure 3. Dynamics of yield and downstream migration of the juvenile fish of the Ural River in the West Kazakhstan oblast in 2007 – 2016

In comparison with 2007 year, having the optimal water content, the total number of the juvenile fish fluctuated in the following years, significantly decreasing in the low-water years 2008 – 2010, 2012 – 2013 and 2015, and increasing in 2011, 2013, 2014 and 2016 (Table 3). In 2016, the total values of the juveniles yield were quite high and close to that of 2007. Although the level of the water content in 2016 was low, the duration of the spring flood (57 days), and, respectively, the periods of flooding of spawning grounds and spawning were long enough (Table 2). Fluctuations in the juveniles yield values for particular species were, in general, close to the common trend, as is seen on the examples of such species as bream, white bream and roach (Table 3, Fig. 3).

Table 4. Dynamics of the biomass of the commercial fish stocks of the Ural River in the West Kazakhstan Region in 2008–2016

Fish species	Biomass of commercial stocks by years, tons								
	2008	2009	2010	2011	2012	2013	2014	2015	2016
Common carp	241,6	186,3	177,7	142,3	95,3	64,4	52,4	42,6	31,6
Bream	149,5	151,0	151,4	124,7	89,7	20,1	20,4	21,8	20,7
White bream	93,6	58,6	56,3	43,2	31,3	33,8	27,3	27,8	24,8
Blue bream	179,7	53,3	54,7	41,9	29,8	12,2	11,0	11,0	12,8

Sabre carp	48,5	57,5	57,5	53,1	47,5	24,0	22,4	22,3	22,6
Asp	51,7	54,8	37,9	40,1	31,2	14,7	13,0	15,1	16,1
Pike perch	32,8	56,0	45,6	28,7	20,8	9,1	9,6	10,1	8,1
Volga pikeperch	-	32,2	28,8	35,6	37,2	20,3	18,9	17,4	13,8
Catfish	54,6	90,0	95,2	37,6	31,5	22,1	16,6	17,7	18,5
Total:	852,0	739,7	705,1	547,2	414,3	220,7	191,58	185,8	169,0

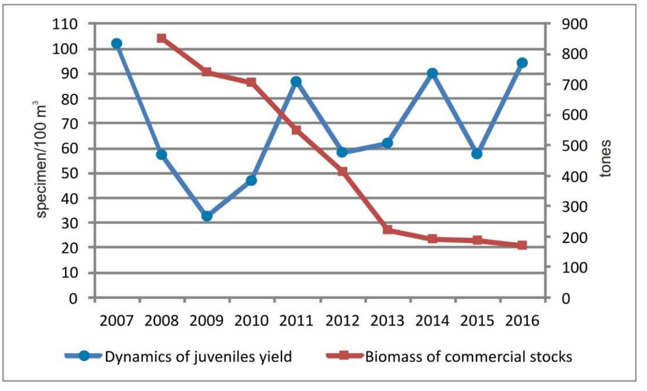

Figure 4. Dynamics of the juveniles yield and the biomass of commercial fish stocks of the Ural River in the West Kazakhstan oblast in 2007 – 2016 (total for 9 commercial species)

Decrease in the juveniles' yield affected the commercial fish stocks of the following years. In the years 2008 – 2016 the resource research of populations of 9 commercial fish species was conducted. Dynamics of the biomass of the commercial stocks over these years has an extremely negative trend (Table 4, Fig.4). The fish resources have been catastrophically decreasing from year to year. To a greater extent decreased the reserves of such species as common carp (by 7.6 times), bream (by 7.2 times) and blue bream (by 14 times). The reserves of white bream decreased by 3.8 times, sabre carp by 2.1 times, asp – by 3.2 times, pike perch – by 4.1 times, Volga pikeperch – by 2.3 times, catfish – by 3.0 times.

Discussion

Hydrological regime of the Ural River during the spring flood is the prevailing factor affecting the fish productivity. Sufficient watering of the spawning areas is a necessary condition for an effective natural reproduction and, consequently, recovery of commercial fish stocks. The optimal water level allows migratory and semi-migratory fish populations to reach the spawning sites located 500 – 800 km upstream from the Caspian.

In 2008 – 2016, the annual runoff volume of the Ural River was below the average level in the range of 15.5 – 58.0% (Fig. 2). As the spring floods were low in level in the years 2008 –2015, this significantly reduced the area of spawning grounds (Table 2). The time of spawning coincides with the period of flooding of spawning grounds with the spring floods. The optimal spawning duration is 55 days, but in low-water years 2008 – 2015 the spring floods were short in time, which noticeably reduced the spawning period.

The deterioration of hydrological parameters negatively affected the yield of juveniles (Table 3). The total number of juveniles was particularly low in low-water years 2008 – 2010, 2012 – 2013 and 2015 (Table 3). The instability of water conditions affected the reproduction of fish both with an early spawning period in the 3 decade of April – 1 decade of May (pike perch, asp, Volga pikeperch), so with a middle spawning period in 1 – 2 decades of May (bream, white bream, blue bream). Especially noticeably was affected the reproduction of the late-spawning common carp, which spawns later than other phytophilic species in the 3 decade of May – 1 decade of June. In low-water years at this time, there is a recession of floods and floodplain spawning areas disconnect from the river. In comparison with the full-water year 2007, in the following low-water years the number of carp juveniles in the river dropped by 60 – 80%. In low-water floods in 2009, 2010, 2012, 2015, in the conditions of water recession in 2 – 3 decades of April, carp had no conditions for spawning. Even in the first decade of June, carps with full gonads were observed in the river.

Reduction of spawning areas and spawning periods caused a decline in the level of reproduction of fish stocks from 11 to 70% (Table 4, Fig. 4). In comparison with 2008, in 2016 the biomass of commercial fish has decreased by 5 times. Since the juveniles yield in 2008 – 2014 was reduced, in 2016 commercial stocks decreased due to a decrease in populations of 3, 4, 5, 6, 7, 8 and 9-year fish.

Thus, there is a clear connection between the negative dynamics of fish resources and the deterioration of water content. Reduction of water runoff worsens spawning conditions, which leads to a decrease in rate of natural reproduction.

To moderate the influence of unstable water content on fish resources, melioration (cleaning and deepening) of the ducts connecting the floodplain spawning grounds with the river bed is necessary. Due to the high humidity in the summer, they quickly overgrow with grass, which causes them to deposit with sand and silt. Also, many driftwood are flooded into the ducts. All this causes clogging of the duct channels and prevents watering of spawning areas, entering fish for spawning and the subsequent downstream migration of the adult and juvenile fish into the river.

However, another important factor in reducing commercial stocks, at least in part, can be illegal fishing on the Ural River. It is illegal fishing that can explain the undermining of populations of sturgeons, since they spawn in the riverbed and not particularly depend on the water content. A study of their natural reproduction in 2015 – 2016 showed a zero result in the downstream migration of sturgeon juveniles in the Ural River in the West Kazakhstan oblast, although 80% of the sturgeon natural spawning grounds are located here.[2)]

Illegal fishing on the Ural River in the West Kazakhstan oblast is widespread, but its exact extent and location is unknown, since there is no constant real control of the water areas. To implement an effective protection regime on the Ural River and the adjacent area of the Caspian Sea, it is necessary to develop and implement a high-tech system of visual control of water areas in feeding, migration and spawning grounds of valuable fish. The proposed system of visual control can be performed by unmanned aerial vehicles (UAVs) having color and infrared cameras of high resolution transmitting the image in real time. Currently, UAVs are widely used for civilian purposes to control extended areas.

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NOTES

1. Report on scientific research work "Determination of the fish productivity of fishery reservoirs and / or their plots, development of biological justifications for the total allowable catches of fish and other aquatic animals, the regime and regulation of fisheries in fishery water bodies of international, republican and local values and reservoirs of the specially protected natural territories of Zhayik- Caspian basin, as well as assessment of the state of fish resources on reserve water bodies of local importance. Section 3. Almaty, pp. 226 – 227 (2016) [In Russian].
2. Report on scientific research work "Assessment of the state of spawning grounds and of natural and artificial reproduction of sturgeon species of the Zhayik River (Ural River). Section Zhayik River (Ural River) in the West Kazakhstan oblast". Uralsk, pp. 10 – 12 (2016) [In Russian]. (in Russian).

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