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Current State of Ichthyofauna and Prospects of Fish Farming in the Syrdarya River Delta Lakes

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Abstract

The article reviews the issues of forming fish populations and studying the current state of commercial fish species in the delta lakes of the Syrdarya River for subsequent effective development of fish farming. In 2020, research works were carried out on lakes Akbilek, Tushchy, Shomishkol, Karakol and Akshatau-Sorgak of Aral District of Kyzylorda Region. At each of them, local ichthyofauna were identified and studied by way of experimental catches. Subsequently, the ichthyologic material was selected, processed and underwent biological analysis. The research also included the determination of physical and geographical parameters of target lakes, as well as evaluation of their chemical water profile. Experimental and control fish catches were carried out using fixed nets with 18-60 mm mesh. For biological analysis, 239 fish were selected, including: snakehead (1 sample), common carp (3 samples), crucian carp (9 samples), roach (102 samples), pikeperch (25 samples), Northern pike (26 samples), perch (35 samples), rudd (19 samples), sabre carp (1 sample), bream (11 samples), and asp (11 samples). The suitability of target lakes for further fish husbandry was determined based on the research findings, available literature, and archival data.

Keywords: delta lakes, current ichthyofauna, Syrdarya River, fish husbandry, commercial fish.

1. Introduction

Thus far, boosting the production of marketable fish by the conventional fishing intensification in natural reservoirs has exhausted its potential. Growing fish in lake commercial fish farms (LCFF) established at natural lakes by way of their development manifests one way to further increase fish production. Setting up LCFFs is more rational than the traditional exploitation of lake natural resources.

Kazakhstan's numerous lakes possess a significant bio-resource potential. However, the development of the natural wealth of domestic lakes has not yet received proper attention due to underestimating their role, as well as insufficient knowledge about these reservoirs (Nortseva et al., 2008). As to fish stocks, such lakes are often characterized by low fish productivity, although many of them have a promising fish-farming capacity (FishRPC, 2016).

Kyzylorda Region has a significant reserve reservoir fund. Their research and assessment of their resources of fish and other aquatic animals are of great importance, both in terms of maintaining the optimal level of fish stocks and preserving the biodiversity of small water body populations (FishRPC, 2016).

Lake and wetland systems of the Syrdarya Delta form the basis for the sustainable existence of aquatic and near-water ecosystems of Kazakhstan's section of the Aral Sea Region, the foundation of fish and fodder production, as well as a prerequisite for life-sustaining activities by the residents of Kazalinsk and Aral Districts of Kyzylorda Region (Toleubayev, 2006).

Fishery represents a traditional industry in Kyzylorda Region. Thus, the restoration and development of lake, pond and cage fishery enterprises will significantly boost the region's economy and create new jobs (Fefelov, Bulavina, 2019).

The increased flow of the Syrdarya River (starting 1988) enhanced water availability in the Kamyshlybash and Akshatau-Sorgak lake systems. The rehabilitation of hydro-technical installations improved these lakes' water supply, thus forging conditions for advancing their fishery use (Research Unit of Tushchy LCFF, 2019).

The objectives of this research included determining the species profile of commercial and non-commercial fish in the delta lakes of the Syrdarya – Akshatau-Sorgak, Karakol, Shomishkol, Tushchy and Akbilek – in Aral District of Kyzylorda Region; assessing the suitability of target lakes for potential commercial fishery management; and, based on the data obtained, elaborating general recommendations for increasing the fish productivity of the target reservoirs.

2. Research area

2.1. Geographic location

The field research on target lakes was carried out during September 6-14, 2020. The reservoirs comprise two lake systems: Akshatau-Sorgak (Akshatau-Sorgak, Karakol, and Shomishkol) and Primorskaya (*rus. Coastal*) Right-Bank (Tushchy, Akbilek). The Akshatau-Sorgak Lake System is located left of the Syrdarya, 60-70 km away from the river mouth; and the Primorskaya Right-Bank Lake System – 30-35 km from the river mouth. The average distance of target reservoirs from the local fish nursery is 20-25 km. The dominating relief in the research area is gently rolling forest-steppe. The geophysical and hydrochemical parameters are presented below.

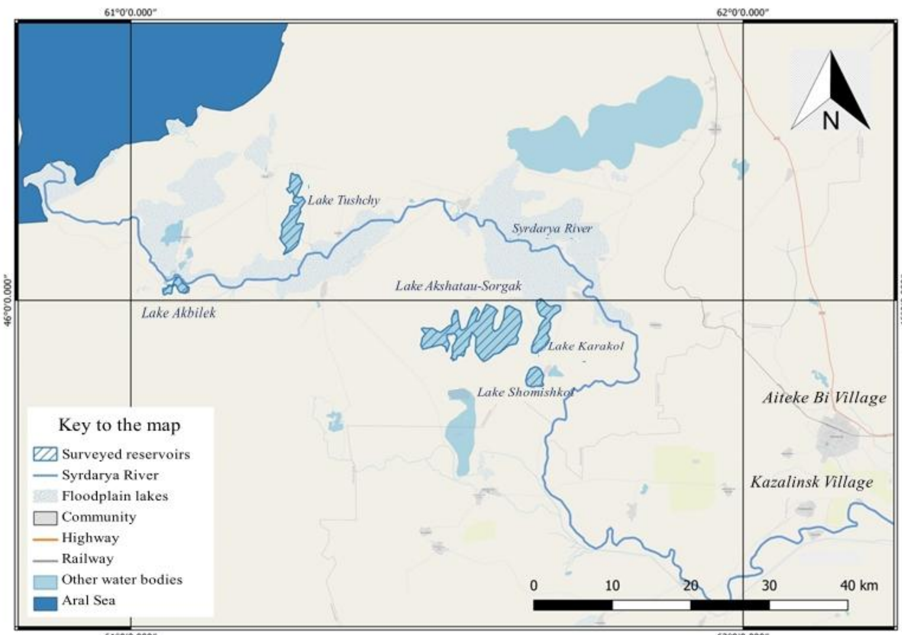

Figure 1. *Map of investigated lakes.*

2.2. Climate

The climate in the research area is sharp continental with significant annual and daily air temperature fluctuations and temporal instability of climatic indexes; and is characterized by abundant heat and predominantly clear and dry weather (Ramazanova, 1969). Aridity is yet another distinctive feature of the area. The mean daily air temperature ranges between 8.2 and 10.3ºC; with the annual amplitude between -30 and +43ºC (Research Unit of Akshatau-Sorgak LCFF, 2019).

The mean annual air temperature is approx. +18ºC. The frost-free period lasts 215-250 days. Low-temperature months are from mid-November to mid-March or early April, with January as the coldest. The hottest period last from June to August (Research Unit of Akshatau-Sorgak LCFF, 2019).

2.3. Ice regime

As a rule, the first ice formations on the lake are observed by November 25 followed by complete ice cover. The ice-breaking period lasts more than 74 days; the water surface completely rids of ice by early March. The ice-free period ranges from 225 to 295 days. From the moment of the ice sheet formation, its thickness rapidly grows – by mid-January it reaches 25 cm, and by the end of winter exceeded 28 cm in some years. The snow cover on ice is usually thin (5-15 cm) (Research Unit of Shomishkol LCFF, 2019).

2.4. Temperature regime

The thermal regime on target lakes has no significant differences. The beginning of the spring heating period falls on late February-early April, when the positive heat flow becomes stable. At this time, the ice on the lakes gets thinner, and the under-ice temperature may rise up to 0.4-0.5°C. Early on, water heating is slow, but after the complete disappearance of ice (on average March 14), water temperature rises very quickly – already by April 15, its values close to the shore may exceed 4°C. Direct temperature stratification, occasionally disturbed by wind, represents a characteristic feature of the summer warm-up period. In case of wind, vertical water temperature gradients sharply reduce, at times down to 0°C/m. In calm and clear weather, the warming up of the water surface is extremely intense. In this case, the water temperature gradient by depth can exceed 2°C/m. After the heat flow over lake surface becomes negative, the cooling period begins. It deserves noting that starting early spring until September, heat accumulation continues in the soils forming lake bottom.

3. Methods and materials

The selection and processing of ichthyological material were done based on the generally accepted methods (Pravdin, 1966; Spanovskaya et al., 1976; Mina, 1976). Ichthyological sampling aimed to collect data on species, sex, age and other biological parameters of the fish populations, their mass and size.

The total of 11 fish species in the amount of 239 specimens were selected for biological analysis. Fish catching was done using a set of standard fishing gear with the following characteristics: fixed (set) nets – each 25 m long and 2-3 m high. The net circuit consisted of 7 net sections with different mesh: 18, 20, 24, 30, 40, 50, 60 mm. A dragnet (6 m long; 3 mm mesh) was used for catching active fish juveniles. At the site, the net circuit was installed at nighttime; the catching period lasted at least 12 hours. In case of increasing or decreasing the catching period due to weather or other reasons, the catch values were re-calculated per time unit – fish net/day. The nets were installed at the pre-planned sites where the coastal conditions (relief, vegetation) allowed it.

The processing of the fixed (gill) net catch included the following:

- Species identification;
- Calculation of the total quantity and mass of each species in the catch for each type of net;

- Mass measuring (fish body length without caudal fin) of the whole catch;
- Identification of the most abundant fish species and their subsequent biological analysis. The sample size was determined as follows – 10 specimens for each analyzed species per 1 centimeter of this species' fish length within the limits of the size range observed in the area (Pravdin, 1966).

The biological analysis (Pravdin, 1966) included the following:

1. Measuring fish body length without caudal fin (ℓ);
2. Measuring total body weight (Q);
3. Measuring body weight without guts (q);
4. Determining sex and maturity;
5. Sampling to determine absolute, relative and population fertility;
6. Collecting material for age determination (scales).

Conservation and storage of ichthyological samples: fish juveniles

Sample conservation was done in 4% formalin solution (mixed with lake water).

Catches by net and other fishing gear underwent sorting by species, with subsequent necessary calculations, weighing, and logging data in special net catch, size and weight profile cards.

Fish vertebrae were used to determine the age of catfish, and scales were used for this purpose for other species. Age determination was done as per the methodology developed by I.F. Pravdin and N.I. Chugunova (Pravdin, 1966; Chugunova, 1959).

Fish catching was carried out using a set of standard fishing gear (i.e., circuit of set capron gillnets with 18-60 mm mesh, and floating nets with 80-120 mm mesh), allowing obtaining data on the species, sex, and age profile of fish populations and species abundance.

While determining the average catch per net, the number of standard net circuits with different mesh (from 18 to 60 mm, 25 m each) was taken into account, and the mean catch per 1 standard net circuit (net 25 m long, 2 m high, fishing duration 12 hours) was calculated.

Statistical processing was carried out based on the methodology developed by G.F. Lakin (1990). Mathematical and statistical processing of the obtained data (creating fish database, calculation of nutritional state and other parameters) was carried out using MS Excel and based on the archival data of the FishRPC Aral Branch.

Fish-husbandry calculations were carried out as per the methods adopted in lake and pond fish farming. While elaborating recommendations on the fish farming use of target lakes, the factors like area and distance from fish nurseries were also considered.

At all the investigated reservoirs, sampling for hydrochemical analysis was carried out based on the industry-accepted methods. The samples were collected from the surface water layer during daytime. In the source sampling, visual observation of water characteristics (oil film on water, dead algae clusters, increased water agitation and foaming, etc.) was done also.

General and water sampling workflow

While conducting hydrochemical analysis directly at the lakes undergoing examination, it was necessary to adhere to a certain workflow.

Collection of surface water samples:

1. Determining water transparency and color using water color disk and scale (only for lakes);
2. Measuring water temperature;
3. Collecting water sample(s);
4. Examining the content of hydrogen (pH), carbon dioxide (CO_2), and carbonate ions (SO3(2-), as well as water oxygen;
5. Filling bottles (1 L volume) with water samples for further laboratory analysis (not more than 3/4 of the container volume);
6. Determining the organoleptic properties of water;
7. Logging the corresponding data in designated spreadsheet while conducting all specified works.

Sampling water from different depths:

1. Determining water transparency and color using water color disk and scale (only for lakes);
2. Lowering, holding (for 10 minutes) and pulling out the bathometer;
3. Measuring temperature using additional and main thermometers;
4. Determining pH, carbon dioxide, oxygen and SO_2 (if possible) content in water;
5. Lowering bathometer again to the same depth and withdrawing enough water to fill the sample bottles; it is not necessary to keep the bathometer at the examined depth;
6. Determining the taste and smell of water;
7. Logging the results.

In lakes, surface water samples are collected by carefully scooping (to avoid shaking) with a sufficiently large vessel like a basin or bucket); to avoid sample contamination, the vessel should be used only for this purpose. The immersion depth should not exceed 0.2-0.5 m.

Sample preservation

Water samples should be preserved using 4% formalin solution. Two (2) water samples should be collected from each investigated reservoir.

The AQUA-CHECK Photometer was used to accurately determine the presence of biogenic compounds in water. The Söll reagents for photometric measurements were used for analysis. The SAMARA-2 Electrochemical Analyzer was used in situ for determining the temperature and hydrogen index.

Water turbidity was determined using the Secchi disk. Electrical conductivity was not measured.

4. Results

4.1. Established characteristics of lakes and water

By their nature of water exchange, the target lakes belong to low-flow (accumulative-transit) reservoirs.

The soft underwater vegetation in the lakes is poorly developed, mainly consisting of perfoliate pondweed and willow weed. The area covered with reed vegetation averaged 40-50% of the lakes' water area (Research Unit of Akshatau-Sorgak LCFF, 2019).

No sources of anthropogenic contamination were detected on any of the surveyed lakes. Unpaved roads passing near the lakes and economic activities (cattle grazing) do not affect the overall ecological situation. Processing enterprises were also absent adjacent to the lakes.

Due to the fact that all target lakes are directly connected and feed from the Syrdarya River, their current ichthyofauna species profile is similar. The summer of 2020 turned out to be hot, and because of irrigation withdrawal, the water level in the Syrdarya was extremely low. That fact could not but affect the water level in the examined lakes. It is also worth noting that the water in all of the reservoirs is brackish and, thus by ionic composition belongs to the sulfate-magnesium type. The biogenic compound content depends on the time of seasonal runoff of inflowing water.

On all the lakes – except for Shomishkol – the overall condition of gateway installations was good, with fish protection devices properly operating on discharge canals. The water ducts on Lake Shomishkol require reclamation as well as strengthening of coastal bottoms.

In terms of their physical parameters, all investigated lakes are optimal for the future fish farming (Table I).

Table I. Geographical coordinates and physical parameters of investigated lakes.

Waterbody	**Coordinates**		**Area, ha**	**Length, km**	**Width, km**	**Depth, min-max, m**
	Latitude	**Longitude**				
Akshatau-Sorgak	45°59'380"	061°38'392"	3,500	7.5	5	2.5-27
Karakol	45°57'020"	061°40'788"	1,100	6.2	1.3	3-10
Shomishkol	45°54'839"	061°38'758"	500	2.8	1.9	2-9
Tushchy	46°08'579"	061°16'527"	1,100	8	1.4	1.8-5.4
Akbilek	46°00'932"	061°04'930"	110	4.7	235	0.7-2.5

Table II. Hydrochemical parameters of investigated lakes.

Waterbody	pH	O_2, mg/L	t, °C	Oxygen demand, mg O/L	Biogenic compounds, mg/L				Mineraliz., mg/dm^3
					NH_4	NO_2	NO_3	PO_4	
Akshatau-Sorgak	7.80	6.5	21.6	4.2	0.29	0.84	6.0	0.906	2,300
Karakol	7.85	7.4	21.7	4.9	0.14	0.03	6.0	0.160	2,100
Shomishkol	7.51	7.0	20.2	4.3	0.01	0.03	6.0	1.500	1,800
Tushchy	8.87	6.8	24.1	3.5	1.50	0.07	6.0	0.160	2,500
Akbilek	8.83	6.7	20.2	2.3	1.30	0.07	6.0	0.160	1,300

4.2. Akshatau-Sorgak Lake

Lake Akshatau-Sorgak gets its water from the Syrdarya River via the Akshakiz Canal (length 1.2 km) and depends on the water level in the river. Water is supplied during spring and summer (Research Unit of Akshatau-Sorgak LCFF, 2019). The canal has an adjustable water outlet with an overrunning road and fish protection installation. The lake's geographic coordinates are presented in Table I.

The water in the lake is clean, colorless off the coast, and dark green at depth, sometimes with blue and yellowish shades. After complete water regulation through the Akshakyz Canal and construction of the cross regulator in the estuary section, water enters the lake from April to late September until filling it to the designated level. The maximum lake's area during the research period amounted to approx. 3,500 ha. The lake's bottom is flat; the bottom soil is sandy and sandy-silty. The lake's mean depth is 3.5 m, with the maximum of about 27 m (Table I). The coast is slightly indented. The lake is brackish and rounded in shape.

The hydrochemical regime of Lake Akshatau-Sorgak during the research period was stable. The dissolved oxygen in the central section amounted to 6.5 mg/L. The hydrogen index was registered as slightly alkaline (7.8). The lake's permanganate oxidizing averaged 4.2 g O/L (Table III). Based on the Secchi disk, water transparency was 1.2 m. The biogenic compound content depends on the time of seasonal runoff of inflowing water. According to the analyses of samples collected at two different sites, the following were detected: ammonium nitrogen – 0.29 mg/L, nitrites – 0.84 mg/L, nitrates – 6.0 mg/L, and mineral phosphate – 0.906 mg/L. The lake's water mineralization is characterized by low ionic compound content (2,300 mg/dm^3) (Table II). In the ion profile, cation content is dominated mainly by calcium and magnesium ions, as well as sulfate compounds making up from 300 to 5,000 mg/dm^3 (Research Unit of Akshatau-Sorgak LCFF, 2019). Overall, the water is brackish and, thus in terms of ionic composition, it belongs to the sulfate-calcium type. The lake's water hardness is 11 mg-equ/L, indicating its belonging to the category of "extremely hard".

4.3. Karakol Lake

Lake Karakol is located on the left bank of the Syrdarya River, 60-70 km from its mouth, east of Lake Akshatau-Sorgak in a meridionally elongated clough with uplands stretching on both its sides for 5-6 km. Narrowing down to 300 m, the lake divides into two stretches: southern (large) – Lake Karakol per se, and northern (small) – Lake Shalandykol. Thus, the entire lake is 8-shaped. Its geographic coordinates are presented in Table I.

The lake's area during the research period amounted to 1,110 ha, length – 6.2 km, and width – 1.3 km. The depth of the reservoir ranges between 3 and 10 m (Table I). Karakol also feeds from the Syrdarya through the Bes-Zharma Collector; water is supplied from early spring until summer.

The water outlet of the Bes-Zharma Collector up to the lake is approx. 5 km long and has a cross regulator. As a rule, water inflow takes place during April-September. The bottom soil is grey mud often with an admixture of sand and shells.

The hydrochemical regime of Lake Karakol during the research period was satisfactory. The presence of dissolved oxygen averaged 7.4 mg/L. The hydrogen index was slightly alkaline (7.85). The lake's permanganate oxidizing averaged 4.9 mg O/L. According to the Secchi disk measurements, the water transparency amounted to 2.10 m. The biogenic compound content depends on the time of seasonal runoff of inflowing water. According to the analysis of water samples collected at two different sites, the following were detected (falling within the designated MAC): ammonium nitrogen – 0.14 mg/L, nitrites – 0.03 mg/L, nitrates – 6.0 mg/L, and mineral phosphate – 0.160 mg/L. The mineralization of the lake water was characterized by low ionic compound content and amounted to 2,100 mg/dm^3 (Table II). In the ion profile, calcium ions and sulfate compounds – making up from 150 to 4,500 mg/dm^3 – mainly dominated in the cation content (Research Unit of Karakol LCFF, 2019). Water hardness in Lake Karakol amounted to 16 mg-equ/L indicating its belonging to the category of "extremely hard" – this level of hardness is within the norm for both ichthyofauna and other hydrobionts.

4.4. Shomishkol Lake

Water flows to Lake Shomishkol from the Syrdarya through the Ardan Collector starting early spring through summer. The Ardan Collector's water outlet (length approx. 13 km) has a cross regulator. The ducts require cleaning and reclamation. The main water influx occurs during April-September. The lake's geographic coordinates are given in Table I.

During the research period, the lake's area was 500 ha, length – 2.8 km, and width – 1.9 km. The depth of the reservoir ranges between 2 and 19 m (Table I). Tamarisk and camel thorn shrubbery grows along the reservoir's shore. The water is clean, colorless off the coast, and at depth its color ranges from dark green to occasional blue and yellowish shades; water transparency is 0.8 m. With the complete regulation via the Ardan Collector and operation of the cross regular in the estuary section, water usually enters the lake from April until late September until filling it up to the designated mark. The lake's bottom is flat; the bottom soil is sandy and sandy-silty. The mean depth is up to 2 meters, and the maximum is about 9 m. The coast is slightly indented. The lake is brackish, has an elongated shape, and a discharge canal. The local mean annual rainfall is 11-20 mm, with over ¾ (74-80%) falling on the winter-spring period.

The lake is located in the crater in the middle of an elevated plateau. It has clearly pronounced shores. The depth increase is gradual.

During spring-summer research period, the hydrochemical regime of Lake Shomishkol was stable (Fig. 1.). The presence of dissolved oxygen in the central and coastal zones was 7.0 mg/L, with the hydrogen index detected as slightly alkaline (7.51). The water's permanganate oxidizing was moderate, indicating low oxidant substance content (4.3 mg O/L). Based on the analyses of water samples collected at two different sites, the following were detected (falling within the designated MAC): ammonium nitrogen – 0.01 mg/L, nitrites – 0.03 mg/L, nitrates – 6.0 mg/L, and mineral phosphate – 1.500 mg/L. The mineralization of the lake water is characterized by high ionic compound content, and amounted to 1,600-1,800 mg/dm^3 (Table II). In the ion composition, the cations are dominated by Mg^{2+} ions, and sulfate compounds making up from 100 to 4,000 mg/dm^3 (Research Unit of Shomishkol LCFF, 2019).

4.5. Tushchy Lake

Like all target lakes above, Lake Tushchy gets its water from the Syrdarya River via the Beketay, Balgabay and Stan Canals, each 2.1-3.4 km long, and depends on the water level in the river. Water is supplied starting early spring through summer (Research Unit of Tushchy LCFF, 2019). The canals have adjustable water outlet cross regulators. The lake's coordinates are provided in Table I.

During the research, the maximum lake area amounted to 1,100 ha, length – 8 km, and width – 1.4 km. The lake's bottom is flat; the bottom soil is sandy and sandy-silty. The mean depth is within 1.8 meters, and the maximum – approx. 5.4 m (Table I). The coast is slightly indented. The lake is brackish and rounded in shape. The water in the lake is clean, colorless off the coast, and at depth varies from dark green to occasional blue and yellowish shades. The water transparency is 1.4 m.

During the spring-summer research period, the hydrochemical regime of Lake Tushchy was relatively stable. The presence of dissolved oxygen in the central section was 6.8 mg/L, and 6.5 mg/L in the coastal section. The hydrogen index was registered as slightly alkaline (8.87). The lake's permanganate oxidizing was moderate – 3.5 mg O/L. According to the analyses of water samples collected at two different sites, the following were detected (falling within the designated MAC): ammonium nitrogen – 1.50 mg/L, nitrites – 0.07 mg/L, nitrates – 6.0 mg/L, and mineral phosphate – 0.160 mg/L. The lake's water mineralization is characterized by low ionic compounds content and amounted to 2,500 mg/dm^3 (Table II). In the ionic composition, the cations are dominated by calcium, magnesium and sulfate ions making up from 200 to 3,500 mg/dm^3 (Research Unit of Tushchy LCFF, 2019). Water hardness in Lake Tushchy is 15 mg-equ/L, indicating its belonging to the category of “extremely hard”. Summing up, the lake’s hydrochemical regime can be described as optimal with an increased content of nitrogenous and nitrifying compounds. The lake’s water positively affects the development of hydrofauna. Qualitative changes in water properties depend on water runoff and sedimentation during spring-autumn period.

4.6. Akbilek Lake

During the research, the lake’s area was 110 ha, length – 4.7 km, and width – 230 m. At times, the water inflow from the Syrdarya depends on the water level in the latter. The inflow canal has a cross regulator. At the time of the study, the mean depth amounted to 0.7 m, and the maximum – 2.5 m (Table I). The lake’s geographic coordinates are given in Table I.

During the spring-summer time of the field research, the hydrochemical regime of Lake Akbilek was relatively satisfactory. The presence of dissolved oxygen in the lake’s central section amounted to 6.7 mg/L. The hydrogen index was recorded as slightly alkaline (8.83). The permanganate oxidizing averaged 2.3 mg O/L. Based on the Secchi disk measurements, the water transparency was 1.2 m. According to the analyses of water samples collected at two different sites, the following were detected (falling within the designated MAC): ammonium nitrogen – 1.30 mg/L, nitrites – 0.07 mg/L, nitrates – 6.0 mg/L, and mineral phosphate – 0.160 mg/L. The lake’s water mineralization is characterized by low ionic compound content amounting to 1,300 mg/dm^3 (Table II). In the ionic composition, calcium ions and sulfate compounds – ranging between 75 and 1,800 mg/dm^3 – dominate among cations (Report. Determination of fish productivity of fishery water bodies, 2016).

5. Results: ichthyofauna

5.1. Current ichthyofauna profile of investigated lakes

The ichthyological surveys within the framework of this research, executed using the circuits of small-mesh nets (18-60 mm), of the target delta lakes in the Syrdarya River Basin showed a relatively small species diversity in the catches. Thus, during the entire observation period (September 6-14), only 16 fish species were encountered in the catches on all five lakes. The species names and designation statuses are presented in Table III, with the following brief biological description.

Table III. Fish species composition, frequency and status in investigated lakes.

Fish species	Status	Waterbody				
		Akshatau -Sorgak	Karakol	Shomish kol	Tushchy	Akbilek
Aral roach – *Rutilus rutilus aralensis* (Berg)	Commercial	+	+	+	+	+
Caspian bream – *Abramis brama orientalis* (Berg)	Commercial	-	+	-	-	-
Aral common carp – *Cyprinus caspio aralensis* (Spitshakow)	Commercial	-	-	+	-	+
Rudd – *Scardinus erythropthalmus*	Commercial	+	-	+	+	+
Sabre carp – *Pelecus cultratus* (Linne)	Commercial	+	-	-	-	-
Prussian carp – *Carassius auratus* (Linne)	Commercial	+	-	-	-	+
Aral asp – *Aspius aspius iblioides*	Commercial	-	+	-	-	+
Pikeperch – *Stizostedion lucioperca* (Linne)	Commercial	+	-	-	-	+
European perch – *Perca fluviatilis* (Linne)	Commercial	+	+	+	+	-
N. pike – *Esox lucius* (Linne)	Commercial	-	+	+	+	-
Snakehead – *Channa argus Warpachowskii* (Berg)	Commercial	-	-	-	-	+
Syrdarya bystranka - *Alburnoides taeniatus* (Kessler)	Non-commercial	+	+	+	+	+
Sawbelly - *Hemiculter leucisculus* (Basilewsky)	Non-commercial	+	-	+	-	+
River abbotina - *A.rivularis* (Basilewski)	Non-commercial	+	-	+	+	-
Stone morocos - *P.parva* (Schlegel)	Non-commercial	+	+	+	+	+
Bitterling - *Rhodeus Agassiz*	Non-commercial	+	+	+	+	+

The majority of the catches in all target lakes comprised widespread species like roach and rudd, and in lakes Akshatau-Sorgak and Shomishkol – pikeperch, perch and Northern pike. The greatest species diversity was observed in Lake Akbilek – 7 fish species (roach, common carp, rudd, Prussian carp, asp, pikeperch, and snakehead) were encountered in the catches. In all the reservoirs, while fishing with a minnow seine stone morocos and bitterling made up the predominant species. The caught non-commercial species included Syrdarya bystranka, sawbelly, and river abbotina (Table III).

5.2. Biological parameters of current ichthyofauna

Table IV. Biological parameter of fish species caught in investigated lakes.

Lake Akshatau-Sorgak						
Fish species	Length. min-max. mm	M±m	Weight. min-max. g	M±m	Fultin's condition factor	N
Roach	160-181	172.8±9.3	89-121	109.8±14.0	2.1	5
Rudd	160	-	90	-	2.2	1
Sabre carp	246	-	151	-	1.0	1
Crucian carp	180-260	238.5±28.3	225-607	479.8±128.3	3.5	8
Pikeperch	265-390	317.2±33.9	247-858	437.1±141.1	1.3	23
European perch	110-203	162.3±27.9	26-163	97±40	2.1	21
Lake Karakol						
Roach	162-205	177.6±10.5	88-172	118.7±22.4	2.1	26
Bream	160-235	195.5±19.8	82-256	163.1±47.2	2.1	11
Asp	250-450	350±141.4	215-1442	828.5±867.6	1.5	2
European perch	165-205	185±15.1	101-205	137±42.1	2.1	8
N. pike	290-370	335±33.5	229-435	334.7±83.6	0.9	7
Lake Shomishkol						
Roach	160-182	171.1±7.8	83-130	104.3±13.9	2.1	14
Common carp	280	-	626	-	2.9	1
Rudd	170-185	175±8.7	104-142	120±19.7	2.2	3
European perch	90	-	11	-	1.5	1
N. pike	312-415	361.3±27.1	272-792	439.2±140.9	0.9	12

Table IV *(continued).*

Lake Tushchy						
Fish species	Length. min-max. mm	M±m	Weight. min-max. g	M±m	Fultin's condition factor	N
Roach	155-220	177.6±21.3	80-223	123.8±45.8	2.1	12
Rudd	150-190	169±12.8	78-174	113.3±30.1	2.3	9
European perch	200-215	208.8±6.6	156-238	190±33.8	2.1	5
N. pike	350-435	395±33.7	340-679	525.6±155.5	0.8	7
Lake Akbilek						
Roach	155-205	171.1±11	72-196	108±22.5	2.1	45
Common carp	310-345	327.5±24.7	673-915	794±171.1	2.2	2
Rudd	150-168	161.7±6.3	86-113	101.2±9.2	2.4	6
Crucian carp	130	-	75	-	3.4	1
Asp	225-300	261.2±36	166-418	281.4±119.9	1.5	5
Pikeperch	365-490	427.5±88.4	563-1592	1077.5±727.6	1.3	2
Snakehead	495	-	1670	-	1.4	1
Note: M – mean value; m – standard deviation.						

Aral roach

According to F.V. Klimov (2007), it is a widespread species in the Aral-Syrdarya Basin, and inhabits all bays, tidal zones, tributaries, discharge and drainage canals. In the delta lakes of the Syrdarya, roach is quite numerous, but is caught as by-catch compared to other species. During the research, Aral roach was encountered in the experimental catches in all 5 studied lakes. The fish length ranged between 15.5 and 22 cm, averaging 17.5 cm; the weight ranged between 72 and 223 g, averaging 110 g. The age profile of Aral roach was represented by three generations, including the dominating 4-year-old specimens. In Lake Akshatau-Sorgak, only 5 specimens were caught; the largest catch was obtained from Lake Akbilek (45 specimens); in other reservoirs, the quantity ranged from 12 to 26 specimens (Table IV). No parasites or other diseases were found in this fish species in all the examined water bodies.

Rudd

The species is well represented throughout the Aral-Syrdarya Basin. Yet, recently its quantity has been sharply declining (Report. Definition of fish productivity..., 2016). It was encountered in all the investigated reservoirs except Lake Karakol. The species length varied from 15 to 19 cm, averaging 17 cm; the weight varied between 78 to 142 g, averaging 110 g. The age profile was represented by three generations, with the dominating 4-year-olds. The largest rudd quantity was detected in Lake Tushchy; the catches in the other four reservoirs were small (Table IV).

Sabre carp

Prior to the regulation of the Syrdarya River flow, sabre carp lived almost throughout the entire river – from the Aral Sea to the Karadarya River. After the construction of the Shardara Reservoir, it became an ordinary ichthyofauna element and spread throughout the entire water area (Research Unit of Shomishkol LCFF, 2019). In the autumn catches, only a single specimen was encountered in Lake Akshatau-Sorgak 24.6 cm long and weighing 151 g (Table IV).

Common carp

The species inhabits all water bodies of the Aral-Syrdarya Basin, and is one of the main fishing objects (Biological Justification…, 2020). During the research period, it was caught in Lakes Shomishkol (1 specimen) and Akbilek (2 specimens). The fish length ranged between 28 and 34.5 cm, and the weight was 626-915 g (Table IV). Despite the small common carp catch, according to the archive materials of FishRPC its populations in all the studied lakes are stable. The reason for the small amount of common carp in experimental catches could be the structure of the fixed nets used, fluctuation of the water level in the Syrdarya during spawning, as well as short field research duration.

Crucian carp

In the reservoirs of Southern Kazakhstan, the occurrence of (silver) crucian carp is apparently associated primarily with water mineralization, which in its turn depends on the water supply of target lakes (Research Unit of Tushchy LCFF, 2019). Of the five lakes, the fish species was caught only in two – Akshatau-Sorgak (8 specimens) and Akbilek (1 specimen). The fish length ranged from 13 to 26 cm, averaging 23 cm; and the weight ranged between 75 and 607 g, averaging 225 g (Table IV). The crucian carp's age profile was represented by four generations, with dominating 4-year-old specimens.

Bream

Currently, the species is widespread in almost all the main fishing water bodies of the country (Research Unit of Karakol LCFF, 2019). During the research, bream was encountered only in Lake Karakol (11 specimens), with the length of 16 to 23.5 cm and weight of 82 to 256 g (Table IV). The species age profile was represented by three generations, including the dominating 3-year-olds.

Pikeperch

The species is well represented in the fresh water bodies across Asia, and inhabits rivers and basins of the Caspian and Small Aral Seas, as well as other lakes and desalinated sections of the seas mentioned above (Zharikova, 2017). In Lake Akshatau-Sorgak, 23 specimens of pikeperch were caught, in Akbilek – 2 specimens. In other target reservoirs, the species was not encountered. In the experimental catches, the fish length ranged from 26.5 to 39 cm, averaging 31.7 cm; the weight ranged from 247 to 437 g (Table IV). The species age profile was represented by three generations, including the dominating 3-year-old specimens.

European perch

The species is widespread in the Aral-Syrdarya Basin within Kyzylorda Region. During the study, it was encountered in all reservoirs except Lake Akbilek. The fish length ranged between 9 and 21.5 cm, averaging 16.5 cm; the weight ranged between 11 and 238 g, averaging 99 g. The European perch age profile was represented by four generations, with the dominating 3-year-olds. The largest catch was obtained from Lake Akshatau-Sorgak – 21 specimens (Table IV).

Northern pike

The species is well represented in the fresh water bodies of Eurasia. In this research's catches, Northern pike was encountered in Lake Karakol (7 specimens) (Picture 1), Shomishkol (12 specimens), and Tushchy (7 specimens). The fish length ranged from 29 to 43.4 cm, averaging 37 cm; the weight ranged from 229 to 792 g, averaging 440 g (Table IV). The stomachs of the 55% of all the Northern pike caught contained shrimp, roach and atherine. The species age profile was represented by four generations, including the dominating 4-year-old specimens.

Picture 1. Bioanalyses of Northern pike caught in Lake Karakol.

Asp

The species is widespread in the Small Aral Sea, as well as in the inflowing rivers. During the study, it was encountered only in Lakes Karakol (2 specimens) and Akbilek (5 specimens). In the research catches, the fish length varied between 22.5 and 45 cm, and the weight – from 166 to 1,442 g, averaging 30 cm and 510 g, respectively (Table IV). The species age profile was represented by four generations, with the dominating 3-year-olds. The excellent nutritional status of the asp inhabiting the Syrdarya delta lakes is also noteworthy.

Snakehead

The species got into the Syrdarya in the early 1960s together with herbivorous fish species from China, and soon spread through the Aral Sea Basin, including the Talas and Shu

Rivers, as well as the Sarysu River's lower reaches (Barakbayev, 2012). In recent years, snakehead in the Aral-Syrdarya Basin has reached the commercial fishing quantity. Only a single species specimen was caught during the research, namely in Lake Akbilek. The fish length was 49.5 cm; the weight was 1,670 g (Table IV); and the age was 6 years.

6. Discussion

Ichthyofauna

The current lake ichthyofauna profile detected during the research includes the following 16 fish species, 11 of which represent commercial value: Aral roach, rudd, sabre carp, common carp, crucian carp, bream, Northern pike, perch, pikeperch, asp, and snakehead. It is also worth noting the non-commercial species caught using the minnow seine, which are typical for the research area, namely: Syrdarya bystranka, sawbelly, river abbotina, stone morocos, and bitterling. Overall, the research catches appear excellent considering the short study duration, as well as the overall sharp decline of commercial fish catch volume and fish diversity in the first decade of the 21st century due to overfishing, poaching and habitat alteration (Mitrofanov, Mamilov, 2015). To investigate the dynamics of the restoration of commercial and non-commercial fish species, it appears necessary to conduct spring and autumn monitoring of the Syrdarya River delta lakes on an annual basis.

Due to the good feed base, both predator and non-predator fish species demonstrated excellent nutritional status (Table IV). The reasons for the predominance of pikeperch and perch in the catches on Lake Akshatau-Sorgak include the good feed base of non-commercial species, lake's suitable hydro-chemical regime, as well as seasonality and duration of legal fishing periods. It is worth noting that over 75% of the caught pikeperch and perch had full stomachs containing shrimp, small fish, and nymphs. Despite the restoration of perch population, this fish no longer has commercial significance as it did during the Soviet period (Dukravets, 2009).

Visual examination of fish before biological analysis showed no diseases. During dissection, no parasitic diseases were detected either. Based on the survey of local fishermen, common carp is abundant in local reservoirs. The small number of this species in the catches under the study may be due to the technical features of fixed nets (small length in contrast to commercial fishing nets), as well as short research duration.

The application of the old biological analysis method (Pravdin, 1966) was due to its insignificant differences compared to modern methods, and most importantly the possibility of comparing this study's outcomes with the findings of other researchers (Zinoviev, Mandritsa, 2003).

Commercial development prospects

Considering the excellent compatibility and abundant presence of both species in the reservoir, it appears expedient to recommend pikeperch and common carp for breeding in Lake Akshatau-Sorgak.

Fish farming in natural reservoirs, unlike pond and aquaculture, is associated with lower capital expenditure for the construction of buildings and installations, procurement of feedstuff, mineral fertilizers and other production costs.

In addition to the general commercial value, the taste and dietary features of pikeperch predetermine its high export potential. The species develops and grows well in lakes. It can be successfully bred and grown in large ponds and lakes, especially in reservoirs saturated with oxygen and these inhabited with abundant coarse fish (roach, bystranka, ruff, bleak, bitterling, small perch, groundling, etc.). In the presence of suitable spawning grounds, large amounts of small fish and oxygen in the water, pikeperch breeds perfectly and grows well even in small pond-type reservoirs with abundant vegetation. Culturing pikeperch in combination with carp creates the best conditions for its growth – in this case, the total fish productivity increases by 50-100%, including by 10-20 kg/ha for pikeperch (Alexandrov, 2005).

Modern carp breeds are represented by 4 types of scale covering: scaly, scattered-linear, scattered-bare, and bare. There is also a carp species with big-scaled covering (Sukhoverkhov, 1975). The researchers of the Kazakh Fishery Research and Production Center developed a carp species group capable of crossbreeding with local (non-bred) carp specimens and producing offspring characterized by high survival rate and productivity.

The introduction of herbivorous fish, which have a food sector different from carp, allows using the fodder resources of reservoirs to a fuller extent and conduct highly intense fish farming. The temperature and abundance of food in such lakes create favorable conditions for rapid fish growth. Considering the proximity of the Kamystybas Fish Nursery, egg incubation of plant-eating fish can be done in special heated devices (Fish Breeding Manual..., 2012). Of the herbivorous species, grass carp, silver carp and bighead are grown in Kazakhstan (Bogeruk, 2000). The mother herds of these fish species were created at the fish farms in the southern part of the country, including in Kyzylorda Region. In the future, this could facilitate the transportation of fish juveniles for stocking the target lakes.

7. Conclusion

Summing up, the hydrochemical regime of the examined lakes could be deemed satisfactory for hydro-fauna – all hydrochemical indicators fell within the fish husbandry norms (Table II). The overall condition of the lakes, their large surface area, and presence of collector water supply sources make them suitable for using as basic reservoirs for setting up lake and commercial fish farms.

Stocking with fish is inextricably linked to the management of fish resources in a given reservoir. In small-sized water bodies, the economic effect of fish-breeding can be obtained quite quickly provided the stocking is carried out according to the requirements simultaneously with reclamation works (fishing off competitors and enemies of the introduced species, improving environmental conditions like spawning grounds, gas regime, etc.) (Kulikov, 2007).

It should be borne in mind that in the course of fish stocking the intended species are usually accompanied by large quantities of unintended species. Most unintended species represent the undesirable introduced species. Developing a significant population, they, as a rule, represent no commercial value but create food competition against commercial species (Asylbekova, Kulikov, 2016). Thus, fish stocking should be carried out taking into account the natural food base regeneration capacity and only using the local planting material in order to preserve the gene pool of local fish populations, as well as to prevent the accidental import of new fish species alien to a specific lake.

Combined with proper organization of management systems at lake-commercial fish farms, the implementation of integrated fish-reclamation and biotechnical measures will ensure achieving the necessary level of development of the newly established fish-breeding enterprises as well as their profitability. Setting up lake-commercial fish farms at the examined lakes will likewise significantly boost employment and improve the well-being of local communities.

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