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Feeding resources and key nutrients of commercial fish in the Ural-Caspian Basin

Abstract. The article presents information on hydrobiological monitoring in the Ural–Caspian Basin, including phytoplankton, zooplankton, and benthic communities in the Ural–Caspian Basin. The annual dynamics of hydrobiont biomass density have been established, showing seasonal variations with the highest values in summer and the lowest in winter. The qualitative and quantitative composition of aquatic organisms was studied depending on the discharge volume and flow levels of the Ural (Zhayyk) River. In high-water years, the biomass of phytoplankton and the abundance of zooplankton increased by 1.4 and 2.2 times, respectively. In recent years, an increase in the biomass of gelatinous zooplankton has been observed. Among them, the comb jelly *Mnemiopsis* is spreading particularly actively, successfully colonizing shallow, low-salinity areas of the sea. This species is a major consumer of zooplankton, which negatively affects the food base of planktivorous fish and the juveniles of all ichthyofauna species in the Caspian Sea. An analysis was also conducted on the feeding preferences of anadromous, marine, semi-anadromous, and freshwater species inhabiting the Caspian Sea.

Keywords: forage base, abundance, biomass, ichthyofauna, fish diet.

Introduction

The development of fish stocks is largely determined by the state of the reservoir's food base, since at different stages of their life cycle, their diet includes planktonic organisms of both plant and animal origin, zoobenthos, and, for predatory species, representatives of the freshwater and marine ichthyofauna. Semi-anadromous and river fish mainly feed in the coastal zones of the Northern and Middle Caspian, which are influenced by freshwater inflow [1-8]. After spawning, the grown juveniles and adult individuals begin their downstream migration to feeding grounds in the Caspian Sea. These feeding grounds are generally restricted to the isobath with a salinity of 6–7 ‰ [9-11]. Sturgeons, herrings, sprats, and mullets feed not only in the Northern but also in the Middle and Southern Caspian [8, 12].

The Ural–Caspian basin plays a key role in the Republic of Kazakhstan in the reproduction and har-

vesting of fish resources. It includes the northeastern part of the Caspian Sea, where active efforts are being made to preserve and increase the populations of commercial fish species. In this area, feeding migrations occur on an abundant food base, followed by the formation of stocks of many fish populations.

The aim of this work was to assess the hydrobiological characteristics of the study area, including phytoplankton, zooplankton, and macrozoobenthos (at the group level), and to identify the main nutritional components of adult individuals of commercial fish species in the natural environment.

To achieve the stated goal, it is necessary to address the following main objectives: to study the species diversity and seasonal changes in the abundance and biomass of aquatic organisms; to determine the influence of river discharge regimes on the increase of biological productivity of the studied groups; and to investigate and identify the main diet of commercial fish species under natural conditions.

Materials and methods

In 2023, comprehensive scientific research was conducted in the Ural–Caspian basin, including the coastal zones of the Caspian Sea. The purpose of these studies was to examine hydrological and hy-

drobiological parameters, as well as to assess the distribution and abundance of aquatic biological resources in the Caspian Sea. The field expeditions were carried out during the winter, spring, summer, and autumn periods. Sampling maps are shown in Figure 1.

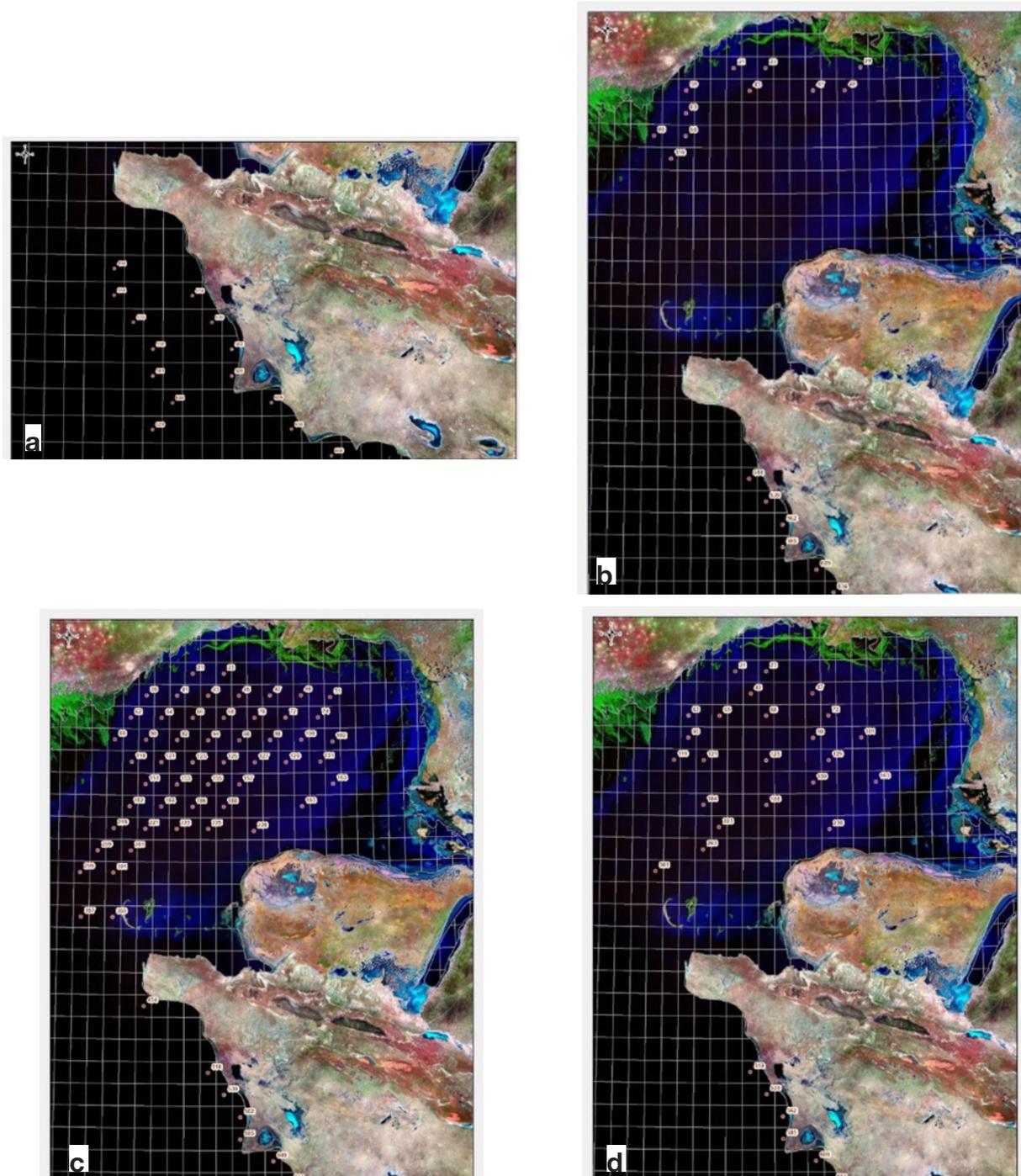


Figure 1 – Map-diagram of the observation station's location for hydrobiological and ichthyological sampling in (a) winter; (b) spring; (c) summer; (d) autumn

The results of studies on hydrobiological and ichthyological indicators in the Zhaiyk–Caspian basin in 2023 and during the comparative period of 2019–2022 were obtained from the reporting materials of Kazekoproekt LLP.

Phytoplankton samples were collected using Molchanov bathometers (GR-18) or BM-48, zooplankton samples – with an Apstein net, and benthos samples – with Petersen and Van Veen grab samplers, covering an area of 0.025 m². The processing of phytoplankton samples was carried out according to the method [13], zooplankton and zoobenthos by [14] at laboratory conditions. Phytoplankton samples were concentrated by centrifugation and examined by direct microscopic observation using a light microscope (OLYMPUS BX 41, Japan). Zooplankton was analyzed by direct microscopic examination with a binocular microscope (Levenhuk MED 900B, USA) using a Bogorov counting chamber. Zoobenthos was identified using a binocular microscope (Levenhuk MED 900B, USA), and biomass was determined using torsion and analytical balances (MT-HA203E, Mettler Toledo, Switzerland). The abundance and biomass of planktonic algae and invertebrates, including benthic organisms, were also quantified by [15–19].

The species composition of fish was taken from the recommendations on the allocation of total allowable catches (TAC) in the Atyrau region, following the territorial (administrative) principle within the waters of the Kazakhstan part of the Caspian Sea [20]. The methodology for dividing the TAC by regions is based on research data on the distribution of ichthyofauna and on data regarding the exploitation of fish resources, whose stocks are in a satisfactory condition.

Statistical processing of the research materials was carried out using standard methodologies. The main statistical parameters were calculated using the Microsoft Excel software package. To compare the mean values of several groups and to identify significant differences between them, analysis of variance (ANOVA – Analysis of Variance) was applied. The Statistica software was used for analysis of variance. Calculations were performed using Student's t-test.

$$t = \frac{\left(\bar{x}_1 - \bar{x}_2 \right)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

\bar{x}_1 – observed mean of first sample

\bar{x}_2 – observed mean of second sample

s_1^2 – standard deviation of first sample

s_2^2 – standard deviation of second sample

n_1 – sample size of first sample

n_2 – sample size of second sample

Results and discussion

Phytoplankton is the primary producer of organic matter in a water body and serves as food for zooplankton and zoobenthos. During different seasons of the year, due to climatic conditions, the qualitative and quantitative composition of phytoplankton varies widely. At the end of February – beginning of March 2023, the phytoplankton community included 42 algal taxa from 5 divisions: Cyanophyta (blue-green algae) – 4, Bacillariophyta (diatoms) – 28, Myzozoa – 7, Ochrophyta – 1, and Chlorophyta (green algae) – 2. In terms of abundance and biomass, diatoms dominated, accounting for 75.6 mln inds/m³ and 1067.9 mg/m³, or 77.5% and 96.2% of the total phytoplankton, respectively. The average values were estimated at 97.5 mln inds/m³ and 1110.6 mg/m³ (Figure 5).

In April–May, the number of divisions (groups) remained unchanged; however, there was a sharp increase in newly appearing species, reaching 92 taxa. The most widely represented were Cyanophyta (blue-green algae) – 22 species (869.9 mln inds/m³ and 82.3 mg/m³), Bacillariophyta (diatoms) – 49 taxa (39.1 mln inds/m³ and 361.4 mg/m³), and Chlorophyta (green algae) – 15 species (127.0 mln inds/m³ and 36.5 mg/m³). The average abundance of phytoplankton increased 10.6 times (to 1033.4 mln inds/m³), while the biomass decreased 1.9 times (to 568.7 mg/m³) due to the dominance of small-sized and newly formed species.

During the summer period (June–August), the phytoplankton list included 170 algal species from 7 divisions: Cyanophyta (blue-green algae) – 38, Bacillariophyta (diatoms) – 79, Myzozoa – 10, Ochrophyta – 2, Charophyta – 4, Chlorophyta (green algae) – 34, and Euglenophyta – 3 species. The first three groups, compared to the spring indicators, continued to intensively increase their biopotential, which also included green algae. The number of taxa and the total abundance of phytoplankton (1935.7 mln inds/m³) reached their maximum values, with an average biomass of 1127.1 mg/m³. In the September samples, the quantitative and qualitative composition of aquatic plants remained at a fairly high level, although a tendency toward a decrease in the average number of taxa and their abundance was noted (Table 1).

Table 1 – Phytoplankton of the eastern part of the Northern Caspian in 2023

№	February-March		April-May		June-August		September		Biomass, mg/m ³			
	Number of taxa	Abundance, mln inds/m ³	Biomass, mg/m ³	Number of taxa	Abundance, mln inds/m ³	Biomass, mg/m ³	Number of taxa	Abundance, mln inds/m ³				
1	4	10.6 ± 1.3	0.3 ± 0.1	22	869.9 ± 102.6	82.3 ± 8.3	381	1,672 ± 103	179.2 ± 8.5	31	1,487 ± 257	132.0 ± 21.5
2	28	75.6 ± 1.2	1,068 ± 106	49	30.1 ± 6.8	361.4 ± 32.3	79	94.4 ± 9.8	684.1 ± 75.9	74	83.6 ± 20.5	891.1 ± 106.3
3	7	2.6 ± 0.6	32.4 ± 9.3	5	2.5 ± 0.2	31.5 ± 5.3	10	6.5 ± 1.1	142.7 ± 32.5	12	10.2 ± 2.4	145.3 ± 25.6
4	1	0.6 ± 0.1	8.7 ± 1.2	1	4.0 ± 1.1	57.0 ± 4.2	2	2.6 ± 0.5	35.7 ± 8.6	1	1.9 ± 0.2	26.3 ± 3.5
5	nd	nd	nd	nd	nd	nd	4	2.6 ± 0.4	5.2 ± 1.1	1	1.9 ± 0.3	1.9 ± 0.2
6	2	8.0 ± 1.2	1.3 ± 0.2	15	127.0 ± 10.2	36.5 ± 3.2	34	156.5 ± 5.6	61.1 ± 6.5	17	185.3 ± 20.4	56.3 ± 5.8
7	nd	nd	nd	nd	nd	nd	3	1.5 ± 0.2	19.1 ± 3.5	nd	nd	nd
Σ	42	97.4	1110.6	92	1033.5	568.7	170	1935.8	1127.1	136	1770.2	1252.9

Note: nd – not detected; №1. Cyanobacteria; №2 Bacillariophyta; №3. Miozoa; №4. Ochrophyta; №5. Charophyta; №6. Chlorophyta; №7. Euglenozoa

The analysis of the data showed that the seasonal dynamics of the phytoplankton species composition are characterized by a gradual increase in the number of taxa throughout the growing season. The highest species diversity is observed in summer and autumn. During the monitoring, a significant increase in the abundance and biomass of phytoplankton was recorded, mainly due to the development of certain species of filamentous and colonial cyanobacteria, diatoms, and green algae, which is typical for the studied region of the sea.

Zooplankton communities in aquatic ecosystems serve as a food source for aquatic invertebrates, juveniles, and planktivorous fish. Plankton responds relatively quickly to changes in the aquatic ecosystem and can serve as an indicator of its condition, including in the Zhaiyk–Caspian basin [21].

The dynamics of zooplankton abundance also exhibited a seasonal pattern, with concentrations increasing from the winter–spring to the summer–autumn period. In June–August, 50 zooplankton taxa were recorded in the samples, including 13 rotifers, 12 cladocerans, 10 copepods, 4 gelatinous species, and 11 other taxa, mostly facultative plankters. In February–March and April–May, the number of taxa did not exceed 19 and 23, respectively. During the summer, rotifers dominated in terms of abundance (54%), while copepods accounted for 40% of the total zooplankton population. The average zooplankton abundance in the summer period reached 108,640.9 mln inds/m³, and the biomass was 1,983.4 mg/m³, exceeding the values recorded in other seasons by 1.3–23.6 and 2.6–29.7 times, respectively, with the closest values observed by September (Table 2).

It is particularly important to note the increasing biomass of Jellyfish species, which in summer reached more than 88% (1749.8 mg/m³) of the total zooplankton biomass. Among them, the accidentally introduced Warty comb jelly *Mnemiopsis leidyi* has successfully colonized the brackish areas of the sea. The rapid adaptation and wide distribution of the species have led to a sharp decline in the food base of planktivorous fish. This, in turn, has altered the composition of ichthyocenoses and the structure of trophic chains. *Mnemiopsis*, being an active consumer of pelagic fish eggs and larvae, has had a negative impact on the stocks of many pelagic species.

In February–March, the zoobenthos was represented by 21 species, with a clear dominance of crustaceans – 15 taxa (71.4%). Four species of worms (19.1%) and two species of mollusks (9.5%) were identified. Despite this species composition structure,

the highest average biomass was recorded for mollusks – 31,103.0 mg/m² (91.4%), while worms were dominant in terms of abundance – 1,738.0 ind./m² (77.8%), followed by crustaceans – 400.0 ind./m² (17.9%). In April–May, despite a slight increase in the number of taxa within the same groups (29 taxa), the average abundance and biomass increased compared to the previous period by 2.8 and 1.8 times, respectively. This resulted in values of 6,368.0 ind./m² and 63,107.0 mg/m².

In the summer period, when the number of taxa increased to 41, mainly due to crustaceans, a decrease in abundance and biomass was observed across all taxonomic groups. The only exception was the biomass of worms, which reached 4,356.0 mg/m². In the September samples, with a slight decrease in species composition to 38 taxa compared to the summer values, a significant increase in biomass was again recorded for all groups of benthic organisms (Table 3).

In the formation of the biological productivity of the sea, including that of hydrobionts, the accumulation of river runoff from the catchment basin plays an essential role. The flow of the Ural River provides an inflow of freshwater and nutrients into the Caspian Sea, which is critically important for maintaining the ecosystem – primarily for phyto- and zooplankton. A decrease in river discharge due to climatic changes and anthropogenic impacts leads to a reduction in both the abundance and biomass of the fodder base. In addition, water pollution affects the qualitative and quantitative composition of the food base of the Zhaiyk–Caspian basin. The priority pollutants for the Atyrau region are suspended solids, magnesium, and chemical oxygen demand (COD) [22].

In 2019–2022, the annual discharge of the Ural River (measured at the Atyrau hydrological station) varied from 4.98 to 6.56 km³/year (average 5.52 km³/year), while the water level fluctuated between 330 and 375 cm (average 366 cm) [23–25]. The average number of phytoplankton taxa during the summer period of maximum development was 100, with an abundance of 1907.4 ind./m³ and a biomass of 0.789 mg/m³; for zooplankton, 41 taxa were recorded with an abundance of 50,155 ind./m³ and a biomass of 2862.8 mg/m³. A comparative analysis showed that in 2023, with an increase in river discharge (8.11 km³/year) and water level (440 cm), a sharp rise in the number of taxonomic units, as well as in the biomass of phytoplankton and the abundance of zooplankton, was observed – by 1.4 times (1,127 mg/m³) and 2.2 times (108,640.9 ind./m³), respectively (Table 4).

Table 2 – Zooplankton of the eastern part of the Northern Caspian in 2023

№	February-March		April-May		June-August		September		Biomass. mg/m ³
	Number of taxa	Abundance. mln inds/m ³	Number of taxa	Abundance. mln inds/m ³	Number of taxa	Abundance. mln inds/m ³	Number of taxa	Abundance. mln inds/m ³	
1	3	1,163 ± 127	7	2,185 ± 456	13	58,289 ± 855	8	22,346 ± 1,203	13.8 ± 2.5
2	3	79.4 ± 20.4	4	477.7 ± 102.6	12	1,772 ± 265	6	237.5 ± 56.8	9.8 ± 1.2
3	6	1,793 ± 252	6	7,993 ± 897	10	43,971 ± 876	6	50,998 ± 8,966	212.0 ± 12.6
4	1	1.3 ± 0.2	nd	Nd	4	57.4 ± 10.2	5	191.1 ± 10.5	503.2 ± 68.6
5	6	1,565 ± 242	6	3221 ± 325	11	4,552 ± 457	6	6,442 ± 866	12.8 ± 2.5
Σ	19	4600.9	23	13876.1	50	108640.9	31	80214.5	751.6

Note: nd – not detected; №1. Rotatoria; №2. Cladocera; №3. Copepoda; №4. Jellyfish; №5. Others

Table 3 – Zoobenthos of the eastern part of the Northern Caspian in 2023

№	February-March		April-May		June-August		September		Biomass. mg/m ³
	Number of taxa	Abundance. inds/m ³							
1	4	1,738 ± 368	8	3,302 ± 653	7	2,129 ± 506	8	3,633 ± 199	7,104 ± 1,109
2	2	97.0 ± 22.6	2	236.0 ± 62.5	4	45.0 ± 12.5	3	87.0 ± 8.6	35,249 ± 8,366
3	15	400.0 ± 96.5	19	2,830 ± 713	29	2,007 ± 486	26	1,625 ± 168	3,908 ± 569
4	nd	nd	nd	nd	1	3.0 ± 0.2	n/d	n/d	n/d
5	nd	nd	nd	nd	nd	nd	1	5 ± 1.1	0.2 ± 0.01
Σ	21	2235	29	6368	41	4184	38	5350	46261.2

Note: nd – not detected; №1. Vermes; №2. Mollusca; №3. Crustacea; №4. Insecta; №5. Others

Table 4 – Comparative analysis of the dynamics of phyto- and zooplankton abundance and biomass in the Ural River under different water discharge levels

Years	Discharge volume	Water levels	Phytoplankton			Zooplankton		
	km ³ /year	cm	taxa units	ind./m ³	mg/m ³	taxa units	ind./m ³	mg/m ³
2019–2022	5.52	354	100	1907	0.789	41	50155	2862.8
2023	8.11	440	170	1936	1.127	50	108641	1983.4

Note: The results of studies on hydrobiological indicators in the Zhaiyk–Caspian basin in 2023 and during the comparative period of 2019–2022 were obtained from the reporting materials of Kazekoproekt LLP.

The research results indicate that the decrease or increase in the concentration of hydrobionts throughout the year mainly reflects the seasonal dynamics of variability in the abundance and biomass of phyto-, zooplankton, and zoobenthos, with the highest values observed in the summer period. Over the years, the mass development of planktonic organisms has been greatly influenced by the volume of water discharge and water levels in the river, the increase of which promotes the growth of both taxonomic units and the overall productivity of hydrobionts. In 2023, due to the increase in hydrobiont abundance, the fish feeding base was in a satisfactory condition.

The species composition of the ichthyofauna in the Ural–Caspian Basin is diverse and includes both typically marine forms and migratory, semi-migrato-

ry, and freshwater fish species [7]. These fish utilize the full range of food organisms – from predation to consumption of phyto- and zooplankton, benthos, plants, and detritus. Since juvenile fish at early stages of development feed exclusively on planktonic organisms, Table 5 presents the species composition of fish along with the spectrum of their main food organisms in adulthood, based on the recommendations for the allocation of total allowable catches (TAC) within the Atyrau region, including recommendations for determining fishing effort standards for coastal fishing in the Caspian Sea [26]. Additionally, migratory species – sturgeons – should be mentioned, as their stocks have been severely depleted, and their artificial reproduction is carried out at the state level (Table 5).

Table 5 – Commercial fish species and main food components of adult individuals in the natural environment

№	Fish species	Main nutritional components of adult individuals*
Semi-anadromous and freshwater fish species		
1	Zander – <i>Sander lucioperca</i> (L., 1758)	Predator: feeds on fish and their juveniles (roach, white bream, carp, bream, bleak, sprat, and kilka).
2	Asp – <i>Aspius aspius</i> (L., 1758)	Predator; even young-of-the-year individuals already start feeding on fish such as roach, bleak, rudd, white bream, and sabrefish.
3	Wels (European) catfish – <i>Silurus glanis</i> L., 1758	Predator: fish make up 86.7% of its diet (up to 27 species, mainly roach, bream, white bream, rudd, and carp); frogs account for 10.3%.
4	Pike – <i>Esox lucius</i> L., 1758	Predator: up to 22 species were found in its stomach (roach, bleak, rudd, carp, white bream, perch, and others).
5	European perch – <i>Perca fluviatilis</i> L., 1758	Predator: feeds on juveniles of commercial fish species, as well as gobies and bleak.
6	Common carp – <i>Cyprinus carpio</i> (L., 1758)	Gastropods, chironomids, gammarids, worms, crustaceans, vegetation, detritus.
7	Caspian roach – <i>Rutilus rutilus caspicus</i> (Jakowlew, 1870)	Benthic organisms, mainly mollusks of the genera <i>Dreissena</i> , <i>Monodacna</i> , and <i>Didacna</i> .
8	Bream – <i>Abramis brama</i> L., 1758	Benthic crustaceans, mollusks, and worms.
9	Silver crucian carp – <i>Carassius auratus</i> (L., 1758)	Bloodworms, small mollusks, and plants.
10	Rudd – <i>Scardinius erythrophthalmus</i> (L., 1758)	Plants, algae, chironomid larvae, insects, worms, and small mollusks.

Continuation of the table

№	Fish species	Main nutritional components of adult individuals*
11	White bream – <i>Blicca bjoerkna</i> (L., 1758)	Benthic organisms: bloodworms, worms, mollusks, and occasionally vegetation.
12	Sabrefish – <i>Pelecus cultratus</i> (L., 1758)	Aquatic insect larvae, juvenile fish, and small crustaceans.
13	Vimba bream – <i>Vimba vimba</i>	Small mollusks, insect larvae, crustaceans, and worms.
14	Blue bream	Mainly small mollusks, crustaceans, and bloodworms.
Marine fish species		
15	Common kilka <i>Clupeonella delicatula caspia</i> (Svetovidov, 1941)	Zooplankton feeders: copepods and mysids.
16	Anchovy kilka <i>Clupeonella engrauliformis</i> (Borodin, 1904)	Zooplankton: copepods and mysids.
17	Caspian shad <i>Alosa caspia caspia</i> (Eichwald, 1838)	Feeds mainly on zooplankton, primarily copepods, and juvenile fish.
18	Bigeye shad <i>Alosa saposchikowii</i> (Grimm, 1887)	Feeds on both fish (such as sprat and gobies) and crustaceans.
19	Golden grey mullet – <i>Liza aurata</i> (Risso, 1810)	Feeds on vegetation and detritus.
Anadromous fish species		
20	Beluga – <i>Huso huso</i> (L., 1759)	Predator: feeds on herring, roach, white bream, atherine, sprat, and gobies. The transition to feeding on fish occurs during the first months of life.
21	Russian sturgeon – <i>Acipenser gueldenstaedtii</i> Brandt, 1833	Feeds on both benthic invertebrates and fish (such as herring, atherine, sprat, and gobies). The transition to feeding on fish occurs at the age of two years.
22	Starry sturgeon – <i>Acipenser stellatus</i> Pallas, 1771	The diet is dominated by crustaceans; mollusks are of lesser importance. Among fish, sprat and gobies prevail.
Note: * according to [1, 7, 27, 28, 29]		

According to their ecological characteristics, the fish of the Ural–Caspian basin can be divided into four groups:

- River species are represented by 42 species and subspecies, accounting for 34.4% of the ichthyofauna composition. Throughout their life cycle, these fish inhabit the freshwaters of the river lower reaches, the desalinated areas of the sea, and the water bodies of the delta.

- Migratory fish include 18 species and subspecies (14.7%). Before reaching sexual maturity, they inhabit the sea, and for spawning, they migrate into rivers, far from the estuary, using specific sections of the riverbed and floodplain for reproduction. The migratory forms include the Caspian lamprey, all Caspian salmon species, all Caspian sturgeons except the sterlet, the Volga many-spined herring, the black-backed herring, the Caspian barbel, the Caspian roach, the shemaya, and others.

- Semi-anadromous fish are represented by 9 species and subspecies (7.4%). These fish feed in the desalinated areas of the sea and spawn in the river deltas formed during the flood season. Typical representatives of this group include bream, roach (vobla),

common carp, pikeperch, white-eye bream, sabrefish, and others.

- Marine fish are the most numerous in terms of species diversity – 53 species and subspecies (43.5% of the ichthyofauna composition). The entire life cycle of these fish takes place in the sea. This group includes all three species of Caspian sprats (common, big-eyed, and anchovy sprat), herrings such as the Caspian shad, big-eyed shad, and Dolgin herring, as well as most Caspian gobies, the atherine, mullets (sharp-nosed and singil), and the marine pikeperch.

The state of sturgeon populations in the Ural–Caspian basin is assessed as unfavorable, which is largely explained by the impact of anthropogenic factors. The current critical situation is associated with the disruption of spawning and feeding conditions for sturgeon, irrational legal and large-scale illegal fishing, as well as economic activities in the rivers and the sea carried out without regard for the interests of fisheries management [30, 31, 32].

The stocks of marine fish remain stable. In recent years, there has been a recovery in sprat stocks, particularly for the common sprat [33].

Among semi-anadromous fish, the most abundant species are the roach (vobla) and bream. The commercial stock of vobla is in a depressed state, with its numbers declining due to the formation of low-yield generations corresponding to years of low water levels. Currently, bream is the most numerous species in the Ural–Caspian basin. However, its stocks have been decreasing in recent years due to a reduction in natural reproduction rates [7, 11].

At present, one of the main factors affecting the fish population in the Ural–Caspian basin is the decline in the level of the Caspian Sea, especially in its northern, shallowest part [7].

For aquatic biological resources, feeding conditions in the sea are deteriorating, as the shallow, highly productive zone of the Northern Caspian is shrinking year by year. It is bounded to the south by a sharp depth gradient separating it from fully marine waters, while to the north it is constantly being encroached upon by advancing land. Processes of restructuring in the composition of the ichthyofauna are taking place, associated with the decline in the abundance of some species and the increase of others. The ecological niches vacated by endemic species are being occupied by eurybiont species, whose prosperity does not depend on flood conditions. As the delta of the Ural River advances into the sea, the highly nutritious shallow and desalinated areas suitable for fish feeding are decreasing.

Commercial species, including semi-anadromous and freshwater fish, are largely represented by typical predators such as pikeperch, catfish, asp, pike, and perch. During their feeding migrations, these species inhabit the estuaries of river systems and the desalinated coastal areas of the sea. The main component of their diet in these zones is the juvenile fish of most ichthyofauna species found there. In particular, they prefer roach, bream, common carp, white bream, and bleak, while in marine waters their diet mainly includes sprat, herring, and gobies.

The remaining representatives of the commercial semi-anadromous and freshwater fish species (such as bream, roach, and common carp) feed on mollusks, crustaceans, worms, and may also consume plant material.

The dietary components of marine fish species vary significantly: Caspian sprats feed exclusively on zooplankton; mullet (singil) feed on algae and detritus; while marine herrings include sprats, gobies, and crustaceans in their diet.

The diet of adult sturgeon species is generally similar in composition, though there are significant species-specific differences in the quantitative struc-

ture of their feeding. Beluga sturgeon is a predator, feeding mainly on fish. It begins predatory feeding while still a juvenile in the river, although it also consumes mollusks. The Russian sturgeon feeds on crustaceans (worms, gammarids, mysids) and mollusks; its diet also includes fish such as sprats, gobies, and herrings. The stellate sturgeon (sevruga) feeds on invertebrates (crustaceans and worms) as well as fish, primarily gobies, herrings, and sprats.

Conclusion

The formation of commercial fish stocks largely depends on the condition of the water body's forage base, since at various stages of their life cycle the diet includes planktonic organisms of both plant and animal origin, zoobenthos, and, for predatory species, representatives of the freshwater and marine ichthyofauna. The Ural–Caspian basin, which encompasses the northeastern part of the Caspian Sea, plays a key role in the migratory routes and feeding of various fish species. This region provides a rich natural food base for the majority of aquatic biological resources.

Research shows that the abundance and composition of aquatic organisms vary throughout the year and can fluctuate within a wide range. The density of aquatic organism concentrations reflected the seasonal dynamics of changes in the abundance and biomass of phytoplankton, zooplankton, and zoobenthos from winter to autumn, with maximum values observed during the summer period.

Over the years, the mass development of planktonic organisms has been greatly influenced by the volume and level of river water releases, the increase of which contributes to the growth of both taxonomic diversity and the overall productivity of aquatic organisms. In 2023, under conditions of increased water discharge, the forage base of fish was in a satisfactory state due to the rise in the abundance of aquatic organisms. Comparative analysis showed that with an increase in river discharge (8.11 km³/year) and water level (440 cm) compared to 2019–2022, there was a sharp rise in species diversity of taxonomic units, as well as in the biomass of phytoplankton and the abundance of zooplankton, which increased by 1.4 and 2.2 times, respectively. The discharge of the Ural (Zhaiyk) River continuously supplied the Caspian Sea with fresh water and nutrients, which was critically important for maintaining the ecosystem, particularly for phytoplankton and zooplankton. In the case of zoobenthos, such biomass fluctuations were not observed; rather, annual variations in biomass fluctuated around a relatively stable level.

As a negative factor, attention should be paid to the increasing biomass of gelatinous species, among which the accidentally introduced ctenophore *Mnemiopsis leidyi* has successfully colonized the brackish areas of the sea. Being a mass consumer of zooplankton, it contributes to the reduction of the forage base not only for planktivorous fish but also for the juveniles of nearly all fish species in the Caspian Sea.

The ichthyofauna of the Zhaiyk–Caspian basin includes anadromous fish species (sturgeons, blackback herring, whitefish), semi-anadromous species (roach, bream, pikeperch, common carp, catfish), freshwater species (silver bream, sabrefish, perch, blue bream, rudd, pike, etc.), as well as marine fish species (kilkas, atherina, marine herrings, mullet). The status of aquatic biological resources in the basin varies. The most depleted and vulnerable species include beluga sturgeon, Russian sturgeon, stellate sturgeon, and whitefish. Roach and blackback herring are in a depressed state, whereas populations of bream, common carp, catfish, and marine fish species remain relatively stable. The main factors affecting the abundance of commercially important fish spe-

cies are low spring river discharges and the decline in the water level of the Caspian Sea.

The main group of commercially valuable species of interest for fish farming consists of typical predators (beluga, pikeperch, catfish, asp, and pike) or fish with a mixed diet that feed on both benthic invertebrates and other animals (sturgeon, stellate sturgeon). The remaining representatives of commercial resources, including semi-anadromous and freshwater fish species (such as bream, roach, common carp, and others), feed on mollusks, crustaceans, worms, and may also include plant material in their diet. Based on the literature review, the range of main forage organisms for producers of commercial fish species in natural conditions has been established, which can serve as a certain guideline when developing feed components for fish kept under artificial conditions.

Conflict of interest

The authors declare that they have no conflicts of interest.

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