

Composition and productivity of zooplankton as basis of forage base for larvae Baikal omul (*Coregonus migratorius*) in Posolsky sor (Lake Baikal) in 2024

Nataliya G. Sheveleva¹, Svetlana Yu. Neronova^{2,3},
Anna S. Semenova⁴, Pavel N. Anoshko¹

1 Limnological Institute, Siberian Branch of the Russian Academy of Sciences, 3 Ulan-Batorskaya St., Irkutsk, 664033, Russia

2 Irkutsk State University, 1 Karl Marx St., Irkutsk, 664003, Russia

3 Baikal branch of the Federal State Budget Scientific Institution "Russian Federal Research Institute of Fisheries and Oceanography", 4b Khakhalova St., Ulan-Ude, Republic of Buryatia, 670034, Russia

4 Papanin Institute for Biology of Inland Waters of the Russian Academy of Sciences, Borok, Necouz Region, Yaroslavl Oblast, 152742, Russia

Corresponding author: Nataliya G. Sheveleva (shevn@lin.irk.ru)

Academic editor: R. Yakovlev | Received 14 May 2026 | Accepted 19 June 2026 | Published 20 July 2026

<http://zoobank.org/8103B5B3-C73B-450E-8B97-8C1C321B364C>

Citation: Sheveleva NG, Neronova SYu, Semenova AS, Anoshko PN (2026) Composition and productivity of zooplankton as basis of forage base for larvae Baikal omul (*Coregonus migratorius*) in Posolsky sor (Lake Baikal) in 2024. Acta Biologica Sibirica 12: 871–890. <https://doi.org/10.5281/zenodo.21428421>

Abstract

The temporal species composition, abundance, and productivity of zooplankton have a direct impact on the food availability for larval omul (*Coregonus migratorius*) in Posolsky sor of Lake Baikal. Posolsky sor is a feeding place for omul larvae produced at the Bolsherechensk fish breeding plant. Sampling was carried out during May–October 2024. The feeding period of omul in Posolsky sor coincides with the presence of zooplankton, and this sor serves as its primary forage reserve. Zooplankton composition included 53 species, of which 60% were crustaceans. Maximum density (708 thousand individuals/m³) and biomass (2000 cal/m³) of zooplankton were observed in the second ten-day period of July. During the open water season rotifers constituted the major component (50–80%) of zooplankton, while crustaceans contributed the most to biomass. Based on the zooplankton community structure, as measured by numerical abundance and biomass, the trophic state of the Posolsky sor is classified as mesotrophic with some eutrophic characteristics. *Cyclops kolensis* (naupliar and copepodid stages)

and some species of Rotifera were the most abundant when the omul larvae were present in the sor. Analysis of the gut content of omul larvae revealed the presence of all developmental stages of *C. kolensis*. From May till the end of June the consumption rate of zooplankton predators (214 cal/m³ per day) slightly surpassed the production rate of the zooplankton community (188 cal/m³ per day). It is notable that during this period ovigerous cyclopoid individuals of the spring community of copepods that are known for their high energy characteristics were found in plankton.

Keywords

Zooplankton communities, abundance, biomass, production, Baikal omul larvae, diet diversity, Posolsky sor

Introduction

Shallow lagoons and sors in Lake Baikal represent ecosystems with distinct faunal habitats partially isolated from the main body of the lake. These warm, shallow water bodies (2–3 meters) create favorable conditions for the development of planktonic organisms, thus increasing zooplankton species diversity and biomass and altering the relative abundances of taxonomic groups. These, in turn, affect the next link in the ecosystem – larval and juvenile fish, especially the Baikal omul (*Coregonus migratorius*), for which zooplankton are the basis of the diet (Dolgoarshinnykh 1990; Sorokin and Sorokina 1991; Pavlitskaya and Bobkov 2000; Bobkov and Pavlitskaya 2003).

Since 1933, Posolsky sor has served as a natural breeding reservoir for the larvae of the benthic deep-water (posolskaya) population of omul (Smirnov et al. 2009), which are produced at the Bolsherechensk fish breeding plant (Pavlitskaya and Bobkov 2000). Zooplankton, especially Cyclopoida and Calanoida is the most valuable component in the larvae diet (Dolgoarshinnykh 1990; Freeberg et al. 1990; Sorokin and Sorokina 1991). The majority of studies concerning zooplankton as a forage base for young omul were conducted in the second half of the 20th century and the early 2000s (Vilisova 1954; Shnyagina 1963; Levkovskaya 1977; Kardasheva et al. 1981; Sorokin and Sorokina 1991; Dolgoarshinnykh 1990; Pavlitskaya and Bobkov 2000; Bobkov and Pavlitskaya, 2003). In recent years these studies have once again gained their relevance (Neronova et al. 2023; Anoshko et al. 2025).

The decline in stocks of the Baikal omul, including its Posolsky population, occurred against the background of high larval release numbers for the respective year classes (Voronova 2023). There is still no consensus on the main causes of this decline. A distinctive feature of the Posolsky population of the Baikal omul is its belonging to the benthic–deepwater morpho-ecological group (Smirnov et al. 2009). Individuals of this group are largely inaccessible to commercial fishing with trap nets and beach seines, except during the formation of pre-spawning aggregations, as well as to poaching along the spawning migration routes. However, the catch volumes of broodfish for artificial reproduction purposes during the period preceding

the stock decline were quite sufficient to ensure recruitment and stable exploitation of this population's stocks.

The main hypothesis proposed to explain the decline in the abundance of the Posolsky omul population is high mortality of juvenile omul during the first months of life (Anoshko et al. 2025) due to food shortage. During a period of temporary climate aridification in the region and reduced productivity of the coastal-sor zone and floodplains of tributary rivers, the excessive release of larvae likely led to a deficit in food base production. A reduction in the available food base for juveniles in their first year of life is a typical cause of stock decline in coregonid species. This was likely a reason for the decline in whitefish abundance in the Great Lakes during a period of significant ecosystem changes (Hoyle et al. 2011; Hébert and Dunlop 2025). Moreover, a mismatch between the hatching and transition to active feeding of larvae and the timing or magnitude of plankton blooms caused by spring climatic shifts can act as a further negative factor for juvenile fish (Cushing 1990; Ludsins et al. 2014).

Currently, it is necessary to study the interannual variability of the carrying capacity of Posolsky sor for omul larvae and the factors that determine it. Therefore, to make decisions on improving the efficiency of artificial reproduction of the Posolsky omul population, information on the current condition of zooplankton in Posolsky sor, which serves as a natural rearing reservoir for omul larvae – is required.

Materials and methods

Site description

Posolsky sor is a typical sor separated from the main body of Lake Baikal by spits oriented in a north – south direction (Fig. 1). Posolsky sor is connected to Lake Baikal through a strait more than 200 m wide. The waters of Lake Baikal influence the sor during surge winds, but this influence is insignificant. Posolsky sor is located in the southeastern part of the lake, 20 km to the south of the Selenga River delta. The sor is divided into two reservoirs, Bolshoy and Maly sors, interconnected by a narrow strait. The overall area of Posolsky sor is approximately 35 km², with Bolshoy sor covering 32 km² of that total. The maximum length and width are 12.6 km and 4.6 km, respectively. The deepest areas of the sor (3–3.5 m) are found in the central part of Bolshoy sor. The Abramikha, Kultushnaya, and Tolbuzikha Rivers flow into Bolshoy sor. The Bolshaya Rechka River flows into Maly sor and contributes over 50% of the total water volume from all the rivers entering the reservoir (Kozhov 1963).

Posolsky sor becomes ice-free in early May; its tributaries, in late April. At the end of May, the water temperature in the sor reaches 14–18.5 °C at the surface, while in the tributaries the temperature remains at 9–10 °C (Table 1). The water in the area of the sor, which abuts the channel connecting it with Lake Baikal is 2–3 °C colder

than in other areas of the sor. In July–August, temperature in the sor increases due to heating and reaches 19–23.6 °C. The maximum temperatures are recorded in the second decade of July. Ice formation in the sor begins in early November and the thickness of ice reaches 1.5 m concluding an open water that lasts about 6 months. The dissolved oxygen saturation during May–June in the sor was 98%, indicating absence of fish kill phenomena. The water in the lake is poorly-mineralized (Kozhov 1963).

Collection and processing of zooplankton samples. Zooplankton samples were collected in May–October at 5 sites of the Bolshoy sor totally from the bottom to the surface (Fig. 1) using a Juday net (mesh size 70 µm, diameter 25 cm). At depths of less than 1 m, samples were taken by filtering 100 L of water through an Apstein net (mesh size 70 µm). In May and June samples were collected twice a month, followed by monthly samples in July, September, and October. A total of 35 samples were collected. Samples were fixed using 40% formalin at a final concentration of 4% according to standard hydrobiological methods (Methods of hydrobiological... 2024). The planktonic fauna included rotifers, cladocerans and copepods which were identified based on the identification guides and keys (Kutikova 1970; Einsle 1996; Chang 2013; Korovchinsky et al. 2023). We computed the abundance, N , (thousand ind./m³) and biomass, B (mg/m³) for each zooplankton species of the three major taxonomic groups (Rotifera, Cladocera, Copepoda) and for the total of all zooplankton. To calculate zooplankton biomass individual masses of the Baikal species were used, which were based on measurements from Kozhova and Melnik (1978). For those organisms where individual weights were lacking, we employed formulas. For crustaceans, biomass was calculated using the formulas for the relationship between individual mass and animal body length (Balushkina and Vinberg 1979; Methods of hydrobiological... 2024). For rotifers biomass was calculated according to individual sizes and weights (Ejsmont-Karabin 1998).

The trophic state was assessed by determination of the number of species indicators of eutrophication (S_E); biomass ratios of crustaceans and rotifers B_{cr}/B_{rot} , as well as cyclopoid and calanoid copepods B_{cycl}/B_{cal} ; number of cladocerans and copepods N_{clad}/N_{cop} , crustaceans and rotifers N_{cr}/N_{rot} ; $w_{average} (B_{total}/N_{total})$ – average individual weight of a specimen in the community; B_3/B_2 – biomass ratio of consumers and producers. The trophic state was determined according to the Mäemets trophic coefficient (Mäemets 1979, 1980): $E = K(x+1)/(A+V)(y+1)$ (Andronikova 1996), where K – number of Rotifera species, A – number of Copepoda species, V – number of Cladocera species, x – number of meso-eutrophic species, y – number of oligo-mesotrophic species (Andronikova 1996). Dominant species were considered those whose proportion was $\geq 5\%$ of the abundance or biomass of the corresponding taxonomic group (Lazareva et al. 2001).

Zooplankton production was calculated based on data collected from May 16 to June 26, the period when omul larvae are present in the sor. At water temperatures above 16 °C, zooplankton migrate to the open waters of Lake Baikal. For productivity calculations, a physiological method using the K_2 coefficient, a measure

of net growth efficiency, was applied (Methodological recommendations... 1984; Ivanova 1985). When assigning zooplankton to trophic levels, older copepodite (CIII–CIV) and adult stages of cyclopoid copepods, and half the biomass of the rotifer *Asplanchna* were classified as predators (Methodological recommendations ... 1984).

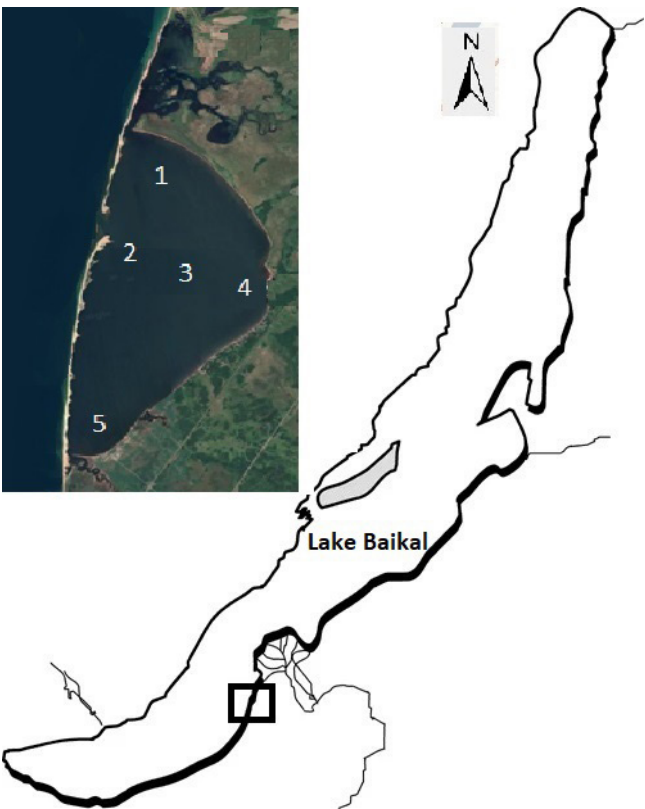


Figure 1. Map of Lake Baikal, Russia. Inset shows five sampling stations in Posolsky sor.

Table 1. Temperature and depth of sampling stations of the Posolsky sor during May – October, 2024

Number of station	Coordinates		Water temperature °C (min. – max.)	Depth, m
	N	E		
1	51°58'37.90"	106°10'62.59"	4.0–11.0	1.2
2	51°57'13.89"	106°10'88.14"	4.0–22.9	3.0
3	51°56'59.42"	106°09'51.44"	4.2–23.2	3.5
4	51°55'90.8"	106°11'25.61"	3.0–25.6	1.0
5	51°54'30.25"	106°06'88.26"	4.0–23.6	2.0

Sampling of Baikal omul larvae for feeding studies was carried out using a fry trawl (gauze sieve No. 8, mesh size in the wings 8 mm, horizontal opening width 1.0 m) towed by a Wellboat 53 motorboat. A total of eight fry hauls were performed. Captured fish were fixed in 4% formalin. Each fry was measured to the nearest 0.5 mm, blotted dry with filter paper, and weighed on a VT-500 torsion balance to the nearest 0.01 mg. Examination of gastrointestinal tract (GIT) contents was carried out in the laboratory following standard procedure for fish feeding studies (Methodological guide 1974). Diet composition was determined for 90 specimens of fish. The analysis of the gut content was based on the contents of the entire digestive tract. Planktonic organism mass was determined using reconstructed weights (Kozhova and Melnik 1978). Insect larvae were weighed on a torsion balance.

Calculation of carrying capacity. Larval growth was described by an exponential curve: $W = 8 \cdot e^{bt}$, where W is larval weight (mg), 8 is the larval weight at the transition to active feeding (mg), t is age in days after the transition to active feeding, and b is the regression coefficient. The daily ration was calculated using G.G. Vinberg's energy metabolism equations (Anoshko et al. 2025): $0.8 \times C = P + T$, $T = a \times 3.38 \times 24 \times Q$, $Q = 3.38 \times (0.3 \times (W)^{0.81} / q)$, where C is daily ration (cal), P is growth increment (cal), T is metabolic expenditure (cal), a is the coefficient of active metabolism, Q is oxygen consumption rate ($\text{mg g}^{-1} \text{h}^{-1}$), q is the temperature correction factor according to Krogh's curve, W is larval weight (g), and 3.38 is the oxycaloric coefficient ($\text{cal mg}^{-1} \text{O}_2$). When weight-based rations were computed, the ratio of zooplankton caloric content to larval caloric content was taken as 0.5. Taking into account the patterns of zooplankton biomass and production dynamics in 2024, carrying capacity was assessed as the ratio of daily zooplankton production to the daily ration of larvae. In ration calculations, the recommendation to use doubled metabolism (based on the ratio of active to basal metabolism) was adopted: $N = P / (2 \times R \times K)$, where N is the number of larvae that can be supported by the zooplankton food base, P is daily zooplankton production (cal), R is daily larval ration (cal), and K is a food coefficient equal to 3 (Toporkov and Tugarina 1963; Shirobokov 1988; Anoshko et al. 2025).

Results

Zooplankton. During the research period, 53 species were identified in the plankton fauna, of which 39% were Rotifera. The crustacean species composition included 32 species, 15 of which were classified as Copepoda. We note the presence of endemic species in the plankton fauna of Lake Baikal, specifically *Epischura baikalensis* (Sars, 1900), *Harpacticella inopinata* (Sars, 1908), *Chydorus baicalensis* (Smirnov et Sheveleva, 1996). *Diacyclops crassicaudis* (Sars, 1863) was identified for the first time in Lake Baikal. Comparison of zooplankton composition to that of 2022 revealed an increase by 17 species: 8 Rotifera, 6 Cladocera, and 3 Copepoda. Perhaps,

Four species of Cladocera, *Daphnia galeata*, (Sars, 1863), *Bosmina longirostris* (O.F. Muller, 1776), *Acroperus harpae* (Baird, 1834), and *Sida crystalline* (O.F. Muller, 1776) constituted the dominant core of cladoceran abundance (Table 2). Only *Daphnia galeata* and *Bosmina longirostris* formed the base of the zooplankton community structure. At the end of May, *Daphnia galeata* comprised up to 98% of the cladoceran abundance. Its density was also relatively high in July and October (Table 2). *Bosmina longirostris* was a part of the dominant community during the entire period of open water, with the exception of late May and mid-October.

Two species of cyclopoid copepods, *Cyclops kolensis* (Lilljeborg, 1901) and *Mesocyclops leuckarti* (Claus, 1857) and one species of the calanoid copepod *Eudiaptomus graciloides* (Lilljeborg, 1888) dominated the abundance of the Copepoda (Table 2). *Cyclops kolensis* played a relatively significant role in the crustacean community as the water temperature increased in May and again as water temperature decreased in October (Table 2). A large proportion (from 12 to 85%) of copepod abundance in the sor was comprised of the population of *Mesocyclops leuckarti*, a thermophilic species.

During the entire open water period, the proportion of Rotifera varied between 50 and 80% of the total zooplankton abundance. Copepoda ranked second, and the proportion of Cladocera was minimal, except during the second week of July, when they constituted almost 15% (Fig. 2). However, Cladocera constituted the base of the community biomass at the end of June (90%) and during the first decade of July (50%). The proportion of Copepoda in the biomass of zooplankton is relatively significant during five months (from mid-May to the first decade of June and from September to mid-October) (Fig. 2B).

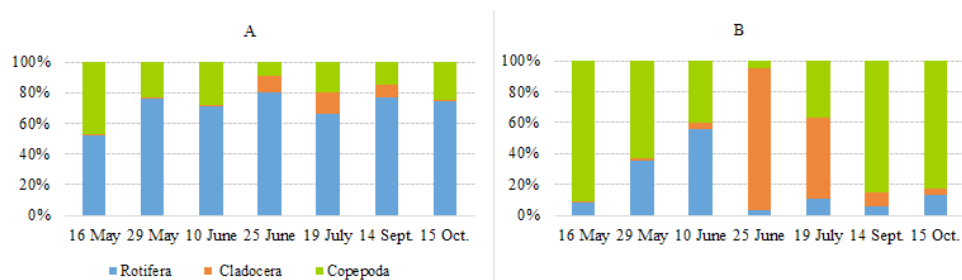


Figure 2. Proportion of the major taxonomic groups based on zooplankton density (A) and biomass (B) in Posolsky sor.

Zooplankton abundance increased with growing water temperature from mid-May to the end of the second decade of July when their maximum values were observed (Table 3). Thus, at a water temperature of 24 °C, the maximum abundance (708 thousand ind./m³) and biomass (about 3000 cal/m³) of zooplankton were observed. During this period, peaks in abundance were recorded for the rotifer

Conohilus unicornis (342 thousand ind./m³), the cladocerans *Daphnia galeata* and *Bosmina longirostris* (80 and 18 thousand ind./m³, respectively), and the cyclopoid copepods *Mesocyclops leuckarti* and *Thermocyclops crassus* (Fisher, 1853) combined (100 thousand ind./m³). In mid-October, the total density of zooplankton barely accounted for 40 thousand ind./m³. Biomass was 61 cal/m³. A relatively large abundance (18 thousand ind./m³) was noted only for *Keratella cochlearis* and *Cyclops kolensis* which formed the base of biomass (85%).

The trophic state of Posolsky sor can be classified as mesotrophic with characteristics of eutrophication based on various structural characteristics of zooplankton, such as abundance, biomass and productivity and ratios among these characteristics (Table 3). During the spring period, the oligotrophic state of the sor is characterized based on the following characteristics: the ratios of cladoceran to copepod abundance, predatory to nonpredatory biomass, and rotifer to cladoceran to copepod biomass. We consider that the assessment of the trophic state based on biomass characteristics alone to be unacceptable for Lake Baikal because the classification provided by Kitaev (2007) mainly characterizes an α -oligotrophic state of water body. The relatively low biomass may be explained by the prevalence of small bodied rotifers throughout the study period.

Zooplankton production. In mid-May, when the water temperature was about 9 °C, the productivity of zooplankton was minimal. Daily production did not exceed 7 cal/m³ per day, while the ration of the predators was 5 times more than plankton invertebrates (Table 3). The community was composed almost equally of rotifers and cyclopoid copepods, with a population not exceeding 15.000 ind./m³ for each taxonomic group. The population of cyclopoid copepods primarily consisted of 80% younger copepodite stages (C1–C3). The biomass of crustaceans (Bcrustacean) exceeded 11 times the biomass of rotifers.

At the end of May, when the water warmed to 12 °C, the productivity reached its maximum. The biomass of zooplankton was 303 cal/m³, corresponding to 80% of the community's production (approximately 74.8 cal/m³ per day) and was represented by prey organisms. The ration of zooplankton predators slightly exceeded the zooplankton community production (Table 4). Cyclopoid copepods (*C. kolensis* and *Cyclops vicinus* (Uljanin, 1875) combined with *Cyclops kikuchii*) (Smirnov, 1932) accounted for 42% of the biomass, primarily consisting of their nauplii and adult individuals, while calanoid copepods (*Eudiaptomus graciloides*) represented 20% of the total biomass of the zooplankton community. Crustacean biomass exceeded twice the biomass of rotifers. During this period, cyclopoid copepodite stages (C4–C5) that are in diapause undergo another molt resulting in a larger number of mature individuals, with both males and ovigerous females with attached egg sacs, in plankton. It is possible that the high caloric content of calanoid and cyclopoid copepods provided a diet for the omul larvae.

In the first decade of June, the water in the sor warmed up to 15 °C, the abundance of zooplankton remained at the same level with rotifers dominating, but the biomass decreased by almost three times (Table 3), mainly due to the decline in the

population of mature *C. kolensis*. Additionally, in comparison to the prior period, the biomass of calanoid copepods decreased (13% compared to 20%, respectively). The biomass of cyclopoid copepods, which accounted for 30% of the total biomass, was significantly reduced due to a decrease in the proportion of nauplii and mature cyclopoid copepods. The daily production of the zooplankton community and the ration of predators decreased during this period when the production of plankton animals slightly exceeded the ration of consumers (Table 4).

At the end of June, at a water temperature of 16°C, the dominant core consisted of 8 species, and the abundance of thermophilic species increased. In the zooplankton community during this period, the populations of *Sida crystallina* (91%), *Euchlanis dilatata* and *Asplanchna priodonta* (6%), and *Keratella cochlearis* (64%) reached relatively high abundance compared to the entire study period. Zooplankton biomass increased more than 4-fold relative to the previous sampling date (Table 3), owing to crustaceans, and exceeded that of rotifers by a factor of 29. Production ($86.9 \text{ cal m}^{-3} \text{ day}^{-1}$) exceeded the food ration of predators (Table 4).

Table 3. Characteristics of the trophic level using zooplankton indicators in Posolsky sor in 2024 during the open water season. (N refers to average abundance for a specific date; B refers to average biomass for a specific date; w – wet weight/mass of individual organism; B3/B2 – predatory to non-predatory biomass ratio; E – the trophic coefficient; H – Shannon-Wiener Diversity Index)

Indicator	Sampling date						
	16.05	29.05	10.06	25.06	19.07	14.09	16.10
Rotifera: Cladocera:	50:1:49	83:1:16	71:1:28	80:12:8	66:14:20	74:11:15	76:1:23
Copepoda (% N)							
Rotifera: Cladocera:	9:1:90	90:1:9	62:4:34	2:96:2	11:52:38	6:9:85	13:1:86
Copepoda (% B)							
w	0.005	0.002	0.001	0.002	0.005	0.003	0.003
Cladocera: Copepoda (N)	0.005	0.001	0.01	1.5	0.73	0.78	0.02
Crustacea/Rotifera (B)	11	1.9	0.74	29	8	15.12	6.41
B3/B2 (%)	88	14	52	7	44	40	17.6
E	1.1	0.3	0.3	0.3	0.2	0.3	0.5
H(B)	1.17	1.65	2.01	0.64	1.56	2.22	1.82
N, thousand ind./m ³	39.0	246.0	220.0	387.1	708.0	152.0	39.0
B, mg/m ³	105	302	104	438	1992	243	61

Feeding of the omul larvae. Zooplankton are a critical component in the diet of many fish during their early developmental stages. The food value of zooplankton is assessed by the level biomass, which is primarily influenced by the production of Copepoda and Rotifera during various seasons of the year. The diet of the omul larvae consisted mainly of cyclopoid copepods. Thus, in mid-May and the first dec-

ade of June, 98% of the stomachs of omul larvae contained adult stages and mature individuals of *C. kolensis*. It should be noted that in the first decade of June, the number of naupliar stages in zooplankton content was relatively large (30%), but less than 5% were observed in the stomachs of the larvae. Nevertheless, by the end of May, the naupliar stages in the larval diet accounted for over 20% of the diet (Fig. 3). Throughout the study period, Rotifera dominated in terms of abundance, but in terms of biomass they dominated only in the first decade of June.

Calculation of carrying capacity. The growth equation for Baikal omul larvae was derived from three mean larval weight values (Table 5), the regression coefficient was $b = 0.092$. This coefficient corresponds to a relative daily weight increment of larvae (9.2%). Thus, over 10 days, the mean weight of larvae nearly doubles. A considerable spread between the minimum and maximum length and weight values is noteworthy: by June 10, the weight range reached a factor of five. High size–weight variability is probably attributable to the extended hatching period from April 29 to June 5. On the other hand, size variability represents an adaptation for the most efficient utilization of the food base.

Table 4. Productivity and biomass of zooplankton in Posolsky sor from May 16 to June 10, 2024 in cal/m³ per day. (B – biomass; P – production; P/B – coefficient; C – ration)

Date	Prey level (herbivorous zooplankton)			Predator level (carnivorous zooplankton)			
	B	P	P/B	B	P	P/B	C
16.05	10.61	1.1	0.1	94.2	5.94	0.06	33.9
29.05	112	59.6	0.53	190.6	15.17	0.07	86.12
10.06	80.12	15.36	0.19	42.4	3.74	0.08	18.43
25.06	334.5	54.26	0.16	151.2	32.63	0.2	81

Ration calculations showed that the ration increased from 3.8 cal on May 16 to 24.6 cal on June 10. On June 25, larvae were absent in the catches, therefore, the potential ration was calculated based on larval weight obtained from the growth equation. It amounted to 68.8 cal. The maximum values of carrying capacity, recalculated for the entire volume of Posolsky Sor (80 million m³), were recorded on May 29 – 529 million larvae, and the minimum on June 10 – 62 million larvae. After June 10, an increase in zooplankton production was observed. By June 25, the carrying capacity reached 101 million larvae, assuming a mean weight of 200 mg. However, between June 10 and 25, larvae migrated from Posolsky Sor into open Lake Baikal, therefore, the June 25 carrying capacity estimate is of theoretical significance as a reference for possible changes during that period.

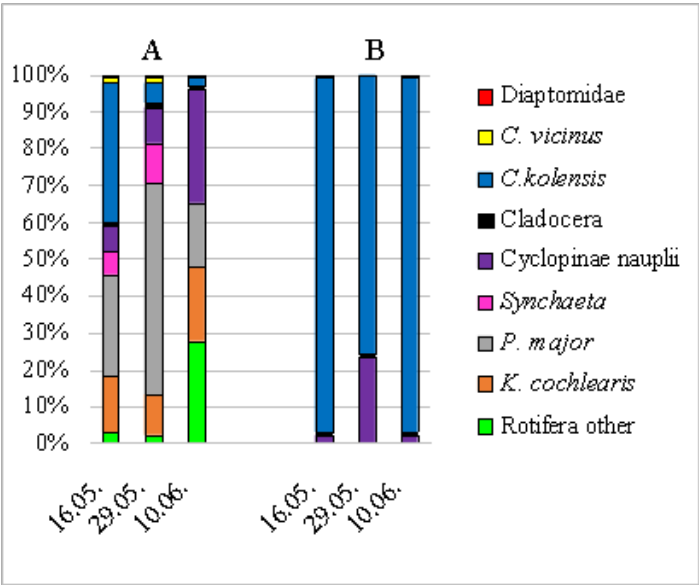


Figure 3. The proportion (%) of dominant zooplankton species in the plankton of sor (A) and in the stomachs of omul larvae (B) in May and June of 2024.

Table 5. Size–weight characteristics of juvenile Baikal omul in Posolsky Sor and carrying capacity in 2024

Parameter sample size, ind.	Sampling date			
	16.05	29.05	10.06	25.06
Total length, mm	14.4 13.5 – 15.5	20.4 15.0 – 24.5	22.6 18.5 – 29.0	–
Length from snout tip to end of notochord, mm	12.8 11.5 – 13.5	18.1 13.0 – 22.0	20.1 17.0 – 25.0	–
Weight, mg	11.9 8.5 – 14.0	33.4 10.0 – 61.5	68.7 35.0 – 179.0	200.2**
Daily ration, cal	3.8	11.3	24.6	68.8
Daily zooplankton production, cal	7	74.9	19.1	86.9
Carrying capacity, million ind. (ind./m ³)	146 (1.8)	529 (6.6)	62 (0.8)	101 (1.3)

Note: Values are presented as mean (range).** – calculated value based on the formula $W=8 \cdot e^{0.092t}$.

Discussion

This study focused on the identification and dynamics of the species composition of zooplankton, its quantitative, structural and productivity characteristics and the omul larvae diet in Posolsky sor of Lake Baikal during the growth period. In 2024, 21 species of Rotifera and 32 species of Crustacea were collected. Copepoda are represented by 15 species, in addition to one species of cyclopoid copepod (*Cyclops kikuchii*), and one species of harpacticoid copepod *Canthocamptus* (*Canthocamptus microstaphylinus* (Wolf, 1905) (Alekseeva et al. 2024). In the early spring period, a population of *Diacyclops crassicaudis* consisting of mature individuals, was found for the first time in the shallow water zone. The analysis of morphometric and morphological parameters indicates that the *D. crassicaudis* inhabiting Posolsky sor is identical to the species described in the identification guides of Monchenko (1974) and Rylov (1948). Previously this species was found in shallow lakes of the Lake Baikal basin, with depths not exceeding 1 meter, on the eastern macro-slope of the Baikal Range near Cape Shartla (Pomazkova and Takhteev 2009). In earlier studies, this species had not been detected possibly due to limited research, as well as because it is cold-stenothermic and occurs for a limited period of time.

The sor serves as a crucial link in the ecology of the Baikal omul, specifically within the benthic-deepwater morphogroup, whose population has been sustained for many years by artificial reproduction. The growth period for young omul in the sor before its migration to Lake Baikal is closely correlated to the growth of zooplankton, a primary forage reserve for fish. Temperature determines the duration of the young omul's growth in the sor; when the water temperature in the sor does not exceed 18 °C, the omul migrates from the sor to the shallow waters of Lake Baikal (Bobkov and Pavlitskaya 2003).

The dynamics of quantitative zooplankton parameters are characterized by a single peak occurring in the second ten-day period of July, when the zooplankton abundance was 708 thousand ind./m³ and biomass was about 2100 cal/m³. Rotifers were the core of zooplankton abundance throughout the open water period, among them *Conochilus unicornis* (342 thousand ind./m³) and species of the genus *Polyarthra* (more than 100 thousand ind./m³) dominated. Crustaceans formed the core biomass (about 1000 cal/m³) with *Daphnia galeata* among cladocerans, and *Mesocyclops leuckarti* (600 cal/m³) among copepods consisting of naupliar stages and copepodites. Based on the majority of characteristics (individual and combinations of abundance, biomass, productivity that determine species diversity), the trophic state of the sor is classified as mesotrophic with characteristics of eutrophication (Kryuchkova 1987; Andronikova 1996; Kitaev 2007).

The low estimates of zooplankton biomass and production on June 10 may be attributable to sampling error caused by the patchy distribution of zooplankton both across the area and by depth, depending on weather conditions. Despite of it presence dense aggregations of small zooplankters (rotifers and naupliar stages of cyclopoid copepods) creates favorable feeding conditions for fish larvae. According

to published data (Pikhtova 1981; Rivier 2000), the role of non-loricate rotifers in the diet of planktivorous fish is underestimated due to the difficult recognition of these soft bodied invertebrates in fish stomachs. For instance, in Lake Beloye *Conochilus hippocrepis* accounted for up to 17% of the gut content mass in the diet of blue bream and 20% in that of vendace (Pikhtova 1981). Many authors (Anderson and Smith 1971; Savino et al. 1994; Selgeby et al. 1994; Lucke et al. 2020; Cubbage et al. 2024) consider copepods, particularly naupliar stages, to be the primary food for coregonid larvae. There are literature reports where copepod naupliar stages were absent from the diet despite their high availability (Hoyle et al. 2011; Pothoven et al. 2014; Pothoven and Fahnenstiel 2015; Pothoven 2020).

Our studies showed that throughout the entire research period, Rotifera dominated the plankton in terms of abundance (50–80% of total abundance). Crustaceans determined the bulk of zooplankton biomass. The exception was the first ten-day period of June, when Rotifera contributed more than 50% of the biomass (Fig. 2A, B). From the third ten-day period of June through the second ten-day period of July, Cladocera dominated the biomass, mainly *D. galeata* and *Bosmina longirostris* (Table 2, Fig. 2B). It should be noted that throughout the open-water period, Copepoda occupied a leading position in biomass. Calanoid copepods may provide better nutrition for omul larvae owing to their higher fatty acid content (Vanderploeg et al. 1998; Smyntec et al. 2008). Analysis of the food bolus contents of omul larvae revealed that a large proportion of the diet consisted of copepodite stages and adult cyclopoids. According to many authors, cyclopoid copepods are an important food source for coregonid larvae and juveniles of all sizes and ages (Hart 1930; Pothoven et al. 2014). The preference for cyclopoids over calanoids is explained by their different swimming patterns (Anneville et al. 2011; Cubbage et al. 2024), although coregonid larvae may select calanoid copepods when they are abundant (Cubbage et al. 2024; Hébert and Dunlop 2025). It is known that the highest caloric content is recorded in older copepodite stages of the spring cyclopoid assemblage. Egg-bearing crustacean females have higher energy characteristics (Sherstyuk 1980; Mitsukova 1983; Romanova and Bondarenko 1984; Romanova 1996). Possibly, from mid-May to June 10, the high caloric value of calanoid and cyclopoid copepods sustained the diet of omul larvae despite the relatively low zooplankton productivity.

A comparison of the quantitative abundance and production of zooplankton with those from the previous study period (Neronova et al. 2023; Anoshko et al. 2025) showed that in 2022 zooplankton biomass increased from mid-May to late June (from 83 to 338 cal/m³), with the maximum community production recorded in late June and not exceeding 31 cal/m³ per day. This is because the biomass was dominated by large cyclopoids (*Cyclops vicinus*, *C. kikuchii*) with a long development period. In 2024, the maximum zooplankton productivity (abundance, biomass, and production) was recorded in late June and was slightly higher than in 2022 (Table 4).

The obtained results on the carrying capacity of Posolsky Sor for Baikal omul larvae are comparable with those obtained earlier (Anoshko et al. 2025), except for

the anomalously low zooplankton biomass and production values observed on June 10. This fact may be a consequence of the shift from a cold-water assemblage to a warm-water one, including the redistribution of the former into the cooler near-bottom zone. Zooplankton development in late May–early June probably does not limit the carrying capacity for larvae at the stocking volumes of the Bolsherechensky Fish Hatchery (Voronova 2023). The exponential weight growth of larvae and the corresponding increase in their rations are the determining factors for changes in carrying capacity during their feeding period in the sor. Therefore, to determine the carrying capacity, it is sufficient to establish the biomass and production of zooplankton in the second half of June before the larvae migrate to open Lake Baikal. However, the process of larval emigration from Posolsky Sor and its role in reducing competition for resources among larvae have been insufficiently studied. An indicator of well-being and favorable feeding conditions for larvae may be their size composition during this period, which should correspond to growth under conditions of low competition for food resources. In 2024, the release of larvae into Posolsky Sor amounted to 400 million individuals, which is less than the estimated carrying capacity of Posolsky Sor on May 29 and greater than that on June 10. At the same time, the high growth rate of larvae should be noted, indicating favorable conditions and an adequate food base. According to the exponential growth equation for larvae, the daily growth increment under favorable conditions is close to 9%, which confirms the results of V.N. Kuzmich's studies in 1988 (Anoshko et al. 2025).

Conclusion

The zooplankton of Posolsky sor serves as the critical food source for the Baikal omul larvae during the period from mid-May to end-June, when the water warmed to 16 °C. In the Posolsky sor zooplankton in 2024, 53 taxa below the genus rank were identified, including large copepods and cladocerans (*Cyclops kolensis*, *C. vicinus*, *C. kikuchii*, *Mesocyclops leuckarti*, *Eudiaptomus graciloides*, *Daphnia galeata*, *Bosmina longirostris* and *Sida crystallina*), which are considered to be valuable food items for fish. During the period of active larval feeding, beginning from the moment of breaking ice in the sor (mid-May) and continuing until the end of June, the species composition and quantitative characteristics of zooplankton increased with the water warming. Thus, during this period, the abundance increased 9-fold (from 39 to 346 thousand ind./m³), while the biomass increased by a factor of 4.6 (from 105 to 486 cal/m³). The productivity was at a maximum at the end of June amounting to 87 cal/m³ per day. Studying the omul larvae diet revealed the preference for *C. kolensis*, which accounted for up to 90% of the gut content. At the same time the biomass of some species, such as rotifers, which varied from 50 to 80% of the zooplankton abundance, was not found in the food bolus, possibly due to their avoidance or underestimation of soft bodied rotifers as a result of digestion. Based on structural and quantitative characteristics, as well as seasonal dynamics of abun-

dance and biomass, the trophic state of the sor has been classified as mesotrophic with characteristics of eutrophication, providing a high biomass of zooplankton, and creating favourable conditions for feeding of omul larvae.

Acknowledgements

This study was supported by the projects of the Ministry of Education and Science of the Russian Federation FWSR-2026-0016 No. 1025032600024-3-1.5.13 and FWSR-2022-0004 No. 122012600083-9. We are deeply indebted to Grace Wyngaard, whose valuable suggestions and support were instrumental in improving the quality of this paper.

References

- Alekseeva TM, Fefilova EB, Sheveleva NG, Timoshkin OA (2024) First record of *Canthocamptus* (*Canthocamptus*) *microstaphylinus* Wolf, 1905 (Harpacticoida, Copepoda) from a shallow coastal area of Lake Baikal. *Zoologicheskii Zhurnal* 103(4): 26–35. <https://doi.org/10.31857/S0044513424040037> [In Russian]
- Anderson ED, Smith Jr LL (1971) Factor affecting abundance of lake herring (*Coregonus artedii* Lesueur) in western Lake Superior. *Transactions of the American Fisheries Society* 100: 691–707.
- Andronikova IN (1996) Structural and functional organization of zooplankton in lacustrine ecosystems. Nauka Publisher, Saint-Petersburg, 190 pp. [In Russian]
- Anneville O, Berthon V, Glippa O, Mahjoub MS, Molinero JC, Souissi S (2011) Ontogenetic dietary changes of whitefish larvae: insights from field and experimental observations. *Environmental Biology of Fishes* 91(1): 27–38. <https://doi.org/10.1007/s10641-010-9755-1>
- Anoshko PN, Sakirko MV, Nepokrytykh AV, Sheveleva NG (2025) Adjustment of the assessment of the receiving capacity of Posolsky Sor of Lake Baikal for the larvae of the Baikal omul. *Rybnoe Khozyaistvo* 1: 91–101. [In Russian]
- Balushkina EV, Vinberg GG (1979) The relationship between body mass and length in planktonic crustaceans. In: *Experimental and field studies of biological foundations of lake productivity*. Nauka Publisher, Leningrad, 58–79. [In Russian]
- Bobkov AI, Pavlitskaya VP (2003) The ecology of the young posolskaya population of the bottom-deepwater omul. In: *Proceedings of the regional scientific and practical conference dedicated to the 70th anniversary of the Bolsherechensk fish breeding plant*. Irkutsk, 11–23. [In Russian]
- Chang CY (2013) Invertebrate fauna of Korea. Arthropoda: Maxillopoda: Copepoda: Cyclopoids. Vol. 21. No. 26. National Institute of Biological Resources, Incheon, 107 pp.

- Cubbage ML, Höök TO, Bunnell DB, Dieter PM, Ackiss AS, Collingsworth PD (2024) Larval coregonine density and diet composition along beaches of Northern Lake Michigan. *Journal of Great Lakes Research* 50: 102380. <https://doi.org/10.1016/j.jglr.2024.102380>
- Cushing DH (1990) Plankton production and year-class strength in fish populations: an update of the match/mismatch hypothesis. In: Blaxter JHS, Southward AJ (Eds) *Advances in Marine Biology*. Academic Press, 249–293. [https://doi.org/10.1016/S0065-2881\(08\)60202-3](https://doi.org/10.1016/S0065-2881(08)60202-3)
- Dolgoarshinnykh ZM (1990) Nutrition and dietary interactions of young fish in the coastal zone of Lake Baikal. Dissertation for the degree of Candidate of Biological Sciences. Irkutsk State University, Irkutsk, 130 pp. [In Russian]
- Einsle U (1996) Copepoda: Cyclopoida genera *Cyclops*, *Megacyclops* and *Acanthocyclops*. *Guides to the Identification of the Microinvertebrates of the Continental Waters of the World* 10. SPB Academic Publishing, Amsterdam, 83 pp.
- Ejsmont-Karabin J (1998) Empirical equation for biomass calculation of plankton rotifers. *Polish Archives of Hydrobiology* 45(4): 513–522.
- Freeberg MH, Taylor WW, Brown RW (1990) Effect of egg and larval survival on year-class strength of lake whitefish in Grand Traverse Bay, Lake Michigan. *Transactions of the American Fisheries Society* 119: 92–100. [https://doi.org/10.1577/1548-8659\(1990\)119<0092:EOEALS>2.3.CO;2](https://doi.org/10.1577/1548-8659(1990)119<0092:EOEALS>2.3.CO;2)
- Hart JL (1930) The spawning and early life history of the whitefish *Coregonus clupeaformis* (Mitchill), in the Bay of Quinte, Ontario. *Contributions to Canadian Biology and Fisheries* 6: 165–214. <https://doi.org/10.1139/f31-007>
- Hébert I, Dunlop ES (2025) Prey availability and diet of early life stages of lake whitefish (*Coregonus clupeaformis*) in the Fishing Islands of Lake Huron. *Ecology of Freshwater Fish* 34: e70010. <https://doi.org/10.1111/eff.70010>
- Hoyle JA, Johannsson OE, Bowen KL (2011) Larval lake whitefish abundance, diet and growth and their zooplankton prey abundance during a period of ecosystem change on the Bay of Quinte, Lake Ontario. *Aquatic Ecosystem Health & Management* 14: 66–74.
- Ivanova MB (1985) *The Production of Planktonic Crustaceans in Freshwater Reservoirs*. Nauka Publisher, Leningrad, 246 pp. [In Russian]
- Kardasheva GP, Nikolaeva EP, Toporkov EP (1981) Zooplankton of Posolsky Sor of Lake Baikal (1972–1975). In: *Hydrobiological Studies in Eastern Siberia*. Irkutsk, 93–105. [In Russian]
- Kitaev SP (2007) *Basic limnology for hydro-biologists and ichthyologists*. Karelian Research Centre of RAS, Petrozavodsk, 395 pp. [In Russian]
- Korovchinsky NM, Kotov AA, Sinev AY, Neretina AN, Garibian PG (2021) *Cladocera (Crustacea) of North Eurasia 2*. KMK Scientific Press, Moscow, 544 pp. [In Russian]
- Kozhov MM (1963) *Lake Baikal and its Life*. Dr. W. Junk Publishers, The Hague, 344 pp.

- Kozhova OM, Melnik NG (1978) Manual to process plankton samples by counting. Irkutsk State University, Irkutsk, 51 pp. [In Russian]
- Kryuchkova NM (1987) The structure of the zooplankton community in water bodies of various types. In: Production and hydrobiological studies of aquatic ecosystems. Nauka Publisher, Leningrad, 184–198. [In Russian]
- Kutikova LA (1970) Rotifera in the fauna of the USSR (Rotatoria). Eurotatoria subclass (orders Ploimida, Monimotrochida, Paedotrochida). Nauka Publisher, Leningrad, 744 pp. [In Russian]
- Lazareva VI, Lebedeva IM, Ovchinnikova NK (2001) Changes of the zooplankton community in the Rybinsk water-reservoir along 40 years. Inland Water Biology 4: 46–57. [In Russian]
- Levkovskaya LA (1977) Zooplankton of the bays and lakes in the coastal zone. In: Florensov NA (Ed.) Limnology of the coastal and sor zone of Lake Baikal. Nauka Publisher, Novosibirsk, 175–191. [In Russian]
- Lucke VS, Taylor R, Stewart, Vinson MR, Glase JD, Stockwell JD (2020) Larval *Coregonus* spp. diets and zooplankton community patterns in the Apostle Islands, Lake Superior. Journal of Great Lakes Research 46: 1391–1401. <https://doi.org/10.1016/j.jglr.2020.07.001>
- Ludsin SA, De Vanna KM, Smith REH (2014) Physical-biological coupling and the challenge of understanding fish recruitment in freshwater lakes. Canadian Journal of Fisheries and Aquatic Sciences 71: 775–794. <https://doi.org/10.1139/cjfas-2013-0512>
- Mäemets AKh (1979) The qualitative composition of pelagic zooplankton as an indicator of trophic lake. In: Anthropogenic impact on small lakes. Tallinn, 54–64. [In Russian]
- Mäemets AKh (1980) Changes in zooplankton. In: Anthropogenic impact on small lakes. Tallinn, 54–64. [In Russian]
- Methodological guide for the study of feeding and food relations of fish in natural conditions (1974) Nauka Publisher, Moscow, 254 pp. [In Russian]
- Methods of hydrobiological studies of inland waters (2024) Krylov AV (Ed.) Filigran, Yaroslavl, 592 pp. [In Russian]
- Methodological recommendations for the collection and processing of materials in hydrobiological studies of freshwater bodies. Zooplankton and its production (1984) National Research Institute of Lake and River Fisheries, Leningrad, 33 pp. [In Russian]
- Mitsukova LD (1983) The relationship between the chemical composition and the energy value of mass forms of zooplankton in relation to their age during the maturity stage in Lake Bele. In: Trophic connections and their role in the productivity of natural water bodies. Krasnoyarsk, 117–121. [In Russian]
- Monchenko VI (1974) Cyclopidae. Fauna of Ukraine 27(3). Naukova Dumka, Kiev, 442 pp. [In Ukrainian]
- Neronova SYu, Sheveleva NG, Misharina EA (2023) Current status and trophic relationships of the zooplankton in Posolsky sor of Lake Baikal in 2022. In: Read-

- ings in memory of Vladimir Yakovlevich Levanidov 10. Vladivostok, 173–181. <https://doi.org/10.25221/levanidov.10.15> [In Russian]
- Pavlitskaya VP, Bobkov AI (2000) Characteristics of functioning of early summer zooplankton in Posolsky sor of Lake Baikal nowadays. In: Proceedings of the International Conference on Hydroecology Issues at the Turn of the Century. Petrozavodsk, 6–8. [In Russian]
- Pikhtova TS (1981) The significance of zooplankton in the diet of planktivorous fish. In: Anthropogenic impact on large lakes of the Northwest USSR. Vol. II. Hydrobiology and bottom sediments of Lake Beloye. Nauka Publisher, Leningrad, 100–108. [In Russian]
- Pomazkova GI, Takhteev VV (2009) The meiofauna of mountain and foothill springs in certain areas of Baikal region. In: Biota of the water bodies of the Baikal rift zone. Irkutsk State University, Irkutsk, 95–106. [In Russian]
- Pothoven SA (2020) The influence of ontogeny and prey abundance on feeding ecology of age-0 lake whitefish (*Coregonus clupeaformis*) in southeastern Lake Michigan. Ecology of Freshwater Fish 29(1): 103–111.
- Pothoven SA, Fahnenstiel GL (2015) Spatial and temporal trends in zooplankton assemblages along a nearshore to offshore transect in southeastern Lake Michigan from 2007 to 2012. Journal of Great Lakes Research 41: 95–103.
- Pothoven SA, Hook TO, Roswell CR (2014) Feeding ecology of age-0 lake whitefish in Saginaw Bay, Lake Huron. Journal of Great Lakes Research 40: 148–155.
- Rivier IK (2000) Zooplankton. In: Current Ecological Situation in the Rybinsk and Gorky Reservoirs: State of Biological Communities and Prospects for Fish Breeding. Yaroslavl State Technical University, Yaroslavl, 175–194. [In Russian]
- Romanova EP (1996) Caloric content of zooplankton in the Kuibyshev Reservoir. Biologiya Vnutrennikh Vod. Informatsionnyi Byulleten' 100: 30–34.
- Romanova EP, Bondarenko LF (1984) Caloric content of crustaceans in the Kuibyshev Reservoir. Biologiya Vnutrennikh Vod. Informatsionnyi Byulleten' 63: 37–42. [In Russian]
- Rylov VM (1963) Fauna of the USSR, Crustacea, Freshwater Cyclopoida. Vol. 3(3). Israel Program for Scientific Translations, Jerusalem, 318 pp.
- Savino JF, Blouin MA, Davis DM, Hudson PL, Todd TN, Fleischer GW (1994) Effect of pulsed turbidity and vessel traffic on lake herring eggs and larvae. Journal of Great Lakes Research 20: 366–376.
- Selgeby JH, MacCallum WR, Hoff MH (1994) Rainbow smelt–larval lake herring interaction: competitors or casual acquaintances? US National Biological Survey, Biological Report 25.
- Sherstyuk VV (1980) Energy assessment of feed crustaceans. Hydrobiological Journal 16(6): 92–93. [In Russian]
- Shirobokov II (1988) Feeding and growth of juvenile coregonids in monoculture and polyculture. Abstract of the dissertation of a candidate of biological sciences. Irkutsk, 24 pp. [In Russian]

- Shnyagina GI (1963) Changes of zooplankton in Posolsky sor and adjacent shallow regions of Lake Baikal in May–August (1960 and 1961). Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva 13: 56–62. [In Russian]
- Smirnov VV, Smirnova-Zalumi NS, Sukhanova LV (2009) Microevolution of the Baikal omul (*Coregonus autumnalis migratorius*) (Georgi). Nauka, Novosibirsk, 244 pp. [In Russian]
- Smyntek PM, Teece MA, Schulz KL, Storch AJ (2008) Taxonomic differences in the essential fatty acid composition of groups of freshwater zooplankton relate to reproductive demands and generation time. Freshwater Biology 53(9): 1768–1782. <https://doi.org/10.1111/j.1365-2427.2008.02005.x>
- Sorokin VN, Sorokina AA (1991) Ecology of Fish Reproduction in Lake Baikal. Irkutsk University Press, Irkutsk. [In Russian]
- Toporkov IG, Tugarina PYa (1963) On the feeding of juvenile Baikal omul up to two years of age. Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva 13: 217–224. [In Russian]
- Vanderploeg HA, Cavaletto JF, Liebig JR, Gardner WS (1998) *Limnocalanus macrurus* (Copepoda: Calanoida) retains a marine arctic lipid and life cycle strategy in Lake Michigan. Journal of Plankton Research 20(8): 1581–1597. <https://doi.org/10.1093/plankt/20.8.1581>
- Vilisova IK (1954) A comparative review of the zooplankton from Posolsky sor and the coastal areas of open Baikal. Proceedings of the Baikal Limnological Station 14: 190–262. [In Russian]
- Voronova ZB (2023) On the estimation of the commercial return of the Baikal omul of the Posolsk population. In: Problems of conservation of commercial fish stocks: Proceedings of the All-Russian Scientific and Practical Conference dedicated to the 70th anniversary of the Honored Worker of Fisheries of Russia Mikhail Grigorievich Voronov. Buryat State Agricultural Academy named after V.R. Filippov, Ulan-Ude, 53–60. [In Russian]