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Influence of environmental factors on the formation of zooplankton communities in a large lake system in Uzbekistan

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Abstract. Currently, the Aidar-Arnasai Lake System (AALS) is of great environmental and commercial importance for Uzbekistan. The article discusses the influence of mineralisation, temperature and diversity of biotopes on the change in the species composition in the lakes. The largest number of species is recorded in oligohaline water in the lakes' littoral zones. They are dominated by the Rotifera and Cladocera and show a greater number of species in the spring. Areas with mesohaline water are dominated by Copepoda, showing the largest number of species in the winter in both littoral and pelagic zones. Biomass of zooplankton poorly correlates with salinity. Depth impacts reliably the distribution of zooplankton biomass, while the spatial accumulation of zooplankton biomass depends on temperature.

1 Introduction

The Aidar-Arnasai Lake System (AALS) is a huge artificial lake system located in Djizak and Navoi regions of Uzbekistan. Throughout their existence, the mineralisation of the water in the lakes depended on the discharge of fresh water from the Chardara Reservoir and on the drainage water coming from the Central Golodnostep Canal (CGC). However, as the amount of water discharged from the Chardara Reservoir into the lake system has gradually decreased over the last decade, the Central Golodnostep Canal has become the main regulator of the water balance in the lake system. Currently, the mineral contents of the water from the canal are smaller than 3 g/l, which is significantly lower than the average contents of the water in the Aidar-Arnasai Lake System, so the canal water can be used to somewhat stabilise the hydrochemical state of the lake system [1,2].

The Aidar-Arnasai Lake System consists of three large lakes – Aydarkul, Tuzkan and East Arnasai with the Arnasai Reservoir, – and has a total area of about 4,000 km^2 and a maximum depth of about 26 m.

In 1998, the Ramsar Convention designated some of the water bodies in the lake system an International Bird Area. It includes Lake Tuzkan, the north-western part of Lake East Arnasay and the Nurata Nature Reserve. The territory of the Aidar-Arnasai Lake System is inhabited by about 300 species of birds, 190 of which are wetland migrants arriving in the

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region in the winter. The increase in the mineral contents has led to a decrease in the birds' food supply and, as a result, their lower species diversity. Other factors impacting the birds numbers are uncontrolled hunting and fishing (in the latter case, old nets left in the water catch birds, especially diving ones).

Zooplankton are good food for zoobenthos and fish, and as active filtrators, the Cladocera and Calanoida play an important role in the self-cleaning of water bodies. Therefore, in order to ensure the sustainable development of fish farming in the water bodies of the Aidar-Arnasai Lake System, including cage aquafarming, a long-term study of the hydrobiological communities in the lake system is being carried out. The maximum increase in the bioproductivity of this large body of water, most likely, will be facilitated by an increase in the area of shallow water with higher plants, which in turn can be achieved by stabilising the water level and the shoreline of the Aidar-Arnasay Lake System. The restoration of old and organisation of new pond farms in the shallow water area, as well as the development of cage fish farming, can become an additional source of income for the population. In addition, the development of pond fish farming and fish factories will solve the problem of stocking the lake system with larvae of commercial species from the carp family, and will open up opportunities for the cultivation of new hydrobiological objects [3].

The paper includes data of the research into the AALS conducted from 2019 to 2021 aimed to study the current status of zooplankton communities in the lakes associated with its increasing salinity. In Uzbekistan, several studies have been carried out to understand the impact of drought-driven salinization on zooplankton communities in the Amu Darya lower reaches in Central Asia [4, 5] and in the eastern part of the Aral Sea [6].

2 Materials and methods

Zooplankton communities were studied in 2019 and 2020 during trips to the lake system in various seasons (winter: January 2019 and February 2020, water temperature T=6-7° C; spring: May 2019 and April 2020 (T=18-20° C); summer: July 2019 (T=29-30° C) and August 2020 (T=25° C); early autumn – September (T=21-22° C) and late autumn – November 2019 (T=10° C).

In total, about 300 zooplankton samples from areas with different mineral contents were analysed. The mineral contents ranged from 2.8 to 8.6 g/l. The zooplankton samples were taken from both littoral and pelagic zones of the lake system. The depth of the littoral zones ranged from 1 to 1.5 m, pelagic ones from 5 to 15 m.

Quantitative indicators of zooplankton (biomass) were processed using the statistical program Prism 5.0 and Excel to establish dependence on environmental factors, such as temperature, mineral contents and depth.

During the salinization of the Aral Sea, the water was classified according to mineral contents and salinity barriers were identified for the distribution of hydrobionts [7]. According to this classification, the oligohaline zone lies within 0-3 g/l, with an oligohaline mineral contents barrier of 3-5 g/l limiting the distribution of freshwater fauna. Mesohaline zones: 5-11 g/l with a mesohaline barrier of 12-14 g/l, which is the lower limit of the distribution of brackish water hydrobiont fauna. These barriers caused a difference in the composition of invertebrate species that in the past inhabited the Aral Sea, where the mineral contents were 11 g/l (mesohaline fauna), and those that lived in freshwater delta lakes (oligohaline fauna).

Currently, two zones can also be identified in the Aidar-Arnasai Lake System. The oligohaline zone includes Lake East Arnasay, the portions of Lakes Tuzkan and Aidar near the canal mouths, and the canals proper feeding the lake system. The mesohaline zone with mineral contents higher than 5 g/l covers the parts of Lakes Tuzkan and Aidar away from the canal mouths.

Zooplankton samples were taken using a conical Jedi net (d=18 cm, filter mesh size No. 72) and processed according to the generally accepted method [8]. The samples were put in 40% formalin, so that the concentration of the sample was 4%. The samples were identified with the help of trinocular and binocular microscopes, using generally accepted guides [9-11].

3 Results and discussion

3.1 Succession of zooplankton communities in the AALS depending on mineral contents

Our long-term research data indicate that the main factor in changing the zooplankton species diversity in the Aidar-Arnasai Lake System is the mineral contents of the water [1, 2]. After the formation of the lake system, the mineral contents of the water in different parts of the system ranged from 2 to 4 g/l. A 1970 research [12] showed that the zooplankton in the Aidar-Arnasai Lake System was characterised by the presence of a freshwater phytophilic complex: *Chydorus latus, Oxyurella tenuicaudis, Macrotrix hirsuticornis* and *Pleuroxus aduncus*, and freshwater rotifers and copepods of temperate latitudes: *Brachionus falcatus, Brachionus calyciflorus, Asplanchna priodonta, Platyas quadricornis, Acanthocyclops bicuspidatus odessana, A.gigas* and *Acanthodiaptomus denticornis.* These freshwater species have been found in the last decade only in areas of the lake system with low mineral contents [1, 13].

As mentioned above, the mineral contents of the lakes in the system depend on the inflow of fresh and canal water, which increases in high-water years and decreases in low-water periods (Fig.1) [1]. Due to climatic changes and the environmental disaster associated with the Aral Sea, the duration of low-water periods increases, while that of high-water periods drops.

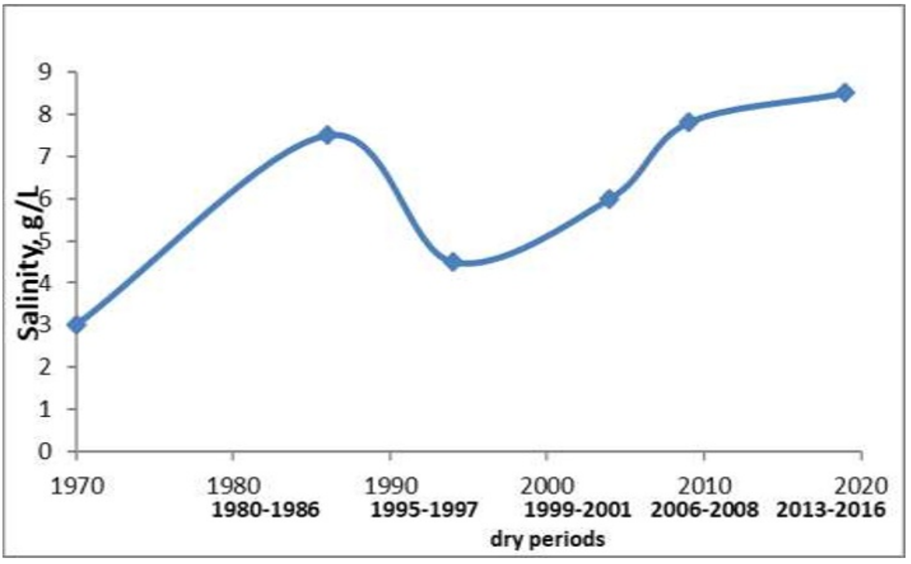

Fig.1 Change in mineral contents in the mesohaline areas of the Aidar-Arnasai lake system in low-water periods

By 1986, due to the long low-water period (1980-1986), the mineral contents of the water increased to 7-8 g/l. The main dominants of the community during that period were *A.salinus*, *Thermocyclops rylovi* and *Cyclops vicinus* (30%) [2].

When in 1994 the lake system received a large amount of fresh water from the Chardara Reservoir, the mineral contents of the lakes dropped to 4-6 g/l. The zooplankton fauna in all the lakes in the system was composed of the following species: *Brachionus quadridentatus, B.q.hyphalmuros, B.plicatilis, Keratella quadrata, Hexarthra fennica, Notholca acuminata, Lecane luna; Arctodiaptomus salinus Thermocyclops vermifer, Mesocyclops ogunnus, Cyclops vicinus; Onychocamptus mohammed, Nitocra lacustris, Chydorus sphaericus, Alona rectangula Diaphanosoma mongolianum, Ceriodapnia turkestanica, Daphnia magna* and *Daphnia longispina*. Harpacticidae were characteristic of the more mineralised Aidar Lake (above 6 g/l): *Schizopera spinulosa, S.aralensis, Cletocamptus cf.deitersi* and *Nitocrella sp.* [2].

In 2009 and 2010, after the low-water period of 2006-2008, the maximum recorded mineral contents of the lakes were 8 g/l. At that time, oligohaline areas were characterised by the following species: *Daphnia laevis, Daphnia galeata Bosmina longirostris*, *Alona rectangula*, *Ilyocryptus sordidus*, *Arctodiaptomus gracilioides*, *Thermocyclops vermifer*, *Th. crassus* and *Th. rylovi.* The following species were recorded in mesohaline areas: *Moina brachiate, Diaphanosoma mongolianum, Leptodora kindtii, Cyclops vicinus* and *Arctodiaptomus salinus* [13].

3.2 Species diversity of zooplankton in the AALS in oligohaline and mesohaline areas in different seasons during 2019-2020 years

In 2019 and 2020, after the low-water period of 2013-2016, the mineral contents of areas remote from the canals increased to 8.6 g/l.

We assumed that the species diversity of the zooplankton in the Aidar-Arnasai Lake System depends on 3 factors: temperature, depth (zones with or without vegetation) and mineral contents. The highest species diversity of rotifers was characteristic of the freshwater littoral zone – 22 species. The Copepoda showed the highest species diversity (12) in January and February, also in the oligohaline littoral zone. The lowest diversity was observed in the Cladocera – 8 (the highest number of species was recorded in April, also in the oligohaline littoral zone). 25 species were recorded in the littoral zone of the lakes, and 7 in the pelagic zone.

In 2019 and 2020, the mesohaline littoral zone of Lake Tuzkan showed the development of a halotolerant complex consisting of 3 to 6 species of copepods, dominated by *A. salinus.* In summer, this zone was dominated by *Mesocyclops aequatorialis* from the class Copepoda (*Paracyclops fimbriatus* was recorded very rarely); *Cletocamptus retrogressus* and *Onychocamptus bengalensis* from the Harpacticoida; and *Alona sp.* and *Ch. sphaericus* from the Cladocera; in the summer months, *Brachionus p. plicatilis, B. nilsoni* and *B. hyphtalmurus* from the phylum Rotifera were also found there.

The mesohaline areas of the pelagic zone of Lake Tuzkan were characterised by the development of the same halotolerant complex, which, however, consisted of a larger number of crustacean species (Crustacea); another dominant species was *Arctodiaptomus salinus.* Less common were the Copepoda *P. fimbriatus* and *O. Bengalensis;* in the winter months, large Copepoda species, *Cyclops heberti* and *Acantocyclops venustus,* were observed, which were later replaced by other species; so in July and September, the areas were dominated by *M. Aequatorialis.* In summer, two species of the Cladocera were observed: *Moina brachiate,* which dominated the biomass, along with *A.salinus,* and *Ceriodaphnia turkestanica,* which was much rarer than the first species.

The oligohaline zone was characterised by the largest number of species, with the biomass dominated in spring by *Daphnia longispina*. The following species of the Palaearctic complex were also found there: the Copepoda – *Arctodiaptomus gracilioides, Acantocyclops biarticulatus, Ectocyclops phaleratus, Nitocra lacustris* and *Onychocamptus mohammed;* the Cladocera – *Daphnia longispina Ceriodaphnia reticulata, Simocephalus vetulus, Acroperus harpae, Chydorus sphaericus* and *Alona rectangula.*

Fig. 2 shows the dynamics of dominant zooplankton groups in different seasons of the year.

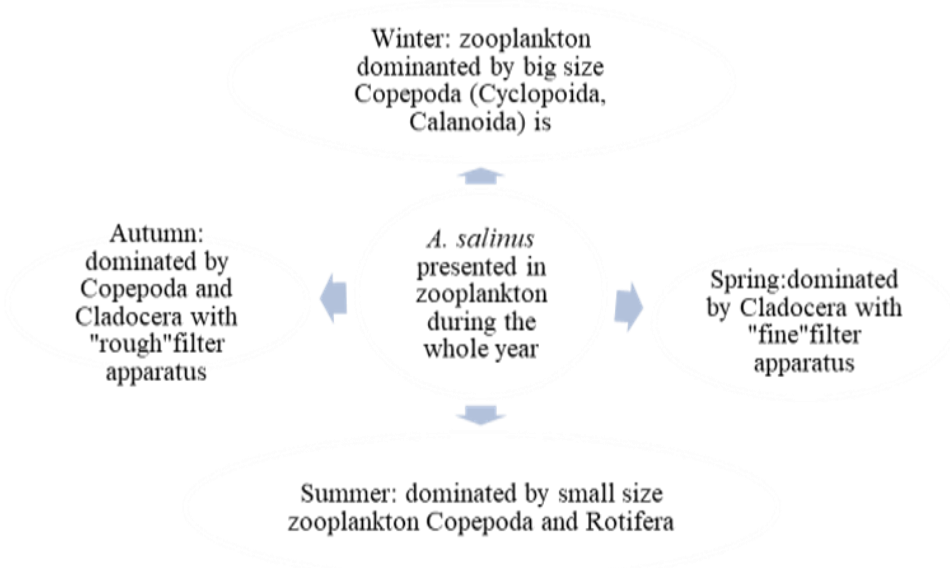

Fig.2 Dominance of zooplankton groups in the mesohaline water of Lake Tuzkan in different seasons

3.3 Influence of factors such as mineral contents, temperature and depth on quantitative indicators (biomass) of zooplankton in the AALS

According to literary sources, the concentration of biogenic substances determines the structure and development of phytoplankton. In turn, the structure and quantitative development of phytoplankton, as well as the presence of dissolved phosphorus and nitrogen in water, determines the species composition and biomass of zooplankton [14].

The zooplankton biomass in the Aidar-Arnasai lake system has seasonal dynamics and spatial distribution associated with the depth of studied water areas (Fig.3).

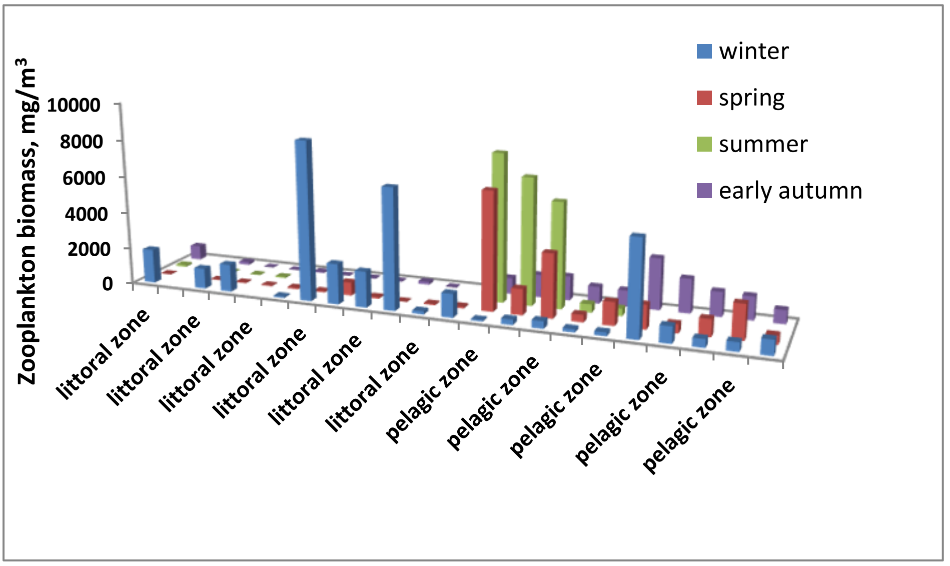

Fig.3 Seasonal changing of zooplankton biomass at the littoral and pelagic sites of the AALS in 2019-2020 years

Statistical analysis of the correlation between zooplankton biomass and factors such as the season and depth showed that biomass depends on both depth (Spearman r_s are '-0.65' and '0.54' for littoral and pelagic zones respectively; $p<0.001$) and temperature (Spearman r_s are '-0.2', '0.66' and '0.76' for winter, summer, autumn/spring seasons respectively; $p<0.001$). Zooplankton biomass has a positive correlation in deep waters (10-15 m), with maximum biomass recorded in the summer season, and has a negative correlation in littoral zones (1-4 m), where the highest biomass is recorded in the winter. Biomass positively correlated with temperature in summer and in autumn/spring seasons, but does not show any significant correlation in this season with temperature.

Analysis using two way ANOVA showed that the level of biomass in different seasons does not differ significantly, while the depth factor has a strong effect on the biomass value ($p<0.05$), with the zooplankton biomass generally higher in deep waters than in littoral zones.

We took samples from areas with different mineral contents and therefore could also check the effect of this factor on the biomass of zooplankton communities. Our study does not show any significant correlation between mineral contents and the development of zooplankton biomass (Pearson's r is '-0.19'), which suggests that mineral contents do not influence the zooplankton biomass.

4 Conclusions

Temperature affects the spatial distribution of zooplankton biomass in the studied lakes: in winter season, maximum biomass accumulates in the littoral zone, and when the water temperature rises above 20° C, maximum biomass is recorded in the pelagic zone. Zooplankton biomass is not affected by salinity; meanwhile, species diversity depends on this environmental factor.

When the salinity in AALS sites dropped to 2-3 g/l, the species diversity of zooplankton increases, especially through growth of the number of species in the oligohaline group of rotifers (the fresh water coming from the Chardara Reservoir can be a source of freshwater rotifers, both by itself and creating favourable conditions for the development of the species). In addition to the group of rotifers, the oligohaline areas of the lake system is characterised by the development of the phytophilic Palearctic complex represented by the Cladocera and Copepoda. When salinity was above 5-6 g/l, the species diversity of both the Cladocera and the Rotifera decreases, with the Copepoda becoming the most representative in terms of the number of species.

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