International Journal of Lakes and Rivers.
ISSN 0973-4570 Volume 17, Number 1 (2024), pp. 1-16

http://www.ripublication.com/ijlr.htm

# A Critical Review of Plankton Diversity and Physiochemical Parameters in Trans Himalayan and Other Lakes in India

**Mehboob Ali[1], Mumtaz Ali[2*], Syed Danish[3] & Anil Gour[4]**

[1, 4] Department of Zoology, Bar. R.D.I.K and K.D College Badnera, Amravati
[2] Department of Zoology, Govt Vidarbha Institute of Science and Humanities, Amravati
[3] Department of Zoology, Shri Shivaji Science College, Amravati.
Correspondence*: mumtazmaahi28@gmail.com

**Abstract**

In India, most studies have been conducted on lakes in other states; however, because Ladakh is a remote and high-altitude region, very few studies have been conducted on any of the lakes other than Pangong Tso and Tso Morori. There are about thirteen lakes in this Ladakh Trans Himalayan region. Of those, research has only been conducted on Pangong Tso and Tso Morori; research on the other eleven lakes has not yet been completed. Two significant lakes in the Kargil district are Sapi and Shashi lakes, but no one is aware of their physiochemical parameters or plankton diversity. We compared and critically reviewed other lakes, such as Pangong, Tso Moriri, Prasar, and Wular Lake. These lakes have a rich diversity of Bacillariophyceae, Chlorophyceae, and Cyanophyceae, with mostly similar zooplankton species found in most of them. Similar conditions may also exist in Sapi and Shashi Lake, which will help in our research when we are going to reveal the plankton diversity and physiochemical parameters in those lakes that are shrinking daily due to climate change and its effects on agriculture, biodiversity, and tourism in Kargil Ladakh.

**Keywords:** Zooplankton, Phytoplankton, Physiochemical Parameters, review, lakes, and Kargil (Ladakh)

## INTRODUCTION

The Himalaya is home to many lakes and wetlands, including the trans-Himalayan region of Ladakh. Despite this, research only on Pangong Tso and Tso Morori has continued. Ladakh is divided into two districts, Kargil and Leh. The majority of the lakes, including Pangong Tso, Tso Morori, Tsokar, Yarab Tso, Mirpal Tso, Chagar Tso, Kiagar Tso, Stat Tso, and Lang Tso are located in the Leh district. Two well-known lakes, Sapi and Shashi Lake, are located in Kargil. Tso Morori is 4569 meters above sea level and is situated in the Changthang region of the Leh district in the eastern Himalayas. It was designated as a Ramsar site in 2002 (Bhat, Farooz Ahmad et al. 2009). The eastern part of Ladakh is home to the landlocked lakes of Pangong Tso. It is roughly three months frozen in the winter at 4266 meters above sea level. Magnesium is more abundant than calcium in these Ladakh lakes. Kashmir's high-altitude lakes have more calcium than magnesium, but the area is still very conductivity and alkaline. Kashmir, Ladakh, and Himachal Pradesh do not have different sodium and potassium ion values (Zutshi et al. 1980).

There are two lakes in Kargil, the Shashi and the Sapi Lake; however, no one is conducting studies on them at this time. Shashi has not been the subject of any research to date. The lake is given its name after the location where it is found, i.e., Shashi and Sapi village respectively. The Shashi Lake occupies the northern portion of Shashi Valley and is one of the most unexplored and untouched lakes to date. It was created artificially by the villagers of Sandoo and Yokma Kharboo in 1935, with the assistance of Kacho Isfandar Khan (an author and the then social activist). The lake's water is renewed yearly by the melting of glaciers, snow, and light precipitation. It is the main water source in valleys, including Sandoo, Samnoo, Karith, and Yokma Kharbo. It extends between 34.56 N and 34.55 N latitudes and 76.64 E and 76.38 E. The altitude of this lake extends from 11,000 to 16,000 feet above sea level (Abul Qasim, 2020). Due to the lake's daily shrinkage, there is a severe water shortage in these valleys, the reason can be attributed to global warming. However, no one is certain of the primal cause because no research explains the causes and their foundations. Since the villages of Sandoo, Yokma Kharboo, and Samanoo had been experiencing a drought-like situation for many years, this lake was built with their needs in mind.

Sapi Lake is a natural lake nestled in the lap of a glacier. It was first discovered by a shepherd from one of the Sapi villages. This is an unresearched lake with no research or exploration into its ecosystem, various species, or distribution. It is commonly called *Norbu Tso*, or a little paradise. The lake, which is encircled by a carpet of wildflowers, and the medicinal plants appear to be a paradise on earth. It is situated 4600m above sea level. Because of a strange occurrence, the lake's colour changes over an average of fifteen days, going from white to bright blue. It lies in Sapi village, which belongs to Kargil district, and it's about 70 km away from Kargil's main market. Sapi village is encircled by the Shargole block to the North, the Drass block to the West, the Shakar-Chiktan block to the East, and the Suru block to the South. The Sapi Nallah river basin originated from Sapi Tso promotes the productivity of agriculture, and is used in the household sector, and for other purposes in Tambis and

Kanoor Valley, which come under the T.S.G. block in Kargil district. Many species of plankton may be present in this body of water, but nobody has identified them. The exploration and identification of a lot of plankton may be expected from these lakes. We have no idea what the physiochemical parameters of the bodies of water in these two lakes are that would act as indicators of how polluted they are. We will reveal the relationship between the physicochemical parameters of the water bodies of these lakes and the biodiversity wealth of zooplankton. The physiochemical parameter would also provide a positive signal for the management and preservation of the lakes.

**Relevant Pieces of Literature**

We employed a search for the relevant works of literature using strings like plankton, phytoplanktons, zooplanktons, plankton diversity, physiochemical parameters, and lakes of Ladakh and Trans-Himalaya on various search engines- Google Scholar, Research Gate, Shodh Ganga (an Indian theses repository), and even a direct search on Google. Numerous results for the search were retrieved, but the ones with a high citation count were chosen. A majority of the studies have not yet been conducted in many distinct high-altitude lakes in Jammu and Kashmir and Ladakh, however, some research publications address the lakes' conditions, plankton variety, and relationship to physiochemical parameters. Upon analyzing intense research literature surveys about Ladakh, we discovered that the region's high altitude and low temperature contribute to a rich diversity of Bacillariophyceae species and a limited number of zooplankton species. Till now only the lakes of Pangong Tso and Tso Moriri have been studied in Ladakh; eleven other lakes are still unstudied, especially the Sapi and Shashi lakes, which have strategic importance, and such studies will help identify and reveal the plankton and physiochemical parameters of these lakes in Kargil Ladakh. Several relevant shreds of literature regarding the physiochemical parameter and plankton diversity have been discussed below.

The primary constituent of biotic aquatic ecosystems, zooplankton affects all fundamental aspects of the marine environment, including the food web, food chain, energy flow, and geochemical cycles. They play an important role in the maintenance of marine and freshwater ecosystems. Some zooplankton species serve as biological markers that are used to gauge the extent of water pollution. A lot of work has been done by limnologists throughout the world, including India. Venkateswarlu (1968), Prabhavathy and Sreenivasan (1977), Badola and Singh (1981), Bilgrami and Munshi (1985), Saunders and Lewis (1988), Jeje (1989), Mishra and Sharma (1990), Tayor and Segers (1999), and Kulshrestha and Sharma (2006) all provided significant contributions towards the zooplanktonic studies and their various impacts. Zafar and Sultana (2005) examined the zooplankton density in the Ganga River in Kanpur, India, and found that it peaked during the summer but decreased during the monsoon season.

Thorp et al. (2005) studied turbid zooplankton and hydrological dynamics in rural areas. Although microcrustaceans were infrequent in turbid rivers, they reported a substantial prevalence of rotifers in turbid waters. Additionally, they stated that the density of crustaceans and rotifers was adversely correlated with current velocity.

Chowdhury and Mamun (2006) have studied the consequences of physicochemical conditions on zooplankton in two fish ponds located inside the university campus in Khulna, Bangladesh. They found the greatest number of zooplankton species and their abundance during August and also estimated the level of eutrophication in these two lakes.

Seema Langer et al. (2007) studied the effect of some abiotic factors on zooplankton productivity in a subtropical pond in Jammu and found that *Moina* among *Cladocerans* and *Brachionus* among rotifers were present at both high and low oxygen levels. It indicates that it has a higher tolerance level for oxygen variation. In addition, copepods' existence in that situation reveals they act as the best pollution indicator species; they survived and had high abundance even at times of high carbon dioxide, high pollution, high temperature, and lower levels of magnesium and calcium.

Aquino et al. (2008) reported 27 species of zooplankton, among which 45% were rotifers, 26% were copepods, and 29% were *Cladoceran* in the Paoay Lake, Philippines.

Paulose and Maheshwari (2008) studied the seasonal variations in the zooplankton community structure of Ramgarh Lake in Jaipur and found that high temperatures promote the metabolic rate, which increases the rate of multiplication that enhances the number of zooplankton in the high-temperature environment.

Zooplankton composition and distribution in vegetated and unvegetated areas in three reservoirs in Hatay, Turkey, was studied by Bozkurt and Guven (2009). They studied zooplankton distribution and composition in unvegetated and vegetated areas. They declared that Cladoceran numbers were higher in vegetated areas than in un-vegetated areas. They revealed that the distribution, growth, and reproduction of plankton were inversely affected by dissolved oxygen. While studying the impact of flood water on the distribution of zooplankton in the main channel of Lake Nasser, El-Serafy et al. (2009) found the copepods to be the superior group and assigned their getup to the better environmental condition of the lake at the time of examination. Rajagopal et al. (2010) studied the relationship between the diversity of zooplankton and physiochemical parameters in three perennial ponds in the Virudhungar district of Tamil Nadu. They described the positive association with physiochemical parameters like hardness, phosphate, alkalinity, temperature, and BOD. A negative relationship was noticed between salinity and rainfall. In addition, they disclosed the occurrence of some species like *Diaptomus*, *Diaphanosoma spp.*, *Monostyla spp*., *Keratella spp*., *Leppadella spp.*, *Mesocyclops spp.*, *Cypris spp.*, and *Branchionus spp*., as biological indicators of eutrophication.

Sharma et al. (2011) studied the zooplankton diversity of Loktak Lake in Manipur and described Rotifers as the superior group to Cladocera, Copepoda, and Rhizopoda. Their experiment disclosed the inverse relationship between zooplankton abundance, water hardness, and chloride. An inverse relationship was seen between the richness of zooplankton and nitrates.

At the time of assessment of the zooplankton population, in correlation to physicochemical parameters in Lal Diggi Pond in Aligarh, Ahmad et al. (2012) described the number and density of *Brachionus spp*., specified for eutrophication in the pond and the resistance of that genus to pollution.

Koli and Mulay (2012) studied the relationship between seasonal variation of zooplankton diversity and physicochemical parameters in the Tulshi reservoir and reported 39 species of zooplankton. Of these 39 species, 12 were copepods, 15 were rotifers, 10 were cladocera, and 2 were ostracoda. Their data disclosed the positive relationship of zooplankton with temperature, alkalinity, phosphate, hardness, and BOD, while a negative relationship was seen with rainfall and salinity. In a study conducted by Shivashankar et al. (2013) on zooplankton species abundance and diversity in Bhadra reservoir, Chikkamagalur district, Karnataka, 23 species of zooplankton were reported, out of which 8 species of Rotifera were found to be dominant, followed by Cladocera (5), Protozoa (5), Copepoda (3), and Ostracoda (2).

According to Pradhanet et al. (2014), an analytical study of zooplankton diversity in a freshwater lake in Wunna, there were three genera of zooplankton, such as *Copepods*, *Cladocerans*, and *Rotifiers*. As per their data, which disclosed that rotifers were superior in the zooplankton population, they were always higher in the winter season.

Dede et al. (2015) studied the zooplankton composition and seasonal variations in the Bhīma River (Maharashtra), and they reported a total number of 21 species of zooplankton, out of which 9 species were Rotifera, 5 species were copepoda, 5 species were cladocera, and 2 species were ostracoda.

Sunder Singh (2015) evaluated the plankton plurality and density with the physiochemical parameters of an open pond in the town of Deeg (Bharatpur), Rajasthan. He took a sample and counted the plankton using the Sedgwick four-rafter counting cell method. He discovered the actual value of a physiochemical parameter and thirty-six plankton. This study encourages the development of sustainable aquaculture practices in man-made habitats and fisheries management policies in Deeg (Bharatpur) and the surrounding aquatic ecosystem. Shukla et al. (2016) studied the diversity and abundance of zooplankton in the Narmada River, and they revealed that the number of Protozoa species was superior to the zooplankton abundance, followed by Copepoda, Rotifera, Cladocera, and Ostracoda. The Shannon-Weiner index (H = -0.839586) also represented higher changes in form.

Sharma et al. (2016) observed the effect of physiochemical parameters on the distribution of plankton in the Gharwal Himalayas headstream. Their study was to assess the relationship between physiochemical parameters and phytoplankton density in the Baldi stream of the Gharwal Himalayas. This study discovered that an increase in the number of physiochemical parameters hurts plankton density during the monsoon season at sampling site S2. Pearson's correlation coefficient was applied to the relationship between physiochemical parameters and plankton density, and the results showed that there was a significant increase in sedimentation in the lake.

Shaikh N. (2017) aimed at and considered the study of zooplankton diversity in the

river Kali on the west coast of India and announced 42 species of zooplankton. In these species, copepods were more dominant than other groups of zooplankton.

Hardikar R. et al. (2017) researched the seasonality of the distribution of phytoplankton and its association with physicochemical parameters in the coastal waters of Malvan, India's west coast. This study looked at phytoplankton groups and diversity in relation to physicochemical parameters in both protected and unprotected areas of the Malvan coast. Canonical correspondence analysis (CCA) demonstrated that water temperature and TSS were the parameters with the greatest impact on determining the distribution and seasonal shift in the species of phytoplankton such as *Skeletonema costatum* and *Chaetoceros spp*.

S.K. Baliarsingh et al. (2018) studied the distribution of zooplankton in coastal water of Gopalpur in the northwestern Bay of Bengal and they reported that the seasonality created a variation in the distribution of zooplankton in two local water types in Gopalpur (Type I and II); type-I had a higher number of zooplankton than type-II, even though the pattern of variation followed a similar seasonal trend in both of them. As per the zooplankton community, there were around 217 species of holoplankton and 22 species of meroplankton. The copepods were the more dominant group in holoplankton. They revealed that the richness was higher in type-I than type-II at the time of the salinity period, and the presence of phytoplankton prey also influenced the distribution and species composition of zooplankton.

Manigandan Vajravelu et al. (2018) assessed the seasonal impact of physiochemical parameters on phytoplankton. According to their findings, there are more plankton present in the pre-monsoon period than during the monsoon. The number of Coscindiscophyceae and Bacillariophyceae is extremely abundant. The CCA results showed that temperature, salinity, silicate, dissolved oxygen, and inorganic phosphate all have a significant impact on phytoplankton abundance.

Majagi S. et al. (2019) studied the correlation between the seasonal variation of various physiochemical parameters and diversity indices of zooplankton in the Chikklindalli dam of Karnataka at the time of their study period. They observed 27 species of zooplankton, out of which 12 belong to the rotifer, which was the most dominant group, followed by the cladocern, copepod, and ostracoda.

Gogoi P. et al. (2019) investigated the seasonal impact of physiochemical parameters on phytoplankton and integration patterns in Khilash Khul, Sunderbans, India. They discovered thirty-six phytoplankton genera and a high number of species abundance in the pre-monsoon, followed by the monsoon and monsoon.

Sarkar R. (2020), conducted a comparative study on the physiochemical status and diversity of zooplankton in Chandan Nagar, West Bengal, India. They noticed and found a lot of variation in physiochemical status in Pond-A and Pond-B. This variation was based on temperature, pH, alkalinity, BOD, TDS, TSS, total hardness, and chloride. These values were higher in Pond-B than in Pond-A. The zooplankton community reveals the maximum number of rotifers observed in Pond-B, which indicates that Pond-B gets highly affected by pollution and enters into eutrophication.

Santos LA. Dos et al. (2022) studied the diversity of zooplankton in Acre State, Amazon, Brazil. They revealed that there were around 170 species of rotifers, followed by 18 species of cladocerans and 4 species of copepods. The result showed that there is a further requirement for research relating to the biodiversity of this group of organisms at present in the basin of the Purus and Jurua rivers, for the most part in the lotic ecosystem and littoral zone.

Sheikh Tajamul Islam et al. (2021) studied immunochemistry and plankton diversity in high-altitude lakes in Kashmir and provided comprehensive information on plankton water quality and physiochemical parameters of these high-altitude lakes. According to bathymetric and morphometric analysis, Gangbal is the deepest and largest lake among other lakes. The water quality index of these high-altitude lakes is in the excellent category. According to statistical analysis, there is variability due to nitrate, nitrogen, nitrite, ammoniacal nitrogen, and total phosphorus. There are 61 taxa revealed, with Bacillariophyceae dominating, indicating the oligotrophic nature of the lakes.

Asulabha, K. S. et al. (2022) assessed the phytoplankton diversity in Bangalore lakes and determined the physiochemical parameter values. In these lakes, they discovered and identified 58 genera of phytoplankton. The *Chlorophyta, Bacillariophyta, Cyanophyta,* and *Euglenozoan* are the five main categories. According to the authors, a decrease in the water quality of the lakes with increased water pollution is linked to a loss in phytoplankton diversity in the monitored lakes of Bangalore. They employed the biomonitoring program of lakes and phytoplankton as an indication.

Meghna Panday et al. (2023) studied comparative analyses of zooplankton and physiochemical parameters of various freshwater sites at Surendra Nagar in Gujarat. They selected three sites in their research: site 1 (Falku dam), site 2 (Dholi Dhaga dam), and site 3 (Nayaka dam). They revealed that around 29 species belong to Site 2, followed by Site 3, and very few species were found in Site 1. They evaluated the water quality of these three sites on the basis of dissolved oxygen (D.O.), biological oxygen demand (B.O.D.), total suspended solids (T.S.S.), total solids (T.S.), and total dissolved solids (T.D.S.). These parameters disclosed how much these three sites get polluted and give us a red signal for the conservation and management of these important sites, and they also contributed toward a better understanding of zooplankton diversity and freshwater ecosystems.

## RESULT AND DISCUSSION

When compared to other high-altitude lakes in the Himalayas, such as those in Srinagar, Leh (Ladakh), we discover that these lakes' great variability in temperature and dissolved oxygen stay constant since the water at high altitude is always lotic in character (Hynes 1979; Bhat 2003). Due to the flowing nature of the water in Sapi and Shashi lakes, dissolved oxygen levels are not variable, but in Pangong Tso, where there is a landlock, they are low (F.A. Bhat et al., 2011). When we get to high altitudes, a lake's conductivity declines, which is inversely related (Zutshi et al. 1980)

but lakes in Kargil don't accept this; yet, because Pangong Lake is landlocked and experiences high summer evaporation, its conductivity is actually rising extremely quickly.

The water in Sapi and Shashi is produced by snow melting, both of which produce water with low conductivity. As the water accumulates in the lakes, which are not landlocked like Pangong Lakes, the conductivity of the lakes' water decreases. The water in the trans-Himalayan lakes is brought in by low-ionic-content rain and snow, which then collect in the lakes (Mianping, 1997). The total hardness and TDS values vary between the Srinagar and Ladakh lakes. In Ladakh, the lakes contain a high amount of magnesium, but in Srinagar, the lakes contain a higher amount of calcium than magnesium. This is due to the soil, which contains a predominance of lime rock (F.A. Bhat et al., 2011). Between the lakes in Ladakh and Srinagar, the total hardness and TDS values also differ.

According to F.A. Bhat et al. (2009) and Sheikh Tajamul Islam et al. (2021), the pH of high-altitude lakes is typically neutral to alkaline, with a pH value between 7.3 and 8.1. While the order of cation equivalence in Jammu and Kashmir was $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$, it was $Mg^{2+} > Na^{+} > K^{+} > Ca^{2+}$ in the lakes of Leh, Ladakh (F.A. Bhat et al., 2011). The anions, however, were $HCO_3^{2-} > Cl^{-} > SO_4^{2-}$, and they followed the equivalent concentration. In Pangong Lake, the chloride ion is higher because it is landlocked, and in the Indian Mountains, lakes and glaciers have higher calcium, magnesium, and bicarbonate due to the higher carbonate weathering phenomenon in these areas (Das and Kaur, 2011; Anshumali and Ramanathan, 2007; Singh et al., 2016). Due to their proximity to India's Himalayan Mountain Range, the same thing occurs in the Sapi and Shashi lakes. These studies help to understand the pH range in those two Kargil lakes. In contrast to $Na^{+}$ and $K^{+}$, which are the same in both lotic and lentic lake water, $Mg^{2+}$ and $Ca^{2+}$ revealed the opposite pattern, with more calcium and lower magnesium in lotic water and lower calcium and higher magnesium in lentic water. In the lakes of Sapi and Shashi in Kargil Ladakh, Zutshi et al. (1980) reported largely the same condition.

Pangong Lake has higher levels of nitrite, nitrogen, ammonium, and total phosphate. This is because of the characteristics of the catchment and because human activity has increased there than in other lakes (Zutshi et al., 1984). In the case of Pangong Lake, biological processes like algae photosynthesis and isothermal conditions cause the catchment characteristics to combine. A comparable event occurred in the high-altitude lakes of Jammu and Kashmir, which are rich in phosphate, ammonium, nitrite, and nitrogen (Tahamul Islam et al., 2021). While all of the lakes in the Himalayas have modest amounts of phosphorus, the majority of these high-altitude lakes are rich in nitrogen (Gurung et.al. 2020). In the high-altitude Pangong and Tso Morori lakes, the maximum surface temperature was around 19°C, and the bottom temperature in the same month was around 8°C. However, during the winter, the temperature starts to decrease until the lakes freeze in late December through to February. The same situation occurs in the monomictic group of lakes, i.e. Sapi and Shashi lakes (Hutichinson, 1937, 1967, Bhat 2009). Plankton species commonly found in Pangong Lake, Tso Moriri, and Wular Lake (F.Bhat 2009, Bhat F.A 2009, and Aaliya Ismat Baba 2014) can be listed in Table 1:

**Table 1**. Table showing the various plankton species in Pangong, Tso Moriri, and Wular lakes.

| **Names of Plankton Species.** | **Pangong lake** | **Tso Moriri lake** | **Wular lake** |
|---|---|---|---|
| **Phytoplankton Species** | **a. Bacillerphyceae** | **a. Bacillerphyceae** | **a. Bacillerphyceae** |
| Achnanthes ovalis | +++ | +++ | _ |
| Amphora sp. | +++ | +++ | +++ |
| Cymbella tumida | +++ | +++ | + |
| Diatoma elongatum | +++ | ++ | + |
| Diatoma hiemale | + | _ | ++ |
| Epithemia zebra | ++ | +++ | + |
| Eunotia spp. | + | + | + |
| Fragillaria sp. | +++ | + | + |
| Gomphonema germinatum | +++ | ++ | + |
| Liomophora anglica | + | + | _ |
| Meriodon spp. | + | + | _ |
| Navicula spp. | +++ | +++ | + |
| Navicula radiosa | + | +++ | +++ |
| Nitzschia sp. | + | _ | + |
| Stauroneis spp. | + | ++ | _ |
| Synedra spp. | + | _ | ++ |
| **Phytoplankton Species** | **b. Chlorophyceae** | **b. Chlorophyceae** | **b. Chlorophyceae** |
| Closteriopsis irregulare | + | + | _ |
| Desmidium aptogonum | ++ | ++ | _ |
| Hormidium subtile | ++ | ++ | _ |
| Schaeroplea annulina | ++ | ++ | _ |
| Tetraedron spp. | + | + | _ |
| Zygnema spp. | + | ++ | _ |
| **Phytoplankton Species** | **c. Pheophyceae** | **c. Pheophyceae** | **c. Pheophyceae** |
| Horea ramosissima | + | ++ | _ |
| Batrachospermum boryanum | ++ | ++ | _ |
| **Phytoplankton Species** | **d. Cyanophyceae** | **d. Cyanophyceae** | **d. Cyanophyceae** |
| Lyngbya spp. | + | ++ | _ |
| Spirulina major | + | + | + |
| **Phytoplankton Species** | **e. Xanthophyceae** | **e. Xanthophyceae** | **e. Xanthophyceae** |
| Arachnochloris minor | + | ++ | _ |
| Vacheria sps. | + | +++ | + |
| **Zooplankton species** | | | |
| Diaptomus spp, | +++ | +++ | _ |
| Nauplius larvae | ++ | +++ | ++ |
| Gastropus sps | + | ++ | _ |
| Cyclops Scutifer | + | +++ | + |

The + sign indicates presence and the – sign indicates absence of the species.

The most prevalent species in this high-altitude lake are *Bacillariophyceae*, followed by *Chlorophyceae*, *Cyanophyceae,* and *Xanthophyceae*. The genera that are present in both the high-altitude lakes of Leh, Ladakh and Srinagar are *Amphora* species, *Diatom* species, *Navicula* species, *Fragalaria* species, *Cymbella* species, *Cyclotella* species, and *Spirula* species. These are common species in the high altitudes of Leh, Ladakh, Srinagar, and Himachal Pradesh.

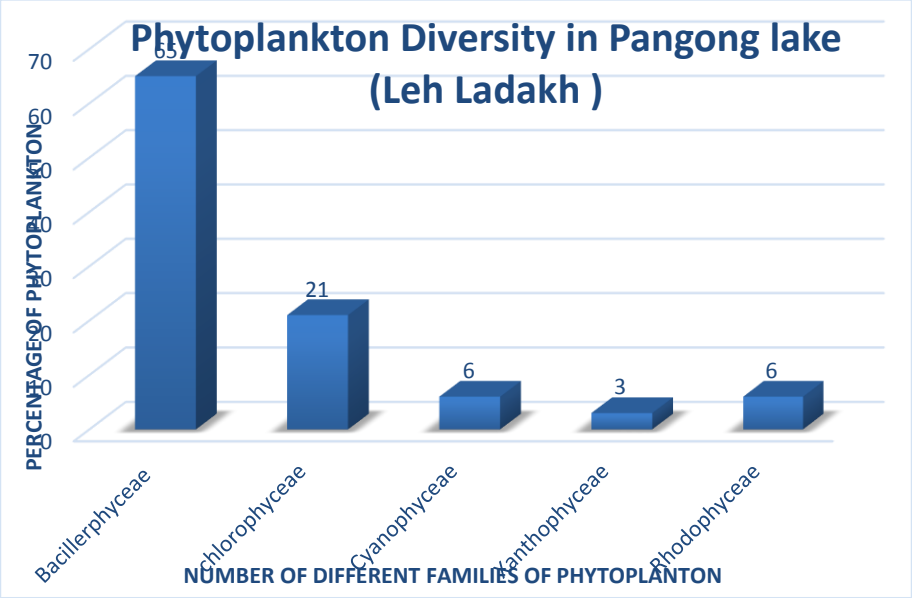


**Figure 1.** Graph showing the various families of phytoplankton in the Pangong Lake

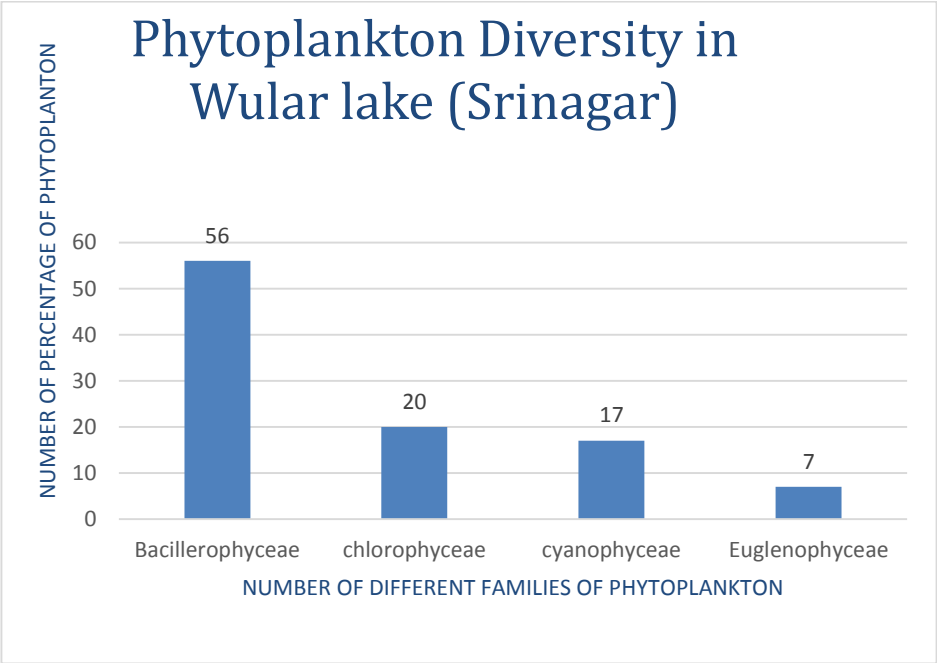


**Figure 2**. Graph showing the various families of phytoplankton in the Wular Lake

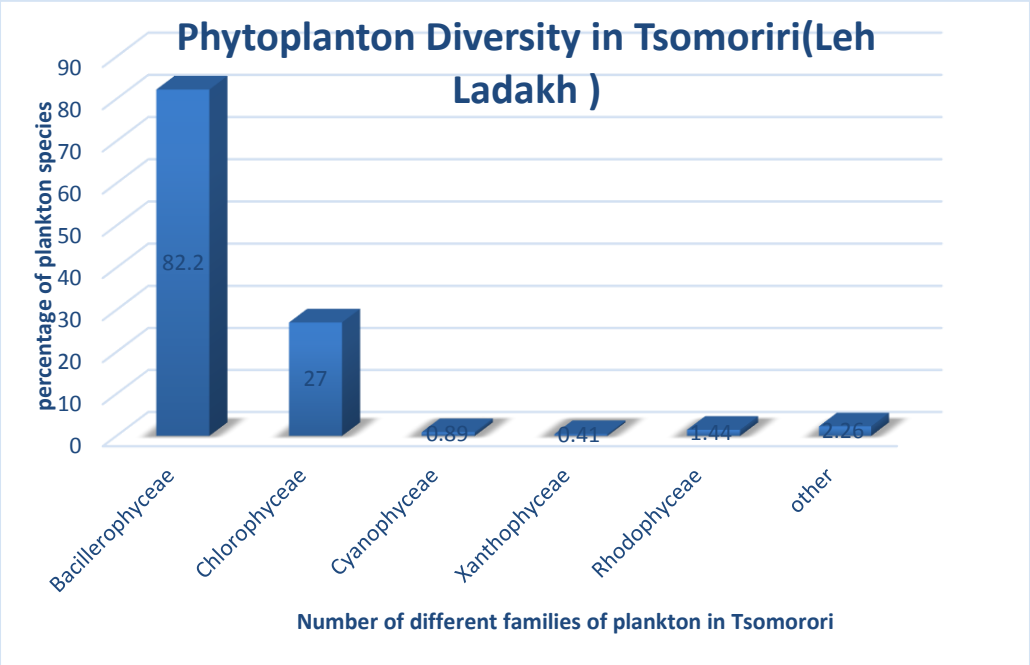


**Figure 3**. Graph showing the various families of phytoplankton in the Tso Moriri Lake

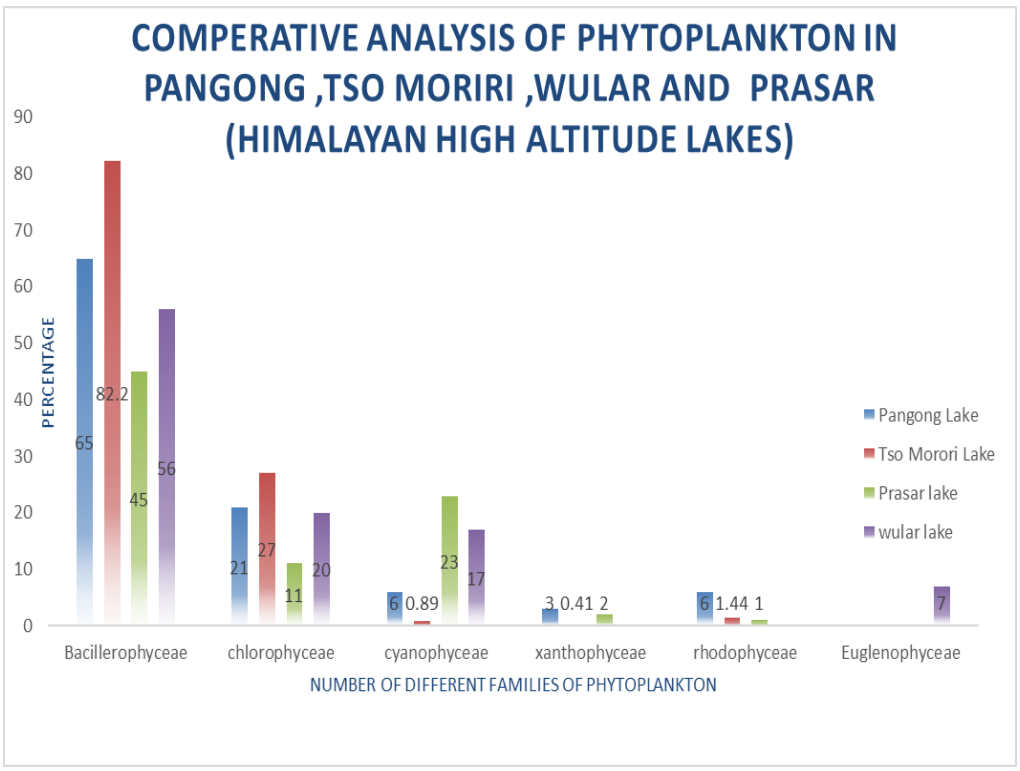


**Figure 4.** Graph showing the comparative analysis of phytoplankton in various tans-Himalayan lakes

### Zooplankton

The majority of zooplankton found in these lakes, such as diaptomous species and naplius larvae in Pangong Lake. However, in Tso Moriri, other zooplankton species, such as copepods like *Cyclop scutifer* and diaptomus species, as well as other Gastropus species, are the most prevalent contributors to the lake. Ilyocryptus species, macrothrix rosae, chydorus ovalis, and Diaphonosoma brachyurum are the most common Cladocera zooplankton species in this lake.

The Shashi and Sapi Lakes in Kargil may contain similar species due to their similar environment, climate, and topography. During this review we observed that mostly similar plankton species are present in both Pangong and Tso Moriri Lakes, and similar cases have also been reported in the lakes of Jammu and Kashmir and Himachal Pradesh. The most dominant phytoplankton in these Himalayan lakes is Bacillariophyceae, followed by Chlorophyceae and Cyanophyceae, whereas copepods and Cladocera constitute the most dominant zooplankton species.

## CONCLUSION

Many studies have been conducted on lakes in other geographical areas of other states, but in Ladakh, the plankton diversity of Sapi and Shashi lakes and their tributaries remains unknown, despite the fact that these two lakes are very important because many villages rely entirely on them. Planktons have not yet been documented in Kargil. The physiochemical parameters of these two lakes are still unknown, and no one knows the relationship between plankton and these lakes' physiochemical parameters. Many changes have occurred in these lakes as a result of climate change; the water level in these two lakes has decreased year after year, and their quality has deteriorated. We recommend the physiochemical analysis and the estimation of the plankton diversity in these lakes, so that we can have an idea of the extent of pollution and propose proper management protocols.

**Conflict of interest:** The authors declare no conflict of interest.

## REFERENCES

[1] Ahmad, U., Parveen, S., Mola, H. R. A., Kabir, H. A., & Ganai, A. H. 2012. Zooplankton population in relation to physico-chemical parameters of Lal Diggi pond in Aligarh, India. *J ENVIRON BIOL*, 33(6):1015.

[2] Aquino, Ma Riyel Y., et al. 2008. "Zooplankton composition and diversity in Paoay Lake, Luzon Is., Philippines." *Philippine Journal of Science*, 137(2): 169-177.

[3] Asulabha, K. S., Jaishanker, R., Sincy, V., & Ramachandra, T. V. 2022. Diversity of phytoplankton in lakes of Bangalore, Karnataka, India. *Biodiversity Challenges: a way forward*, 147-178.

[4] Baba AI, Pandit AK. 2014. Species Composition, Diversity and Population

Dyanamics of Phytoplankton at Saderkot in Wular Lake, Kashmir. *J Ecosys Ecograph* 4:142. https://doi:10.4172/2157-7625.1000142

[5] Bhat, F. A., Yousuf, A. R., Aftab, A., Arshid, J., Mahdi, M. D., & Balkhi, M. H. 2011. Ecology and biodiversity in Pangong Tso (lake) and its inlet stream in Ladakh, India. *INT J BIODVERS CONSERV*, 3(10): 501-511.

[6] Baliarsingh, S. K., Srichandan, S., Lotliker, A. A., Kumar, T. S., & Sahu, K. C. (2018). Zooplankton distribution in coastal water off Gopalpur, north-western Bay of Bengal. *Journal of Ocean University of China*, 17:879-889. https://doi.org/10.1007/s11802-018-3414-0

[7] Bhat, F. A. 2009. Limnological characterization of Lake Tso Moriri Ladakh. [Ph.D. Thesis]. University of Kashmir. Shodhganga: a reservoir of Indian theses @ INFLIBNET. http://hdl.handle.net/10603/93309

[8] Bozkurt, A., & Guven, S. E. 2009. Zooplankton composition and distribution in vegetated and unvegetated area of three reservoirs in Hatay, Turkey. *J ANIM VET ADV*, 8(5):984-994.

[9] Carrera, G., Fernández, P., Grimalt, J. O., Ventura, M., Camarero, L., Catalan, J., & Psenner, R. 2002. Atmospheric deposition of organochlorine compounds to remote high mountain lakes of Europe. *ENVIRON SCI TECHNOL*, 36(12):2581-2588. https://doi.org/10.1021/es0102585

[10] Chellappa, N. T., Câmara, F. R. A., & Rocha, O. 2009. Phytoplankton community: indicator of water quality in the Armando Ribeiro Gonçalves reservoir and Pataxó channel, Rio Grande do Norte, Brazil. *BRAZ J BIOL*, 69:241-251. https://doi.org/10.1590/S1519-69842009000200003

[11] Dede, A. N., & Deshmukh, A. L. 2015. Study on zooplankton composition and seasonal variation in Bhima River near Ramwadi village, Solapur District (Maharashtra), India. *INT J CURR MICROBIOL APP SCI*, 4(3): 297-306.

[12] El-Serafy, S. S., Mageed, A. A., & Hesham, R. 2009. Impact of flood on the distribution of zooplankton in Lake Nasser khors-Egypt. *J. Egypt. Acad. Environ. Dev*, 10:121-141.

[13] Fernandes, A. E. 2019. Comparative Studies on Diversity and Distribution of Mesozooplankton in Chapora and Sal Rivers of Goa. [Doctoral dissertation, Goa University]. http://hdl.handle.net/10603/312491

[14] Gharib, S. M., El-Sherif, Z. M., Abdel-Halim, A. M., & Radwan, A. A. 2011. Phytoplankton and environmental variables as a water quality indicator for the beaches at Matrouh, south-eastern Mediterranean Sea, Egypt: an assessment. *Oceanologia*, 53(3):819-836 https://doi.org/10.5697/oc.53-3.819

[15] Gogoi, P., Sinha, A., Das Sarkar, S., Chanu, T. N., Yadav, A. K., Koushlesh, S. K., ... & Das, B. K. 2019. Seasonal influence of physicochemical parameters on phytoplankton diversity and assemblage pattern in Kailash Khal, a tropical wetland, Sundarbans, India. *Appl Water Sci*, 9:1-13.

https://doi.org/10.1007/s13201-019-1034-5

[16] Hardikar, R., Haridevi, C. K., Chowdhury, M., Shinde, N., Ram, A., Rokade, M. A., & Rakesh, P. S. 2017. Seasonal distribution of phytoplankton and its association with physico-chemical parameters in coastal waters of Malvan, west coast of India. *ENVIRON MONIT ASSESS* 189:1-16. https://doi.org/10.1007/s10661-017-5835-4

[17] Islam, S. T., Dar, S. A., Sofi, M. S., Bhat, S. U., Sabha, I., Hamid, A., ... & Bhat, A. A. 2021. Limnochemistry and Plankton diversity in some high-altitude lakes of Kashmir Himalaya. *Front Environ Sci,* 9:681965. https://doi:10.3389/fenvs.2021.681965

[18] Jindal, R., Thakur, R. K., Singh, U. B., & Ahluwalia, A. S. 2014. Phytoplankton dynamics and water quality of Prashar Lake, Himachal Pradesh, India. *SUST WAT QUAL and ECOL*, 3:101-113. https://doi.org/10.1016/j.swaqe.2014.12.003

[19] Majagi, S., Naik, J., & Chitra, J. 2019. Seasonal Investigation on the Zooplankton Diversity and Distribution in Relation to Water Quality at Chikklingdalli Dam, Karnataka. *Int J Res Anal Rev*, 1, 754-767.

[20] Nusrat, J., & Bakhtiyar, Y. 2007. Effect of some abiotic factors on zooplankton productivity in a subtropical pond in Jammu, India. *Current World Envir*, 2(1), 27.

[21] Pandya M., Teraiya S., Vyas A. 2023. "Comparative analysis of zooplankton diversity and physico-chemical parameters of various freshwater reservoirs in Surendranagar, Gujarat, India". *INT J ENTOMOL & RES*, 8(2): 117-122.

[22] Qasim, A. 2020. Shashi Mountains-An unexplored Major Plant Biodiversity Hotspot of Trans-Himalayan Region of District Kargil (Ladakh). *IJSR*, 9(12):736-740. https://DOI:10.21275/SR201211002400

[23] Rajagopal, T., Thangamani, A., Sevarkodiyone, S. P., Sekar, M., & Archunan, G. 2010. Zooplankton diversity and physico-chemical conditions in three perennial ponds of Virudhunagar district, Tamilnadu. *J ENVIRON BIOL*, 31(3), 265-272.

[24] Santos LA dos, Silva ACS da, Pereira PP, Araujo RMG, Ghidini AR. 2022. Zooplankton diversity in Acre state, Amazon, Brazil: an overview of previous studies. Biota Neotrop [Internet]. (Biota Neotrop. 2022 22(1)): e20201132. Available from: https://doi.org/10.1590/1676-0611-BN-2020-113

[25] Sarkar, R., Ghosh, A. R., & Mondal, N. K. 2020. Comparative study on physicochemical status and diversity of macrophytes and zooplanktons of two urban ponds of Chandannagar, WB, India. *Appl Water Sci*, 10, 1-8. https://doi.org/10.1007/s13201-020-1146-y

[26] Sharma, B. K., & Sharma, S. 2011. Zooplankton diversity of Loktak Lake, Manipur, India. *JoTT*, 3(5), 1745-1755.

https://doi.org/10.11609/JoTT.o2457.1745-55

[27] Sharma, R. C., Singh, N., & Chauhan, A. 2016. The influence of physico-chemical parameters on phytoplankton distribution in a head water stream of Garhwal Himalayas: a case study. *THE EGYPT J AQUA RES*, 42(1):11-21. https://doi.org/10.1016/j.ejar.2015.11.004

[28] Shukla, A., & Solanki, R. 2016. Diversity and abundance of zooplankton in river Narmada at Jabalpur region (MP). *INT J INFO RES & REV*, 3(3):2060-2064.

[29] Shaikh, N. 2017. Zooplankton diversity in river Kali, Karwar, West coast of India.

[30] Singh, S. 2015. Analysis of plankton diversity and density with physico-chemical parameters of open pond in town Deeg (Bhratpur) Rajasthan, India. *INT RES J BIOL SCI*, 4(11): 61-69.

[31] Thorp, J. H., & Mantovani, S. 2005. Zooplankton of turbid and hydrologically dynamic prairie rivers. *FRESHWATER BIOL*, 50(9):1474-1491. https://doi.org/10.1111/j.1365-2427.2005.01422.x

[32] Vajravelu, M., Martin, Y., Ayyappan, S., & Mayakrishnan, M. 2018. Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. *Oceanologia*, 60(2):114-127. https://doi.org/10.1016/j.oceano.2017.08.003