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Review on Physico-chemical factors-based Zooplankton diversity of fresh water ecosystems in West Bengal, India

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ABSTRACT

Zooplanktons are microscopic organisms that play a crucial role in the aquatic food web and greatly increase the productivity of freshwater environments. The fundamental food supply for fish and other aquatic animals in any aquatic habitat is plankton. They have transitioned to converting detritus matter into consumable animal food and are operating at the second trophic level in the energy cycle. In this work, we attempted to evaluate the evenness, diversity, and richness of zooplankton species and to forecast the fresh water aquatic ecosystem of entire West Bengal condition based on physico-chemical factors. Due to their acute sensitivity to environmental changes and quick response to water quality changes, zooplanktons are excellent indicators of changes in water quality. Between phytoplankton and fish, zooplanktons act as a mediator. Therefore, zooplankton research, both qualitative and quantitative, is very important. In this review, we offer quantitative data on the seasonal fluctuations of zooplankton and a few physico-chemical variables from different fresh water ecosystems located in several regions of West Bengal. Present review study focused on the physico-chemical parameters like water temperature, pH, dissolved oxygen and also eutrophication level of fresh water ecosystem of West Bengal. A total of 58 species of zooplanktons have been identified, including 16 species of Rotifer, 4 species of Copepod, 16 species of Cladocera, 16 species of Protozoa, and 6 species of Ostracoda. Zooplankton population showed positive significant co-relation with physico-chemical parameters like water temperature and dissolve oxygen level, whereas negatively correlated with pH and eutrophication level. Seasonal variations in zooplanktons were also observed. The physico-chemical parameters of fresh water ecosystem of West Bengal were suitable for the growth of aquatic biota and represent a resource for scientific management of aquaculture practices and composite fish culture by taking some precautions and also maintain the healthy biodiversity in aquatic ecosystems in West Bengal.

Key words: *Zooplankton, Eutrophication, West Bengal, Water temperature, pH, Dissolved oxygen, Physico-chemical parameters, Seasonal, Aquatic biota, Aquaculture, Rotifer, Copepod, Cladocera, Protozoa, Ostracoda*

Introduction

Aquatic environments, mainly rivers, are among the most threatened natural ecosystems worldwide, due to the damming of their courses (Poff *et al*., 1997; Nilsson *et al.*, 2005; Dudgeon *et al.*, 2006), including the construction of reservoirs. Reservoirs break up the hydric landscape by forming artificial lakes con-

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nected by rivers. In this way, a lotic ecosystem transforms into a lentic system, which changes its ecological processes (i.e. organic matter production and nutrient cycling) (Ackermann *et al.,* 1973) and modifies the structure of communities and ecosystem functioning (Ward and Stanford, 1995). Therefore, reservoirs are considered to be transitional environments between those of rivers and lakes, and show complex dynamics, which combine natural variation and system management, due to water control, energy production, water for navigation, irrigation and other (Kennedy *et al.,* 2003). Natural lakes differ from reservoirs in many respects, such as their slow formation by natural geo-morphological processes or rapid creation as a result of catastrophic events (Loffler, 2004), processes of stratification, water mass circulation and hydrodynamics controlled by natural rhythms (Williamson *et al.,* 2009), and biodiversity, which is historically selected and adapted to natural lake dynamics (Wellborn *et al.,* 1996; Albrecht and Wilke, 2008). These natural dynamics throughout ecological time have made these environments sources of ecosystem services (water, biodiversity, productivity) and therefore, essential for the social, economic and environmental structure of human populations (Beeton, 2002; Junk, 2003). Freshwater ecosystems harbor a vast diversity of micro-eukaryotes (rotifers, crustaceans and protists), and such diverse taxonomic groups play important roles in ecosystem functioning and services (Xiong *et al.,* 2020). Fresh water aquatic system is relatively a shallow body of standing water; an aquatic ecosystem which is generally rich in biodiversity (Battish *et al.,* 1992). Fresh water is a precious resource of planktons in West Bengal (Roy *et al.,* 2016). Fresh water ecosystem in West Bengal includes lakes, rivers, ponds, wetlands, streams, and springs (Dabhade and Chhaba, 2019). Planktons are the plants and animals that drift around on the water currents. They are abundant in the surface waters where sunlight and nutrients are readily available. Zooplankton (Greek: Zoon, animal; planktos, wandering) are myriads of diverse floating and drifting animals with limited power of locomotion (Gupta and Dey, 2019). Zooplankton community is cosmopolitan in nature and they inhabit all freshwater habitats of the world. These species are not only useful as bio indicators, but are also helpful for ameliorating polluted waters (Ghosh and Biswas, 2015). Zooplanktons play an important role in the study of faunal bio-diversity of fresh water ecosystems. They include representatives of almost every taxon of the animal kingdom and occur in the pelagic environment either as adults (holoplankton) or eggs and larvae (meroplankton). By sheer abundance of both types and their presence at varying depths, the zooplanktons are utilized to assess energy transfer at secondary tropic level (Scheffer *et al*., 2001). The zooplankton occurrence and distribution influence pelagic fishery potentials. The fishes mostly breed in areas where the planktonic organisms are plenty so that their young ones could get sufficient food for survival and growth (Ostroumov, 2005). Zooplankton forms an important link in aquatic food chain. Various researches carried out work to study the zooplanktons of different fresh water bodies (Jayabhaye, 2010). Zooplanktons have been recommended as regional bioindicators of physical and chemical properties of fresh water ecosystem (Yoshida *et al.,* 2001a, b; Sinha and Sharma, 2003; Alisha and Pai, 2018). Influence of eutrophication on zooplankton community was studied by Spoljar *et al.,* 2009 and Jayabhaye, (2010) on zooplankton diversity of in a fresh water ecosystem. Vanjare *et al.* (2010) reported that zooplankton occurrence coincided with the level of dissolved oxygen (DO), temparature and pH of water. Zooplanktons are the major trophic link in food chain and being heterotrophic organisms they play a key role in cycling of organic materials in aquatic ecosystem (da Silva, 2011). In addition, their diversity has assumed added importance during recent years due to the ability of certain species to indicate the deterioration in the quality of water caused by pollution or eutrophication (Yoshida *et al.,* 2001a, b). Monitoring the zooplankton as biological indicators could act as forewarning, when pollution affects food chain (Baruah *et al.,* 1993). The species composition, distribution and abundance of zooplankton in any water body depends upon the chemical and physical properties of water (Alfred and Thapa, 1996). The trophic status of fresh water ecosystem depends on zooplankton grazing capacity (Salaskar and Yeragi, 2003; Surya *et al*., 2018). Eutrophication is an exaggerated process that can occur in freshwater aquatic ecosystems characterized by the enrichment of nutrients, specially nitrogen and phosphorus, leading to increased productivity of the system (Gazonato Neto *et al.,* 2014). This process causes changes in communities that may threaten the conservation of aquatic species and, because it is generally associated with some type of pollution, also poses risks to all living beings that directly or indirectly make use of the contaminated water or consume the organisms (Alisha and Pai, 2018). Such an alteration in the trophic state of a water body usually causes profound changes in the structure of plankton communities which is the reason why the interpretation of biological events in these populations and qualitative and quantitative analysis of their structures allows the degree of deterioration of the water body as a whole to be assessed (Matsumura-Tundisi and Tundisi, 2005). Characteristically, the zooplankton community is composed of highly sensitive organisms that respond to a large number of environmental changes in relatively short periods of time (Sampaio *et al.,* 2002). Moreover, because this community is more developed in lentic aquatic systems, studies of its structure and population dynamics can serve as tools in the analysis of the environmental disturbances to which these water bodies are subjected (Eskinazi-Sant'Anna *et al.,* 2013). Planktons are considered as indicator of the trophic status of a water body because of their specific qualitative features and their capacity to reproduce in large number under environmental conditions that are favourable to them (Khaire, 2020). Similarly changes in the water quality as well as zooplankton quality are indicators of rate and magnitude of cultural eutrophication and other physico-chemical properties of freshwater ecosystems (Chari and Abbasi, 2003). Freshwater ecosystems are highly diversified and having wide range of physicochemical conditions, which greatly influence the aquatic life (Abbasi and Abbasi, 2011). The quality of water is described by its physical, chemical and microbial characteristics (Chari and Abbasi, 2005). The Zooplankton is an important group of micro-organisms which indicates the trophic status of water body (Bhat *et al.,* 2015). West Bengal is one of the most important states of India from the point of view of zooplankton (Sinha and Islam, 2003).

There is no information available on zooplankton periodicity in relation to physico-chemical factors in the fresh water aquatic ecosystem of West Bengal, and no systematic work has been done on zooplankton population dynamics in freshwater ecosystem in West Bengal. Therefore, this review focused on the study of species diversity of zooplankton fauna and its relation to physico-chemical characteristics of freshwater ecosystem in West Bengal.

The objectives of this study are i) to study the species diversity of zooplankton fauna in fresh water ecosystem (Pond, River, Lakes etc.) W.B., India, ii) to find out the relationship between physico-chemical characteristics and zooplankton fauna in fresh water ecosystem iii) to understand the impact of eutrophication on zooplankton community in fresh water ecosystems.

Fresh water ecosystems Profile of West Bengal

Owing to differences in geographical, physical and topographical features, different districts of north and South Bengal are characterized by a variety of wetlands, both lotic and lentic (Chakraborty and Mallick, 2020). The important rivers flowing along the West Bengal are Adi Ganga, Ajay River, Anjana River, Atrai River, Bakreshwar River, Balason River, Baleshwar River, Bansloi River, Barakar River, Bhagirathi River, Banka River, Behula River, Bhairab River, Bidyadhari River, Brahmani River (Birbhum), Bhramaputhra River, Kanchan River, Maharaja Hat, Choita river, Churni River, Damodar River, Dharla River, Dud Kumar River, Dwarakeswar River, Dwarka River, Gandheswari River, Ganga River, Ghargharia River, Ghiya River, Gosaba River, Haldi River, Hariabhanga River, Hinglo River, Hooghly River, Ichamati River, Jalangi River, Jaldhaka River, Jamuna River, Kalindi River, Kangsabati River, Kaljani River, Kapaleswari River, Karatoya River, Keleghai River, Ketha River, Khari River, Khong Khola, Kopai River, Kosai River, Kulik River-Raigang, Kunur River, Kunti River, Mahananda River, Matla River, Mathabhanga River, Mayurakshi River, Mechi River, Mundeswari River, Muri Ganga River, Piyali River, Punarbhaba River, Raidâk River, Raimangal River, Rangeet River, Rasulpur River, Rupnarayan River, Sali River (West Bengal), Sankosh River, Saptamukhi River, Saraswati River (Bengal), Shil Torsa River, Shilabati River, Singimari River, Subarnarekha River, Talma River, Tangon River, Teesta River, Thakuran River, Torsha River (Bandyopadhyay *et al.,* 2014; Ghosh *et al.,* 2015). In addition, diverse forms of lentic freshwater water bodies in the form of dams, bandh, jheel, doba, pukur, dighi, beel, and baor are also spread throughout the area (Mukherjee *et al.*, 2009).

Physico-chemical factor

The structure of zooplankton communities is influenced by climatic and physico-chemical parameters as well as biological interactions. Some species are therefore found in a wide range of environmental conditions, while others are limited by many physico-chemical factors (Neves *et al.,* 2003). A complex set of related factors have been implicated for the seasonality in population dynamics and species succession (Behn and Boumans, 2001). These include physical and chemical variables, food and predation (Jeppesen *et al.,* 2005). Some of these parameters of water quality in relation to the incidence of zooplankton are discussed below separately (Abdel-Aziz *et al*., 2006).

a) Temperature: In an established freshwater aquatic ecosystem, the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to the aquatic organisms including zooplanktons and fishes. Temperature is an important factor that affects the chemical and biological reactions in water. Temperature regulates self-purification capacity of water (Shaikh *et al.*, 2003). A rise in water temperature accelerates chemical reactions which in turn reduces solubility of gases and also elevates metabolism of aquatic organisms, leading to decrease in dissolved oxygen and increase in free carbon dioxide. As pH is a measure of the hydrogen ion concentration, a change in the temperature of a solution will be reflected by a subsequent change in pH (Zumdahl, 1993). Khaire *et al.* (2011) also stated that temperature brings out changes in pH. Anderson (1961) has recorded higher pH during summer season and lower pH at winters showing direct relation between pH and temperature in fresh water sources.

b) pH: pH is most important in determining the corrosive nature of water with that it also acts as an indicator for eutrophication (Dhingra *et al.,* 2014). Lower the pH value higher is the corrosive nature of water pH was positively correlated with electrical conductance and total alkalinity (Gupta *et al*, 2009). The reduced rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonates which are ultimately responsible for increase in pH and eutrophic level, the low oxygen values coincided with high temperature during the summer month. Various factors bring about changes the pH of water (Locke, 1992). The higher pH values observed suggests that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physicochemical condition (Karanth, 1987). Fischer *et al.* (2001) emphasized that pH controls zooplankton community structure and food webs in acidified lakes. Out of different acidification variables tested by Walseng *et al.,* (2008), pH showed the strongest correlation with micro-zooplanktron composition.

c) Turbidity: Turbidity may be due to organic and/or inorganic constituents (Dejen *et al.,* 2004). Organic particulates may harbour microorganisms. The series of turbidity-induced changes that can occur in a water body may change the composition of an aquatic community Havens *et al*., (1993). First, turbidity due to a large volume of suspended sediment will reduce light penetration, thereby suppressing photosynthetic activity of phytoplankton, algae, and macrophytes, especially those farther from the surface. If turbidity is largely due to algae, light will not penetrate very far into the water and primary production will be limited to the uppermost layers of water (Roman *et al.,* 2001). The laboratory findings of Kirk and Gilbert, (1990) suggest that suspended clay (turbidity) reduces population growth rates of cladocera much more than it affects rotifers. It is also consistent with findings in various field studies around the world (e.g. Pace *et al.,* 1992; Thorp *et al.,* 1994). A decrease in cyclopoids was linked experimentally to increased densities of rotifers in the turbid St Lawrence River (Thorp and Casper, 2003). Hence, rotifers probably do better in turbid rivers not because this environmental condition favours them but rather because pernicious effects of competition and predation are partially alleviated by high suspended sediment loads.

d) Secchi disk transparency: Secchi disk transparency refers to the depth to which the black and white Secchi disk can be seen in the lake water. Water clarity, as determined by a Secchi disk, is affected by two primary factors: algae and suspended particulate matter (Nogueira, 2001). Transparency of water, expressed through the Secchi depth (distance) and water turbidity are two parameters that are closely related to each-other, and both are dependent on the concentration, type and size of particulates suspended in water. A 25-year record of weekly observations of Smayda (1998) with Secchi-disk depth, phytoplankton, and related parameters, including those affecting the light regime, available for fresh water sources indicates that Low water transparency (when Secchi depths are short) reflects the high level of eutrophication, over population of phytoplanktons and algal blooms. Shil *et al.* (2013) reported that transparency depends on zooplankton abundance and other organic particles. A short clear water phase may be attributable to the grazing pressure by large zooplanktons on edible phytoplankton (Lampert *et al.*, 1986). Water transparency is positively correlated with the presence of some bio-indicator species of in the oligotrophic or mesotrophic or eutrophic reservoir in the tropical zone (Landa *et al.,* 2007; Nogueira *et al*., 2008). Zooplankton abundance shows slightly negative relationship with transparency in semi-intensive culture (Islam *et al*., 2008; Shil *et al*., 2013).

e) Total dissolved solids: The total dissolved solids (TDS) in water consist of inorganic salts and dissolved materials. In natural waters, salts are chemical compounds comprised of anions such as carbonates, chlorides, sulphates, and nitrates (primarily in ground water), and cations such as potassium (K), magnesium (Mg), calcium (Ca), and sodium (Na) (Garg *et al*., 2006). Changes in the ionic composition of water can exclude some species while promoting population growth of others. Some calanoid copepods were dominant in the SO_4^{2-}/CO_3^{2-} dominated lake water (Rao *et al*., 2003). TDS analysis has great implications in the control of biological and physical waste water treatment processes (Medudhula, 2012). TDS value was estimated in different water bodies in seasons in relation to zooplankton study by many workers. The results of studies on lakes with different TDS values show that the number of species in the zooplankton decreases at TDS > 1 g/l. Thus, Rao (1990) noted the number of planktonic crustacean species in fresh water sources decreased from 37 to 7 when salinity increased from 1 to 14 g/l. Thus, among factors influencing the species composition of zooplankton, attention should be paid to total dissolved solids (TDS) of water (Rao *et al*., 2003).

f) Dissolved oxygen: Dissolved oxygen (DO) is one of the most important parameters for aquatic life. Its correlation with water body gives direct and indirect information like bacterial activity, photosynthesis, availability of nutrients, stratification etc.. In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Moss *et al*., 1972; Morrissette and Mavinic, 1978; Kataria *et al*., 1996). The high DO in summer is due to increase in temperature and duration of bright sunlight has influence on the percentage of soluble gases (O_2 and CO_2). During summer the long days and intense sunlight seem to accelerate photosynthesis by phytoplankton, utilizing CO_2 and giving off oxygen. This possibly accounts for the greater qualities of O_2 recorded during summer (Ahmed and Krishnamurthy, 1990). Low oxygen concentrations in the bottom water of the onshore environment i.e. on the shelf affect the distribution of several marine species (Rabalais *et al*. 2010; Shannon *et al*., 1999). Limited studies attempted to investigate the relationship between DO and zooplankton abundance (Lebourges-Dhaussy *et al.,* 2009). Therefore the study of possible correlations of DO with zooplankton diversity and abundance is very important since it puts the zooplankton in context of their environment (Postel *et al.,* 2007).

g) Electrical conductivity: Conductivity of natural water is measure of its ability to convey an electric current. Electrical conductivity is found to be good indicator of water quality (Abbassi *et al.,* 1996). Electrical conductivity used as an indicator of water quality based on total dissolved salts (Rasheed, 1994). According to Gaikwad *et al.* (2008) the dilution of solid substance in turn reduces the EC value alkalinity and zooplankton production. Bozkurt *et al.* (2008) reported the acceptable water conductivity value for aquatic organisms to be between 250 and 500 ìmhos/cm (maximum: 2000 ìmhos/cm). Electrical conductivity values showed positive correlation with zooplankton production. The conductivity variation can be an important regulator of the structure of zooplankton assemblages, especially for species diversity and richness (Williams, 1998).

h) Total hardness: The total hardness showed significant positive correlation with zooplankton production, as observed by Mathivanan *et al.* (2007) and Park and Shin (2007). Calcium is an essential structural component of crustacea carapaces (Korosi *et al.,* 2008) and is an integral part of total hardness. Consequently it has been shown to be important in influencing crustacean assemblages (Zeynep and Mustafa, 2015). Hardness was strongly positively correlated with calcium and magnesium, but shows a negative relationship with pH and zooplankton (Harsha and Malammanavar, 2004). Miah *et al.*, (1981) and Shil *et al.*, (2013) also reported that zooplankton abundance showed slightly positive relationship with total hardness in semi-intensive culture system.

As lower and higher water temperatures might produce a large difference in the primary productivity between temperate and tropical aquatic ecosystems and result observed by Chattopadhyay and Banerjee, (2008). pH is a critical factor which determines many biological factors and various chemical factors (Neves *et al.*, 2003). Aquatic organisms are affected by pH because most of their metabolic activities depend on pH (Wang *et al*., 2002).). Dissolved Oxygen is very crucial factor, it plays critical role in sustaining fauna.

Zooplankton diversity and distribution

A total of 27 zooplankton species were recorded from the different fresh water ecosystem of West Bengal comprising of 11 species of rotifers, 06 copepods, 09 cladocera and 1 ostracods (Chakraborty and Mallick, 2020). The community structure of zooplankton showed a mixed composition of mesotrophic to eutrophic species (Banerjee *et al.,* 2014). Spatial and temporal distribution of zooplankton showed definite seasonal trends associated with environmental fluctuations (Sarkar *et al.,* 1986). Qualitative and quantitative variations in the faunistic compositions were noticeable during different months (Patra *et al*., 2011). The most striking feature in the zooplankton abundance in the fresh water ecosystem of West Bengal was the contrast between the pre monsoon and late monsoon periods (Chari *et al*., 2013). The zooplankton of Indian freshwater bodies consists of varied forms belonging to different taxonomic groups. Their type, number and distribution provide a clue on the environmental conditions existing in that particular region (Hutchinson, 1967). Some of the important zooplanktons and their species are given below.

a) Rotifers

The rotifers are one of the basic groups of the zooplankton community which play a vital role in the fresh water ecosystem, being the food organisms they serve as living capsules of nutrition (Shayestehfar *et al*., 2008). Undoubtedly oxygen plays an important role in the survival index of the rotifera and its population count (Dabhade and Chhaba, 2019). Most remarkable rotifer zooplanktons include *Filinia longiseta, Keratella* spp. *Keratella cochlearis, Keratella quadrata, Keratella hiemalis, Keratella valga, Keratella Canadensis, Keratella tropica, Brachionus plicatilis, Brachionus calyciflorus, Brachionus falcatus, Monostyla closterocerca, Monostyla quadridentata, Mytilina* sp., *Platyias* sp., *Notholca* sp. (Table: 1) (Balai *et al.,* 2014; Abdel Mola and Parveen, 2014; Nusrat and Bakhtiyar, 2007; Chatterjee *et al*., 2013; Gannon and Stemberger, 1978; Rajagopal *et al*., 2010). These plankton fauna mostly abundant in pond, estuaries and river in Ajay River, Anjana River, Atrai River, Bakreshwar River, Bhagirathi River, Banka River, Behula River, Bidyadhari River, Churni River, Damodar River, Dwarakeswar River, Dwarka River, Gandheswari River, Ganga River, Ghargharia River, Ghiya River, Gosaba River, Haldi River, Hooghly River, Ichamati River, Jalangi River, Jaldhaka River, Jamuna River, Kalindi River, Kaljani River, Karatoya River, Keleghai River, Kopai River, Kosai River, Kulik River, Mahananda River, Matla River, Mathabhanga River, Mayurakshi River, Mundeswari River, Muri Ganga River, Piyali River, Raidâk River, Raimangal River, Rupnarayan River, Sankosh River), and lakes Chupi and Santragachi situated in Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, Jhargram, East and West Mednipur, Purulia and Bankura District during Pre-Monsoon, Monsoon and Post Monsoon (Table: 1) (Chakraborty *et al.,* 2023; Sharma *et al.,* 2010; Roy *et al*., 2010). It has found that water temperature varies from 10ºC to 26ºC (Table 1) (Gannon and Stemberger, (1978) and Rajagopal *et al*., 2010). The average pH values of the water of the study area vary from minimum 4 to maximum of 10 (Table 1) (Roy *et al*., 2010; Chatterjee *et al*., 2013) Rotifers can survive at level of dissolved oxygen varies between 2-10 (mg l^{-1}) (Table 1) (Nusrat and Bakhtiyar, 2007; Chatterjee *et al*., 2013). These biota seem to be present mostly in Eutrophic and Mesotrophic water sources, beside that these are also reported to be present in Hypereutrophic aquatic sources (Table 1) (Balai *et al*., 2014; Chakraborty *et al*., 2023).

Protozoa

Protozoans are highly helpful in determining the cleanliness of water as well as its quality, especially in pollution investigations (Kamble *et al*., 2013). Protozoa zooplanktons include *Astramoeba radiosa, Centropyxis aculeate, Centropyxis ecornis, Centropyxis hemisphaerica, Difflugia* spp. *Actinolophus* spp., *Trinema* spp, *Epistylis olicatilis, Metopus sigmoides, Stylonchia notophora, Vorticella compunula, Vorticella microstoma, Paramaecium sp., Arcella discoides, Amoeba proteus, Diffusia* sp. (Table 1) (Patra *et al.,* 2011; Mukhopadhyay *et al.,* 2007; Chattopadhyay *et al.,* 1999; Ismail and Adnan, 2016; Hwang and Heath, 1997; and Adhikari *et al.,* 2017). These biota abundant in different pond, river like Tista, Torsa, Damodar, Ajay, Jamuna River. Kalindi River, Mahananda River, Mathabhanga River, Rasulpur River Rupnarayan River, Gandheswari River, Bakreshwar River, Hooghly River, Brahmani River, Mayurakshi River and lakes Sagardighi, Motijheel, Chupi, Santragachi) of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana. Purulia and Bankura District during Pre-Monsoon, Monsoon and Post Monsoon (Table 1) (Patra *et al.*, 2011; Mukhopadhyay *et al.*, 2007; Chattopadhyay *et al.*, 1999). Physiochemical properties including water that can be tolerated by these biota include temperature can range between 8 to 36^0C with dissolve oxygen level between 4-10 (mg l^{-1}) and pH ranging between 4 to 10 (Table 1) (Chattopadhyay *et al*., 1999; Ismail and Adnan, 2016; Chakraborty *et al*., 2023; Rakshit *et al.*, 2014). Here zooplanktons are mostly abundant in Eutrophic and Mesotrophic fresh water aquatic regime, besides that they are also persist in Hypereutrophic aquatic source two (Table 1) (Patra *et al.*, 2011; Mukhopadhyay *et al*., 2007).

Cladocera

The Cladocera, sometimes referred to as "water fleas," are a common fish food source that prefers to thrive in deep waters (Balai *et al.*, 2014). The benthic community depends heavily on the cladocera components of zooplanktons (Sultana *et al.*, 2023). The cladocera were represented by *Alonella sp*, *Bosmina coregoni, Daphnia longiremis, Daphnia pulex, Daphnia sp., Ceridaphnia reticulate, Chydorus sp., Chydorus ovalis, Holopedium gibberum, Ceriodaphnia spp., Moina spp., Simocephalus spp., Bosmina longirostris, Macrothrix spp, Alona karua, Pluroxus trigonellus, Alona spp.* (Table 1) (Chatterjee *et al*., 2013; Balai *et al*., 2014; Sultana *et al*., 2023; Abdel Mola and Parveen, 2014; Chakraborty and Mallick, 2021, Sharma *et al*., 2015, Sharma and Sharma, 2010, Mondal *et al*., 2015). Daphnia was the most abundant individuals in fresh water among all cladocerans (Table 1) (Chakraborty and Mallick, 2021). The maximum count of zooplankton in pond, river like Ajay River, Anjana River, Atrai River, Bakreshwar River, Bhagirathi River, Banka River, Behula River, Bidyadhari River, Churni River, Damodar River, Dwarakeswar River, Dwarka River, Gandheswari River, Ganga River, Ghargharia River, Ghiya River, Gosaba River, Haldi River, Hooghly River, Ichamati River, Jalangi River, Jaldhaka River, Jamuna River, Kalindi River, Kaljani River, Karatoya River, Keleghai River, Kopai River, Kosai River, Kulik River, Mahananda River, Matla River, Mathabhanga River, Mayurakshi River, Mundeswari River, Muri Ganga River, Piyali River, Raidâk River, Raimangal River, Rupnarayan River, Sankosh River of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, Jhargram, East and West Mednipur, Purulia and Bankura District were found during Pre-Monsoon, Monsoon and Post Monsoon (Table 1) (Chatterjee *et al.*, 2013; Balai *et al.*, 2014; Sultana *et al.*, 2023; Abdel Mola and Parveen, 2014, Chakraborty and Mallick, 2021, Sharma *et al.*, 2015, Sharma and Sharma, 2010, Mondal *et al.*, 2015). High cladoceran population density was found in water temperature in between 6 to 34^0C. (Table 1) (Chatterjee *et al.*, 2013; Abdel Mola and Parveen, 2014). The physico-chemical properties including pH 4 to 10 and dissolve oxygen between 2-10 (mg l^{-1}) has been accounted suitable for abundance of cladoceran population (Table 1) (Sharma *et al.*, 2015, Sharma and Sharma, 2010). These biota are mostly found in Eutrophic, Mesotrophic aqatic fresh water, beside that their presence is also seen in Hypereutrophic fresh water (Table 1) (Balai *et al.*, 2014; Sultana *et al.*, 2023; Chakraborty and Mallick, 2021).

d) Ostracoda

Ostracods are the second most numerous taxonomic group among zooplankters, behind copepods. In zooplankton samples, they are frequently quantitatively lower, especially in freshwater environments. In the wind-mixed layer above the thermocline, they are also significant (Chattopadhyay and Panda, 2021), In the present investigation the Ostracoda population is represented by *Scapholeberis kingi, Cyprinotus spp., Stenocypris spp., Cypris spp., Cyclocypria spp., Entocythere spp.* (Balai *et al.*, 2014; Abdel Mola and Parveen, 2014; Chattopadhyay and Panda 2021; Halder *et al.*, 2008; Bhanja *et al.*, 2014; Jasmine and Saramma, 2009). Among these genera abundant was *Scapholeberis kingi* (Halder *et al.*, 2008). These biota is mostly abundant in Ponds and lakes of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah,

Table 1. Physiochemical properties and Zooplankton Diversity of West Bengal

Class of Zooplankton	Name of Zooplankton	Physiochemical abundance			Eutrophical abundance	Abundant area in West Bengal	Seasonal abundance	Reference
		Temperature	pH	Dissolved O_2				
PROTOZOA	*Astramoeba radiosa*	15-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic	Pond, river (Tista, Torsa, Damodar, Ajay, Jamuna River. Kalindi River, Mahananda RiverMathabhanga River, Rasulpur River Rupnarayan River, Gandheswari River, Bakreshwar River, Hooghly River, Brahmani River, Mayurakshi River) and lakes (Sagardighi, Motijheel, Chupi, Santragachi) of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana. Purulia and Bankura District	Pre-Monsoon, Monsoon and Post Monsoon	Patra *et al.*, (2011), Mukhopadhyay *et al.*, (2007), Chattopadhyay *et al.*, (1999), Ismail and Adnan, (2016), Gallup, (1970), Hwang and Heath, (1997) Adhikari *et al.*, (2017) Balai *et al.*, (2014) Chakraborty *et al.*, (2023) Rakshit *et al.*, (2014) Khan *et al.*, (2020) Abdel Mola & Parveen, (2014) Mozumder *et al.*, (2007)
	Centropyxis aculeate	13-25^{0}C	6-7	2-10 (mg L^{-1})	Oligotrophic, Eutrophic			
	Centropyxis ecornis	8-15^{0}C	6-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Centropyxis hemisphaerica	14-26^{0}C	5-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Difflugia spp.	12-34^{0}C	5-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Actinolophus spp.	15-26^{0}C	4-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Trinema spp	12-34^{0}C	4-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Epistylis olicatilis	10-25^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Metopus sigmoides	14-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Stylonchia notophora	12-35^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Vorticella compunula	14-36^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Vorticella microstoma	8-35^{0}C	4-10	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Paramaecium sp.	9-36^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Arcella discoides	7-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Amoeba proteus	6-25^{0}C	5-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Diffusia sp.	9-30^{0}C	5-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
ROTIFERA	*Filinia longiseta*	15-26^{0}C	4-10	2-10 (mg L^{-1})	Eutrophic, Mesotrophic	Pond, river (Ajay River, Anjana River, Atrai River, Bakreshwar River, Bhagirathi River, Banka River, Behula River, Bidyadhari River, Churni River, Damodar River, Dwarakeswar River, Dwarka River, Gandheswari River, Ganga River, Ghargharia River, Ghiya River, Gosaba River, Haldi River, Hooghly River, Ichamati River, Jalangi River, Jaldhaka River, Jamuna River, Kalindi River, Kaljani River, Karatoya River, Keleghai River, Kopai River, Kosai River, Kulik River, Mahananda River, Matla River, Mathabhanga River, Mayurakshi River, Mundeswari River, Muri Ganga River, Piyali River, Raidâk River, Raimangal River, Rupnarayan River, Sankosh River), and lakes (Chupi, Santragachi) of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur,	Pre-Monsoon, Monsoon and Post Monsoon	Balai *et al.*, (2014), Chakraborty *et al.*, (2023), Sharma *et al.*, (2010), Sultana *et al.*, (2023), Abdel Mola & Parveen, (2014), Roy *et al.*, (2010), Nusrat and Bakhtiyar, (2007)., Chatterjee *et al.*, (2013), Gannon and Stemberger, (1978), Rajagopal *et al.*, (2010)
	Keratella spp.	11-34^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Keratella cochlearis	14-26^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Keratella quadrata	11-34^{0}C	5-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Keratella hiemalis	10-25^{0}C	5-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Keratella valga	12-34^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Keratella canadensis	14-35^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Keratella tropica	15-36^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Brachionus plicatilis	8-35^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Brachionus calyciflorus	14-26^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Brachionus falcatus	11-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Monostyla closterocerca	10-25^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Monostyla quadridentata	12-34^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Mytilina sp.	11-34^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Platyias sp.	14-26^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Notholca sp.	10-25^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			

Table 1. *Continued ...*

Class of Zooplankton	Name of Zooplankton	Physiochemical abundance Temperature	pH	Dissolved O_2	Eutrophical abundance	Abundant area in West Bengal	Seasonal abundance	Reference
						South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, Jhargram,East and West Mednipur, Purulia and Bankura District		
CLADOCERA	*Alonella sp*	12-34^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic	Pond, river (Ajay River, Anjana River, Atrai River, Bakreshwar River, Bhagirathi River, Banka River, Behula River, Bidyadhari River, Churni River, Damodar River, Dwarakeswar River, Dwarka River, Gandheswari River, Ganga River, Ghargharia River, Ghiya River, Gosaba River, Haldi River, Hooghly River, Ichamati River, Jalangi River, Jaldhaka River, Jamuna River, Kalindi River, Kaljani River, Karatoya River, Keleghai River, Kopai River, Kosai River, Kulik River, Mahananda River, Matla River, Mathabhanga River, Mayurakshi River, Mundeswari River, Muri Ganga River, Piyali River, Raidâk River, Raimangal River, Rupnarayan River, Sankosh River) of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, Jhargram,East and West Mednipur, Purulia and Bankura District	Pre-Monsoon, Monsoon and Post Monsoon	Chatterjee *et al.*, (2013)Balai *et al.*, (2014)Sultana *et al.*, (2023)Abdel Mola & Parveen, (2014), Chakraborty & Mallick, (2021), Sharma *et al.*, (2015), Sharma & Sharma, (2010), Mondal *et al.*, (2015).
	Bosmina coregoni	14-35^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Daphnia longiremis	15-36^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Daphnia pulex	11-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Daphnia sp.	14-26^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Ceridaphnia reticulata	9-36^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Chydorus sp.	7-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Chydorus ovalis	6-25^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Holopedium gibberum	9-30^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Ceriodaphnia spp.	11-34^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Moina spp.	14-26^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Simocephalus spp.	7-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Bosmina longirostris	6-25^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Macrothrix spp	11-34^{0}C	4-10	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Alona karua	14-26^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Pluroxus trigonellus	10-25^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Alona spp.	12-34^{0}C	5-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
OSTRACODA	*Scapholeberis kingi*	14-35^{0}C	5-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic	Ponds and lakes of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, East Burdwan, West Burdwan, East Medinipur, Jhargram, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, East and West Mednipur, and Bankura District	Pre-Monsoon, Monsoon and Post Monsoon	Balai *et al.*, (2014), Abdel Mola & Parveen, (2014), Chattopadhyay and Panda (2021), Halder *et al.*, (2008), Mathew *et al.*, (1996), Bhanja *et al.*, (2014), Jasmine & Saramma, (2009).
	Cyprinotus spp.	15-36^{0}C	4-6.5	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Stenocypris spp.	11-34^{0}C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic, Hypereutrophic			
	Cypris spp.	14-26^{0}C	4-8	2-10 (mg L^{-1})	Oligotrophic, Eutrophic			
	Cyclocypria spp.	10-25^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Entocythere spp.	12-34^{0}C	4-9	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			

Table 1. *Continued...*

Class of Zooplankton	Name of Zooplankton	Physiochemical abundance			Eutrophical abundance	Abundant area in West Bengal	Seasonal abundance	Reference
		Temperature	pH	Dissolved O_2				
COPEPODA	*Diaptomus spp.*	14-35⁰C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic	Ponds and lakes of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, East and West Mednipur, and Bankura District	Pre-Monsoon, Monsoon and Post Monsoon	Balai *et al.*, (2014)Sultana *et al.*, (2023) Karthika *et al.*, (2021). Srichandan *et al.*, (2015), Shanthi & Ramanibai, (2011).
	Mesocyclops spp.	15-36⁰C	5-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Halicyclops spp.	10-25⁰C	5-7	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			
	Eucyclops spp.	15-36⁰C	4-8	2-10 (mg L^{-1})	Eutrophic, Mesotrophic			

Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, East and West Mednipur, and Bankura District during Pre-Monsoon, Monsoon and Post Monsoon (Table: 1) (Abdel Mola and Parveen, 2014, Chattopadhyay and Panda 2021, Halder *et al.*, 2008; Mathew *et al*., 1996). High abundance of Ostracoda plankton population is found in water temperature in between 11 to 36 ⁰C (Table 1) (Chattopadhyay and Panda 2021). The physico-chemical requirements for this plankton population include pH 4 to 9 and dissolve oxygen level in between 2-10 (mg l^{-1}) (Table 1) (Halder *et al*., 2008; Jasmine and Saramma, 2009; Balai *et al*., 2014; Chattopadhyay and Panda 2021). This plankton fauna is found mostly Eutrophic and Mesotrophic freshwater but seldom it is found in Hypereutrophic fresh water (Table 1) (Abdel Mola and Parveen, 2014).

Copepoda

Of all the zooplankton, 55–60% belonged to the dominating group of copepods (Karthika *et al.,* 2021). Most abundant taxa of this biota include *Diaptomus spp., Mesocyclops spp., Halicyclops spp., Eucyclops spp.* (Balai *et al.,* 2014; Sultana *et al*., 2023; Karthika *et al.*, 2021; Srichandan *et al*., 2015; Shanthi and Ramanibai, 2011). These copepods fauna is abundant mostly in fresh waters of Coochbihar, Jalpaiguri, Birbhum, North Dinajpur, South Dinajpur, Bankura, Birbhum, Maldah, Murshidabad, Nadia, North 24, Pargana, South 24 Pargana District, Hooghly Howrah, East and West Mednipur, and Bankura District during Pre-Monsoon, Monsoon and Post Monsoon season (Table 1) (Balai *et al.*, 2014; Sultana *et al*., 2023; Srichandan *et al*., 2015). Like other plankton fauna copepodans mostly exploited at water temperature in between 10 to 36 ⁰C (Table 1) (Sultana *et al*., 2023; Shanthi and Ramanibai, 2011). The physico-chemical requirements for this copepod population were recorded pH were recorded 4 to 8 and dissolve oxygen has recorded 2 to 10 mg l^{-1} (Table 1) (Balai *et al.*, 2014; Sultana *et al*., 2023). Eutrophic and Mesotrophic aquatic ecosystem has been found to be most favorable habitat for copepods (Table 1) (Srichandan *et al*., 2015).

Conclusion

Many different types of creatures rely on zooplankton, which is a crucial part of the biodiversity of freshwater ponds. This is true throughout the year. Freshwater zooplanktons play a crucial role in aquatic ecosystems by serving as both primary and secondary food chain linkages. Zooplanktons are tiny, non-motile aquatic creatures that serve a variety of purposes in the aquatic ecosystem, such as monitoring pollution, trophic dynamics, and amelioration. The systematic counting of plankton is very important to biology. The occurrence of zooplankton component throughout i) Brown forest zone ii) Terai zone iii) Tista – Mahananda alluvial zone iv) Vindhyan alluvial zone v) Gangetic alluvial zone vi) Deltaic and coastal zone vii) Red zone and viii) Lateritic zone all around West Bengal has been depicted in this review. One of the fundamental assemblages of the zooplankton community, rotifers are food creatures that function as living nutritional capsules and are essential to the freshwater ecology. The benthic community depends heavily on the cladocera parts of zooplanktons. The cladocera were represented by 16 genus and copepods were represented by 4 genus whereas protozoans and rotifers represented by 16 genera while Ostracoda represented by 6 genera. Water temperature and availability of favorable physico-chemical parameters affects the zooplankton population. This study examined the zooplankton community and water quality in the freshwater ecosystem of all of West Bengal. The primary goal of the investigation was to determine how the physico-chemical characteristics of freshwater affected the zooplankton community. Studies on the biodiversity of fresh water ecosystem ware made by different researchers in these species composition and population dynamics of zooplankton and productivity has been correlated with seasonal variations in physico-chemical characteristics of water. The variety of zooplanktons found in the freshwater sources over the whole West Bengal area is demonstrated by the current study. Throughout the course of the investigation, Rotifer documented all sixteen groups of zooplanktons, finding that the copepoda group had the fewest species-just four-while the most dominating group, represented by sixteen species, was observed.

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