Int.J.Curr.Res.Aca.Rev.2018; 6(10): 1-10

EXCELLENT PUBLISHERS

International Journal of Current Research and Academic Review

ISSN: 2347-3215 (Online) Volume 6 Number 10 (October-2018)

Journal homepage: http://www.ijcrar.com

doi: https://doi.org/10.20546/ijcrar.2018.610.001

Review on Nationwide Surveillance for Phytoplankton Ecology in India

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Abstract

In comparison to lentic systems, the species composition and community structure of phytoplankton in lotic habitats are still poorly understood This paper describes the results of yester years of water quality monitoring of India, with special emphasis on distribution, composition, and abundance of the phytoplankton community, relations of phytoplankton with factors like temperature, sunlight exposure period, sunlight penetration, water pH, wind, transparency, seasonal variations, water characteristics, nutrient enrichment. It's finally concluded that phytoplankton ecology is an indicator for the evaluation of impacts of influencing factors. These factors provide a suitable management plan for water management.

Article Info

Accepted: 04 September 2018
Available Online: 20 October 2018

Keywords

Lentic; Lotic; Phytoplankton

Introduction

The literature on different aspects of phytoplankton community is quiet voluminous which deals with the species composition, organization, stratification, metabolism, periodism, seasonal succession, distribution, production their role as bio indicators and their links in aquatic food chain, however most of these works pertain to lentic habitats and the lotic environs received less attention, however, In recent years, many researchers reported phytoplankton ecology of river ecosystem all over India. This review assess qualitatively for anthropogenic changes which resulted nutrient enrichment and provides a ground for future studies on management of water bodies with phytoplankton distribution. Allan (1995) pointed out that instability of physical chemical characteristics of running water makes rivers unique and challenging ecosystems for biological communities dwelling in various habitats. Plankton, particularly phytoplankton, long have been used as indicators of water quality (palmer, 1969). Some species florish in highly eutrophic waters while others are very sensitive to organic and/or chemical waste. Some species develop noxious blooms, sometimes creating offensive taste and odors (Prescott, 1968) or anoxic or toxic conditions resulting in animal deaths or human illness (Carmichael, 1981). The species assemblage of phytoplankton and zooplankton may be useful in assessing water quality (Gannon and Stemberger, 1978) Plankton is of utmost importance in the freshwater ecosystem as these are the main source of energy and having a very high nutritive value (Mishra and Joshi 2003)

Ecological factors affecting distribution of phytoplankton in lotic and lentic habitats

Distribution patterns of phytoplankton are strongly correlated with environmental factors (Lepisto *et al.*, 2004). Possible physical factors may be (climate, water,

temperature, light intensity), chemical factors include (nutrient concentration) (Reynold *et al.,* 1993; Torremorell *et al.,* 2009), hydrological factors include (river morphology, discharge, water residence time, precipitation) (Descy and Gosslain 1994; kiss *et al.,* 1994; Skidmore *et al.,* 1998) and biotic (grazing, competition, parasitism) (Moss and Balls, 1989; Ha *et al.,* 1998). Unfortunately, there is no general consensus as to which factors regulate phytoplankton communities in lotic habitats (Basu and Pick, 1995) besides, contribution of the main environmental factors to phytoplankton variations are also unclear. Datta and Banik, 1997) concluded that during monsoon, growth of periphyton (mainly constituted by the green and blue green algae and diatoms) was less, which was due to change in physico-chemical environment in the eco-system and also due to the effect of water flow, turbulence and increased depth of water. According to Hynes (1979) the fast water current sweeps up more individuals and during periods of rising water the phytoplankton numbers go up. Hynes (1970) stated that strength of current is the paramount factor for determining species composition. According to Prescott (1973), the oligotrophic waters were characterized by the Chlorophyceae flora with a conspicuous desmids elements, whereas, the eutrophic lakes were characterized by the dominance of class Cyanophyceae. Dickman (1975) while working on attached algae in Ottawa River indicates Bacillariophyceae the nutrient rich and polluted waters. Swanson and Bachmann (1976) opined that the river phytoplankton is simply the sloughed periphyton in transit. Vass *et al.,* (1977) opined that high dissolved oxygen during winter is the result of low biological activity. Kaul *et al.,* (1978) opined that higher transparency and temperature seems to be quite conductive for the dominance of algs. Kaul *et al.,* (1978) conducted studies on summer plankton population in some water bodies of jammu and Kashmir and found this water body in general are low in available phosphorus and rich in calcium. According to kaul *et al.,* (1978), the planktonic communities because of their short life cycles respond quickly to the environmental changes, especially fluctuations in nitrogen and phosphorus content. The rate of phytoplankton gradually increased in post-monsoon to the late spring. Phytoplankton community progresses a serial successions to culminate in a peak sequences with low turbidity and low wind velocity in the lakes (Chaudhary and Pillai, 2009; Sugunan, 2000). In some cases, during post-monsoon and summer, permanent bloom of phytoplankton in lakes of the southern tip of Indian peninsula appeared due to shallow depth, nutrients enrichment and adequate sunlight (Sugunan, 2000). Generally, in Indian Lakes, phytoplankton density peaks found in post monsoon and summer (Gopal and Zutshi 1998). Hydrological factors are thought to be of greater importance to phytoplanktonic development in rivers than in lakes (Pace *et al.,* 1992), whereas other researchers concluded that river phytoplankton is more strongly regulated by nutrient concentrations' such as total phosphorus concentration (Soballe and Kimmel, 1987; Moss and Balls, 1989: Basu and Pick, 1996; Van Nieuwenhuyse and Jones 1996). According to Prescott (1984) in fresh waters the optimum temperature for the majority of algae lies between 20-25 C according to Brown (1987) algae and plants are important to lotic systems as source of energy, for forming microhabitats that shelter other fauna from predators and the current, and as a food resource. Lewis (1988) reported that plankton in rivers does not get enough time to grow and utilize the nutrients present in river waters. The response of phytoplankton to environmental factors has become a central topic of current research (Buric *et al.,* 2007) and identification of the main factors controlling phytoplankton in a particular water body is essential for choosing an appropriate management strategy for the maintenance of a desired ecosystem state (Peretyatko *et al.,* 2007)

Phytoplankton ecology in lotic habitats

During the study on phytoplankton production in the snow-fed river, Bhagirathi in the Garhwal Himalaya, Joshi *et al.,* (1993) found the planktonic production was maximum during December- February and minimum in July- August. Joshi *et al.,* (1996b) observed planktonic density of Ganga canal at Jawalapur (Hardwar) and reported that the plankton density was maximum during winter and it decreased due to increased turbidity during rainy season. Badoni *et al.,* (1997) observed during the study on the variation in the epilithic diatoms community in the Ganga river water that the diatom density begins to decline with the increase in water temperature, current velocity and turbidity. Joshi *et al.,* 1996a) studied selected tributaries of river Ganga and recorded highest population of plankton during winter season with maximum plankton recorded from December to February and lowest population during monsoon months. Sunder (1988) studied the water quality of a stretch of river Jhelum and recorded a seasonal variation in the water quality.

Pande and Mishra (2000) studied the water quality of freshwater bodies of Dehradun and collected the members from group chlorophyceae, bacillariophyceae,

rhodophyceae and cyanophyceae from Sahatradhara stream while members from chlorophyceae, bacillariophyceae and cyanophyceae from Mussoorie Lake. Kutty *et al.,* (2001) have reported a total 81 genus which is consist of 135 species of Bacillariophyta, Chlorophyta, Cyanophyta, Euglenophyta and Pyrrophyta division. They stated that cholorphyta was quantitatively and qualitatively the most dominant division, which was dominated by genus *Staurastrum* spp., *Cosmarium* spp, and *Ankistrodesmus falcatus*. Leghari *et al.,* (2002) conducted the ecological study of algal flora of the river Jhelum in Azad Kashmir. They carried out their study on 134 species, belonging to 68 genera from 7 groups of alga. The basic idea of the study was to assess the population of these algal flora as they play an important role in a balanced ecological system. Dutta *et al.,* 2004 studied the ecology of plankton of Jammu and reported a total of 19 genera of phytoplankton. Out of which the dominance was shown by bacillariophyceae (8 genera), followed by Cyanophyceae (6 genera) and Chlorophyceae (5 genera). Agarwal and Thapliyal, 2005) carried out hydrobiological studied on Bhilangana river and concluded that the maxima fauna density in winter and minima in monsoon season may be due to water temperature, water velocity, and turbidity been lower in winter months and these provide favourable environment for the growth of plankton and other biotic communities.

Negi *et al.,* (2007) reported a total of 38 genera of phytoplanktons from three streams of District Nainital where *Bacsillariophyceae* was the dominant group with 21 genera followed by *Chlorophyceae* (13 genera), *Xanthophyceae* (2 genera), *Crysophyceae* (1 genus) and *Cryptophyceae* (1 genus). Hafiz *et al.,* 2014 assessed the phytoplankton community of river jehlum in Kashmir Himalaya, a total of 53 taxa belonging to bacillariophyceae (24) (Cholorophyceae (17) cyanophyceae (9) euglenophyceae (2) and chrysophyceae (1) were recorded.

Das and Panda (2010) recorded the water quality and Phytoplankton Population in the sewage Fed rivers of Mahanadi, Orissa, Komala *et al.,* (2013) assessed plankton diversity and abundance Arkavathi River with reference to pollution. Laskar and Gupta (2009) investigated Barak Valley of Assam and studied the phytoplankton diversity, density and distribution in different seasons and their correlations with physico-chemical properties of water and maximum number of species during pre-monsoon (29 species) and lowest in winter (23 species). Members of chlorophyceae were recorded in reasonable number throughout the year while being most abundant in pre-monsoon and monsoon. An assessment of seasonal variation in phytoplankton community of Mahi river (India) were done by Sharma and Bhardwaj (2011) obtained results are such as the dominant group among phytoplankton community were Blue green algae and diatoms. Annalakshmi and Amsath (2012) investigated the composition, abundance, frequency of occurrence and diversity of net phytoplankton species inhabiting in river Cauvery and its tributaries river Arasalar at Kumbakonam area. Ramesha and Sophia (2013) investigated plankton species composition and diversity for a period of 14 months in the river Seeta, the Western Ghats, India. A total of 4 phytoplankton divisions were recorded during the study period. Kamble *et al.,* (2013) studied of phytoplankton in river Manjra near Kallam (Table 1).

The phytoplankton communities of the present water body were represented mainly by (4) four groups of algae such as Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. The Narmada River is one among the important rivers in India with varied rich biodiversity (Sharma *et al.,* 2013) Mukati *et al.,* (2014) Studies of Phytoplankton Ecology in Narmada River of West Nimar, MP, India Cynophyceae were recorded as a dominant class in Narmada river.

Shuklaa *et al.,* (2016) assessed phytoplankton diversity in river Ganga at Allahabad. Their findings highlighted the deterioration of water quality of the river due to industrial, commercial and anthropogenic activities. The status of phytoplankton diversity of river was quite low indicating that the river is highly polluted. Hani *et al.,* (2017) studied phytoplankton in the river Barak, south India Dominant taxa like *Chaetophora* sp. was found significantly abundant in different sites whereas *Microthamnion* sp. was significantly abundant in different periods. The study showed that riverine ecosystems can provide better diversity of the phytoplankton

Phytoplankton ecology in lentic habitats

Researchers published some accounts on phytoplankton ecology in freshwater lakes around India.

Phytoplankton ecology in marine habitats

In the North Indian Ocean, the seasonal cycle of phytoplankton exhibits two well defined growing seasons (Banse, 1987).

Table.1 Factors affecting distribution of phytoplankton in freshwater lakes of India

Lakes	**State**	**Dominant groups of phytoplankton**	**Influencing factors**	**Reference**
Damadama, Badkhal, Peacock lakes	Delhi	Blue-green algae	Temperature with seasonality	Dakshini and Gupta, 1979
Badua lake	Bihar	Blue-green algae, Diatoms	Seasonal variations	Verma and Munshi, 1983
Dal, Waskur lake, Anchor lakes	J&K	Diatoms, green algae	Hydrographic properties	Sarwar, 1996
Kitham lake-	Agra (UP)	Green algae, Diatoms	Seasonal variations	Tiwari and Chauhan, 2006
Ranchi lake	Jarkhand	Blue-green algae, diatoms	Organic matter	Mukherjee *et al.*, 2010
Bhavanisagar lake	Tamil nadu	Blue-green algae	Seasonal variations	Sreenivasan, 1964; Sreenivasan *et al.*, 1964
Red hills lake	Tamil nadu	Blue-green algae	Climatic factors	Ganapati, 1940
Osman sagar, Mir-alam lakes	Telangana	Blue-green algae	Temperature, seasonality, water chemistry	Mohan, 1987
Sasthamcottah lake	kerala	Green algae	Water chemistry	Chaudhary and Pillai, 2009
Kodaikanal lake	Tamil nadu	Green algae	Temperature, pH, light, Seasonal variation.	Singh and Balasingh, 2011
Nongmahir lake	Meghalaya	Green algae	Nutrient enrichment	Sugunan and Yadava, 1991
Khecheopalri lake	sikkim	Green algae	Hydrology and nutrients	Jain *et al.*, 1999
Krishnasayer lake	West bengal	Diatoms	Temperature, transparency, nutrients enrichment	Chattopadhyay and Banerjee, 2007
Santragachi lake	West Bengal	Blue-green algae	Climatic conditions	Ghosh *et al.*, 2012
Ramgarh lake	Rajasthan	Diatoms	Seasonality	Jhingran, 1989
Dhom lake	Maharashtra	Green algae	Nutrient enrichment	Trivedi, 1993
Masunda lake	Mumbai	Green algae, Blue-green algae	Seasonality, Nutrient enrichment	Somani *et al.*, 2007
Phutala, Ambazari lakes	Maharashtra	Blue-green algae	Nutrient enrichment	Maske *et al.*, 2010

During the S-W monsoon, the combination of coastal upwelling, lateral advective transport, and offshore Ekman pumping induces the strong phytoplankton blooms (Brock *et al.*, 1991; Latasa and Bidigare, 1998) with chlorophyll-rich filaments that could extend several hundreds of kilometres offshore (Brock and McClain, 1992; Lee *et al.*, 2000). During the N-E monsoon, convective mixing entrains nutrients into the surface layers producing elevated surface chlorophyll concentrations (Madhupratap *et al.*, 1996; Wiggert *et al.*, 2000, 2002). Whereas the intermonsoon periods are characterized by stratified waters devoid of nutrients in

the upper layers due to which, oligotrophic conditions prevail with minimal primary production and the development of deep chlorophyll maxima (Marra *et al.,* 1998; Caron and Denett, 1999). Babu *et al.,* (2013) assessed Diversity of Phytoplankton in Different Stations from Muthupettai, South East Coast of India where *Nitzschia seriata, Coscinodiscus centralis, Thalassiothrix frauenfeldii*, and *Ceratium furca* were the most abundant in phytoplankton community. The percentage composition were recorded as Diatom> Dinoflagellates> Blue greens> Greens> Silicoflagellate respectively. The study revealed that there are no effects due to the aquaculture discharge waters for the mangrove ecosystem. This study also revealed seasonal environmental variables and phytoplankton distributions in Muthupettai lagoon. Schluter *et al.,* (2011) revealed that Haptophytes and pelagophytes were the dominating eucaryotes in the Indian Ocean whereas Prochlorophytes dominated in the subtrophic and oligotrophic eastern Indian Ocean. Zeaxanthin was found to be a pigment of heterotrophic bacteria.

In contrast with the Arabian Sea the Bay of Bengal is subjected to the influence of the monsoon system and some of the largest rivers of the world deliver into the bay large inputs of fresh water and suspended sediments. As a result, the surface waters are much less saline and strongly stratified preventing the upwelling of nutrients (Jyothibabu *et al.,* 2004). Traditionally, the Bay of Bengal is believed to be less productive than the Arabian Sea (Qasim, 1977; Gauns *et al.,* 2005). However, a strong mesoscale activity has been shown to significantly enhance the biological activity, especially during the intermonsoon periods (Prasanna Kumar *et al.,* 2007). The equatorial Indian Ocean differs remarkably from the other two equatorial basins. Owing to semi-annual eastward winds, eastward-propagating Wyrtki Jets develop during the intermonsoon periods, which transport water from the West (Wyrtki, 1973). As a consequence, the thermocline and the nutricline are deeper in the east resulting in a generally modest production in this part of the basin, except along the coast of Sumatra and a significantly higher production in the western part of the equatorial Indian Ocean. Now, at the beginning of 2016, a new paper titled "A reduction in marine primary productivity driven by rapid warming over the tropical Indian Ocean" has just been published in the Journal *Geophysical Research Letters* – http://bit.ly/1PvYhcQ. In the paper led by author Matthew Koll Roxy from the Centre for Climate Change Research at the Indian Institute of Tropical Meteorology, data is presented demonstrating a decline in phytoplankton in the western Indian Ocean by up to 20% over the last 60 years.

The dominance of diatoms seems to be favoured by low temperature and high light penetration (Vasisht and Sharma, 1975) besides the availability of SiO_2 (silicate) which is used to make the bodies of diatom (pandit, 1980). High diversity of diatoms indicates polluted level of river (palmer, 1969, kanonand krishmutthy, 1985). Kant and kachroo (1980) reported rise in temperature provided optimum conditions for the growth and reproduction of chlorophyceae. According to Hutchinson (1967) the presence of euglenophyceae in a greater quantity is attributed to a number of variables like high level of organic matter. According to Adirondack Ecologists (2010) abundance and species composition of algae can have significant implication with regards to both water clarity and quality of any given body of water. Nowrouzi and Valavi (2011) have concluded that, increase of water temperature and nutrients in spring are both essential factors, which cause increasing of phytoplankton abundance and diversity. In summer, despite increasing water temperature, nutrients consumption by phytoplankton and also grazing by zooplankton causes decrease in phytoplankton abundance and diversity. In summer, despite increasing water temperature, nutrients consumption by phytoplankton and also grazing by zooplankton causes decrease in phytoplankton abundance and diversity. They reported maximum diversity of phytoplankton was recorded during the winter months were the water temperature was low as compared to summer and spring seasons.

During summer, the phytoplankton count progressively increased in lake water whereas in monsoon, normal rainfall population of phytoplankton decreased with non-uniform intensity of sunlight. During winters, temperature variation played important role in phytoplankton distribution. However does not vary much in southern region's lakes because the temperature of the peninsula never drops below 16C. Conversely, phytoplankton productivity rate declined in northern lakes because of its low rate of sunshine and effect of continental winds leading to low temperature of the water (Jain *et al.,* 2007).

It is clear from the review; phytoplankton ecology in freshwater lakes and river of India is greatly influenced by factors including climatic conditions, Watershed features, land use, geochemical features, soil or sediment. However, research works on these factors or

other unknown factors are not clearly reported in studies of Indian freshwater lakes. In India most of the discussed case studies are basic and provides necessary information to develop protection and management plans. Authors considered phytoplankton ecology of Indian lakes and rivers as an indicator for evaluating the impact of influencing factors. This review study provides a framework for the improved understanding of research and management strategies in fresh water lakes and rivers. Phytoplankton ecology plays an important role for indicating the eutrophication. Indian freshwater lakes provide an assessment of cultural eutrophication which controls light and temperature on phytoplankton. This may change the response of lake ecosystems to global warming. A rapid loss of phytoplankton threatens to turn the western Indian Ocean into an "ecological desert," a new study warns. The research reveals that phytoplankton populations in the region fell an alarming 30 percent over the last 16 years. A decline in ocean mixing due to warming surface waters is to blame for that phytoplankton plummet, researchers propose online January 19 in *Geophysical Research Letters*. The mixing of the ocean's layers ferries phytoplankton nutrients from the ocean's dark depths up into the sunlit layers that the mini plants inhabit.

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How to cite this article:

Bisma Zahoor Hafiz and Imran Zahoor Hafiz. 2018. Review on Nationwide Surveillance for Phytoplankton Ecology in India. *Int.J.Curr.Res.Aca.Rev.* 6(10), 1-10. **doi:** https://doi.org/10.20546/ijcrar.2018.610.001