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Role of Phytoplankton in Comprehending the Vulnerabilities Imposed due to Gangasagar Festival

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ABSTRACT
Sagar Island, one of the densely inhabited island of Sundarbans deltaic complexes is experiencing severe population pressure in the recent past. Its population count has exceeded over 2.12 lakhs. During Gangasagar festival, another lot of pilgrims come over with an intention to take a holy dip at the Gangotri confluence. This mass gathering elevates the pollution levels. It depicts a cyclic usage of water having religious prototype, consisting of bathing at particular sites resulting in drastic alteration of the biogeochemical symmetry of the aquatic ecosystem. Phytoplankton being the primary producers occupies the base level of aquatic food webs. They have a potent role in indicating water quality. Even minute alterations in phytoplankton community can affect the world climate. Therefore, for maintaining a balanced ecosystem, their respective levels should be kept on a count. Phytoplankton biomass was maximum during post-Gangasagar phase and minimum during pre-Gangasagar. In terms of abundance, Bacillariophyceae exhibited prominence and Dinoflagellates diversified after Gangasagar festival implying high pollution levels of Sagar. The largest influence on phytoplankton plethora is nutrient scarcity. Also, blooms of dinoflagellates due to nutrient variability have large ecosystem impacts on water quality. These changes in the primary producers eventually affect primary production and biogeochemical cycle.

Key words: Diatom, Dinoflagellate, Eutrophication, Nutrient, Pollution, Sagar

INTRODUCTION

Sagar, being one of the largest islands, comprises of the south western boundary of Sundarbans ecoregion. It is encompassed in the North West by the Hooghly River, in the East by the Muriganga estuary and in the South by the Bay of Bengal (Ghosh 2019). Since this island is densely colonized, it poses a risk of vulnerability due to enhanced population pressure and environmental deterioration as a result of pollution, sea level rise, tidal surges, coastal erosion and cyclones (Bera et al. 2022). This place has a religious outlook as it is one of the most sacred pilgrimage sites for Hindus. We are familiar with the Gangasagar festival which is the second largest mass gathering in India and is conducted every year during mid-Januaries. This festival spans for 2-5 days; throughout this time almost 4 lakh pilgrims visit and worship at the Kapil Muni temple for taking a holy dip at the Gangasagar beach. This in turn exceeds the carrying capacity of the island posing a threat to its sustainability (Sinha et al. 2018). Gangasagar festival forms the economic backbone of Sagar by providing numerous scopes of employment to plenty of people but alongside degrades the environment by accumulating several wastes belonging to both organic and inorganic origin that are generated by millions of pilgrims further resulting in poor quality of water and air (Bera et al. 2022). The numbers of visitors' are rising with each passing year and hence continuous environmental inspection of this island is essential. Phytoplankton, however, are the microscopic organisms that drift freely in water and contribute to about 98% of marine productivity and 40% of global productivity (Choudhury et al. 2014). They are gobbled up by the zooplankton and other minute creatures residing in the aquatic system that further get ingested by the large fishes. This chain slowly extends upwards to the topmost level of predators such as sharks and humans. So if ever the phytoplankton vanished, the organisms belonging to the next tropic levels wouldn't be lagging behind and this destructive chain reaction would soon start spreading outside the ocean (Anonymous 2019). Along with serving as a potent source of food and oxygen for varying life forms on Earth, phytoplankton monitors the levels of inorganic atmospheric carbon and makes the surrounding air suitable for breathing. They, as a biological carbon pump eliminates approximately 10 trillion kg of carbon every year from the atmosphere carrying it with them till the core of the ocean when they die, further reducing the risk of greenhouse gas formation (Fondriest Environmental Learning Center). Thus, in the absence of phytoplankton the atmospheric carbon concentration would not only elevate but will simultaneously accelerate climate change, making the air impossible for humans to breathe in. Phytoplankton also has a promising role as water quality indicator. Hence, in order to maintain a balanced ecosystem, phytoplankton levels in the marine ecosystem should be kept on a count (Mullick et al. 2022). The main objective behind this work was to assess the water quality of Sagar over the Gangasagar period along with determining whether the increasing pollution pressure on Sagar gets reflected in their phytoplankton community, as not much work has been done previously in this arena.

Figure1. Map of Sagar Island highlighting the collection spot

STUDY AREA

The study was carried out at an interval of 3 months and sampling was split into 3 phases: a Pre-Gangasagar period (Pre-GF) (October), immediately after the Gangasagar festival (GF) (mid-January) and Post-Gangasagar period (Post-GF) (April). Since phytoplankton are more abundantly found in stagnant water body than beaches, hence the collection spot S1 (21°63.485’ N, 88°07.613’ E) was chosen as it acted as a channel allowing polluted water from the beach to enter into its system (Fig. 1).

MATERIAL AND METHODS

Analysis of hydrological parameters

Samplings were conducted twice per sampling period from October 2022 to April 2023 from the abovementioned spot of Sagar Island. Water samples were collected in triplicate. From the boat, the temperature, pH, salinity, total dissolved solids (TDS) and dissolved oxygen (DO) of water were measured using a Hanna multiparameter probe. For dissolved nitrate (NO_3^-), dissolved phosphate (PO_4^{3-}) and dissolved silicate (SiO_3^{2-}), the collected water samples were filtered using a GF/F filter paper and the filtrate was stored on ice. The nutrient content was then measured following modified protocols of Grasshoff et al. (1999).

Phytoplankton collection

For phytoplankton collection, modified methods as deduced in the article of Catching Plankton were used. Specialized scientific equipment such as a phytoplankton net was used to achieve our desired objective. The plankton net (30 μ mesh size and 28.5 cm diameter) was equipped with a flow meter and towed horizontally for 3 minutes from the boat. Phytoplankton samples were collected in triplicate from our sampling station. The collected samples were then preserved in 4% formalin (Manna et al. 2010) until further analysis. As it was later observed that the water sample was dominated by diatoms, frustule cleaning using 3% chromic acid (Santra et al. 1991) was necessary as it helps to remove the organic material from the sample of interest leaving only the silicified cell wall behind.

Table 1. Variability of hydrological parameters at our study site in Sagar Island

SEASON	**TEMP (°C)**	**pH**	**SALINITY (psu)**	**TDS (ppt)**	**DO (mg/L)**	**NO_3^- (mg/l)**	**PO_4^{3-} (mg/l)**	**SiO_3^{2-} (mg/l)**
Pre-festival (Pre-GF)	28 ± 0.31	6 ± 0.11	12 ± 0.32	10 ± 0.13	5.09 ± 0.15	1.4 ± 0.3	2.9 ± 0.05	13.18 ± 0.25
During festival (GF)	21 ± 0.41	8.7 ± 0.12	14 ± 0.15	9.5 ± 0.2	4.7 ± 0.19	1.29 ± 0.4	4 ± 0.37	16.6 ± 0.3
Post-festival (Post-GF)	31 ± 0.44	7.1 ± 0.07	18 ± 0.29	11 ± 0.29	6.31 ± 0.29	1.1 ± 0.3	2.64 ± 0.15	12.94 ± 0.11

DO = Dissolved Oxygen, NO_3^-= Total Nitrate, PO_4^{3}{= Total Phosphate, SiO_3^{2-}= Total Silicate. Data represented as Mean ± SE of 2 replicates taken per time frame

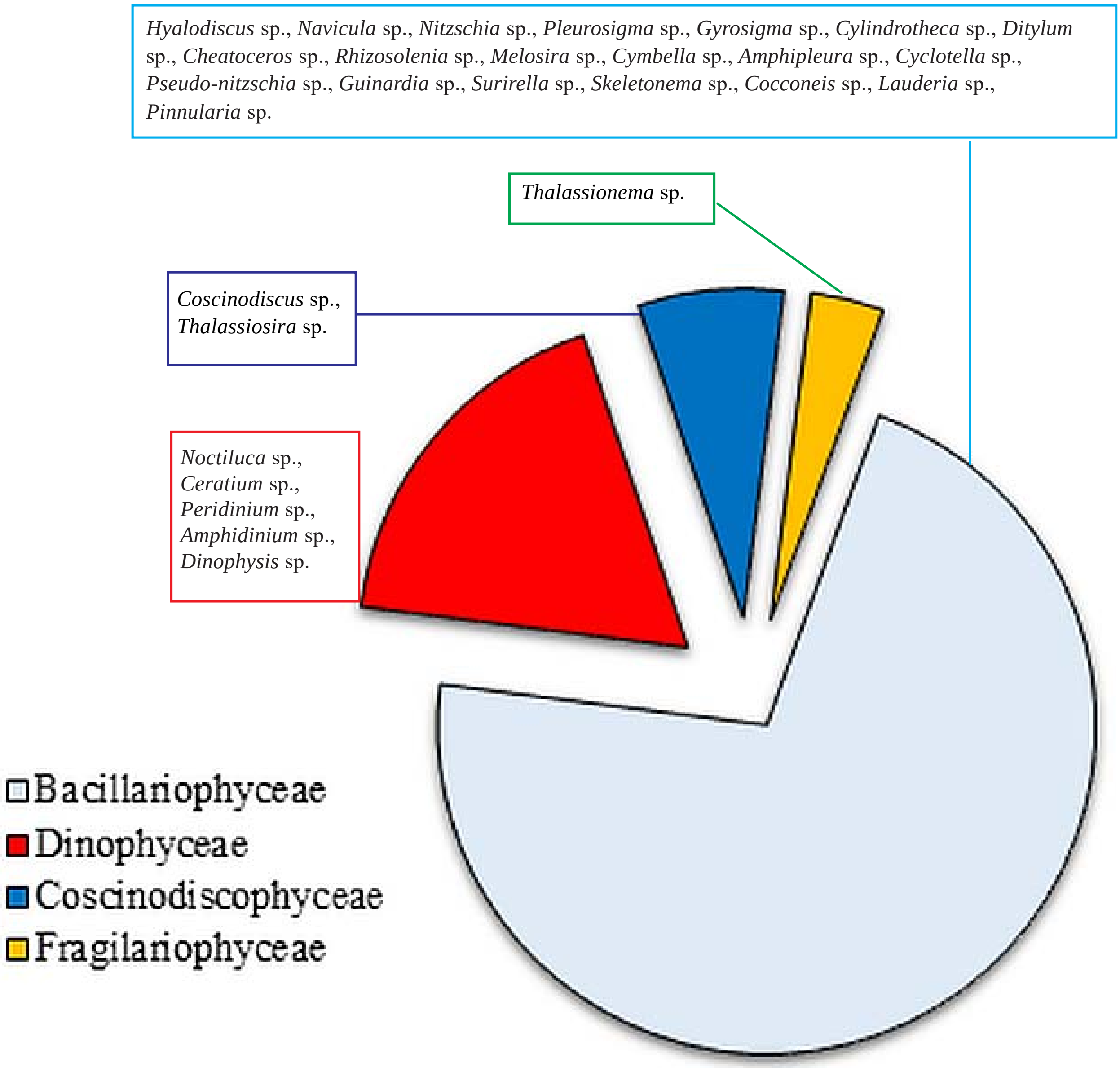

Figure 2. Variation in the abundance of phytoplankton members belonging to different classes

Identification and enumeration

For phytoplankton enumeration, Sedgewick-Rafter counting chamber was used (Woelkerling et al. 1976). One ml of preserved water sample was added to the counting chamber, covered with a cover glass and analyzed under a phase contrast Carl Zeiss Primostar 3 microscope. The abundance of each taxon was expressed as individuals per liter (ind. L^{-1}) (Mamun et al. 2009).

Statistical analysis

All the statistical analyses were performed using CRAN R.4.2.2 software. Statistically evaluated results were reported along with F value, P values and degrees of freedom (df) using two-way ANOVA.

RESULTS

Hydrological variability

Statistical analysis revealed that surface water temperature significantly varied (F = 92.33, df = 2, P = 0.01) among the 3 sampling periods and was maximum during Post-GF period (Table 1). Salinity ranged between 12 to 18 and varied significantly (F = 129, df = 2, P < 0.00007) among seasons with maximum salinity observed during Post-GF period. Total Dissolved Solids did not vary much (P > 0.05). pH levels were significantly lower during Pre-GF period and gradually increased from Post-GF to GF periods (F = 24.78, df = 2, P = 0.0038). A distinct variation was noted in case of Dissolved Oxygen level (F = 38.42, df = 2, P = 0.002).

Phytoplankton abundance

A total of 28 species of phytoplankton were identified among which 20 belonged to Class Bacillariophyceae, 5 belonged to Dinophyceae, 2 of them belonged to Class Coscinodiscophyceae and 1 to Fragilariophyceae. Hence the dominance hierarchy goes like Bacillariophyceae > Dinophyceae > Coscinodiscophyceae > Fragilariophyceae (Fig 2). Phytoplankton abundances of few dinoflagellates such as *Noctiluca* sp. exhibited seasonal (F = 1572.4, df = 2, P = 0.0006) variability with highest abundance during GF period than Post-GF and Pre-GF periods. Similarly, *Dinophysis* sp. also showed significant difference among the 3 sampling periods (F = 188.3, df = 1, P = 0.00003). Significant seasonal variation was also prevalent for both *Ceratium* sp. (F = 23.52, df = 2, P = 0.004) and *Peridinium* sp. (F = 23.18, df = 2, P = 0.0041). The abundance of *Amphidinium* sp. didn't vary significantly among the seasons, however, their abundance was found to be comparatively low during Pre-GF than GF and Post-GF periods.

DISCUSSION

A list of components such as variability in hydrological parameters (Table 1) were essentially related to the offset and onset of Gangasagar festival as the inorganic wastes produced during this time directly leaches into the water body. Variation in temperature was directly proportional to the intensity of light falling on the surface of water. During Pre-Gangasagar festival (Pre-GF), salinity was considerably low because of rainfall, freshwater inundation and tidal alterations (Mandal et al. 2012) and its level escalated from GF to Post-GF periods. TDS was directly proportional to the levels of salinity as salt encroachment during tide and its leaching directly influences the levels of TDS (Das 2018). During all the three sampling periods, pH of water was found to be neutral to slightly alkaline; this could be due to bicarbonate degradation that removes carbon dioxide during photosynthesis (Basu et al. 2021). Low levels of pH during Pre-Gangasagar implied the dilution effects owing to freshwater influx that washed away the organic matter mineralization products near the catchment basin (Chakrabarty et al. 2022). The lower values of DO during Gangasagar period was due to high salinity. DO concentrations will also depend on the cumulative impact of photosynthesis rate along with nutrient levels (Basu et al. 2021). Similar observations were recorded by Sinha et al. (2018), during GF period. Thus, it can be stated that during Post-GF period, as temperature increases, more and more evaporation takes place from the surface of water. Also during this time of the year, freshwater inundation is low resulting in an elevation in salinity and henceforth elevated TDS content. Primary productivity is assisted by the nutrients present in water. Tidal surges are one of the potent causes for change in the nutrient content. Level of total Phosphate was maximum during GF period and

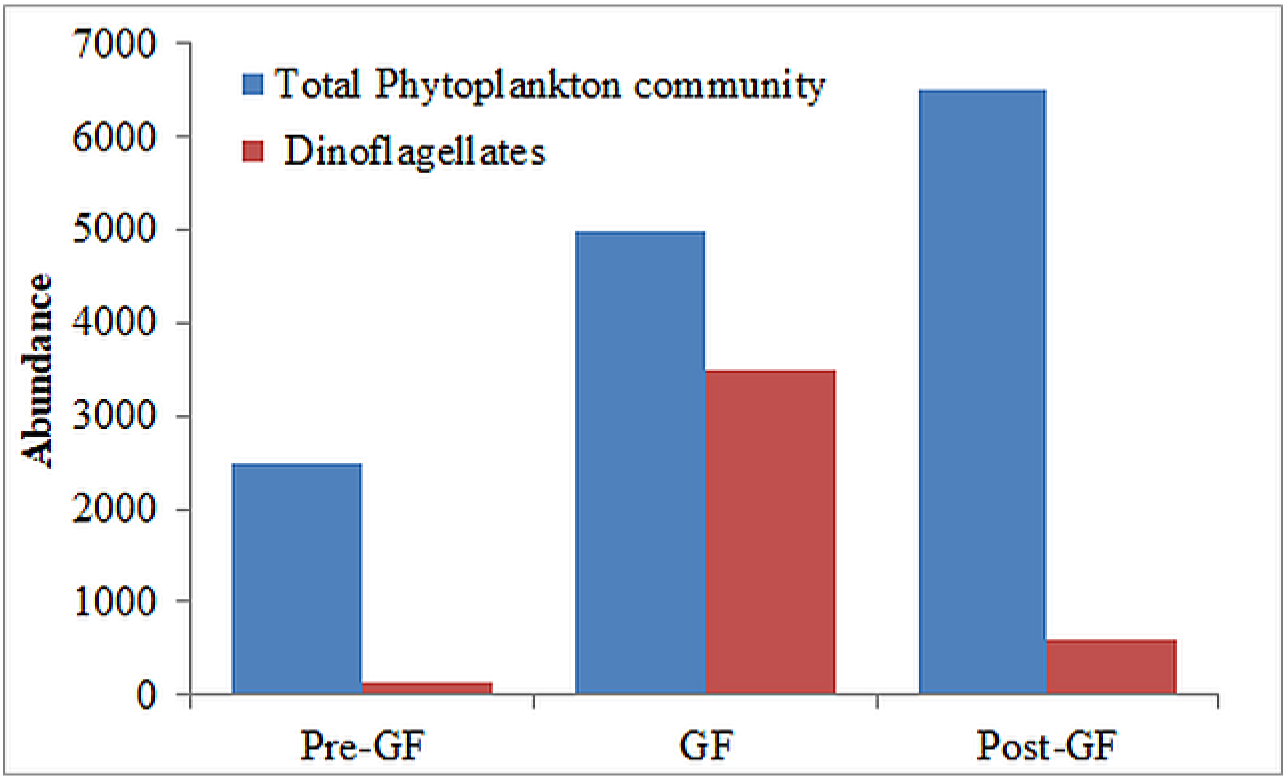

Figure 3. Total abundance of phytoplankton (individuals L^{-1}) and those of Dinophyceae members during the sampling periods

minimum during Post-GF period since majority of it got used up by the photoautotrophs (Basu et al. 2021). Total Nitrate and total Silicate levels increased from Pre-GF period due to influx of freshwater and land inundation (Table 1). The Silicate: Phosphate ratio that was below the Redfield ratio implied large periodic alterations whereas Nitrate: Phosphate ratio indicating a nitrogen limiting environment (Choudhury and Bhadury 2015). Our results were in accordance with those of Mandal et al. (2012).

Among the phytoplankton community, diatoms were the most abundant ones in our study site. Mamun et al. (2009) also deduced the abundance of phytoplankton members as Bacillariophyceae > Chlorophyceae. The abundance of Dinophyceae members were seen to increase after the Gangasagar festival. Diatoms *Hyalodiscus* sp., *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp., *Cylindrotheca* sp., *Coscinodiscus* sp., *Ditylum* sp., *Cheatoceros* sp. and *Rhizosolenia* sp. were caught frequently (cumulative abundance of each species > 5000 individuals L^{-1}). The environmental factors directly had an impact on the abundance of phytoplankton as during post-GF period when temperature, salinity and other physical parameters were found to be higher, phytoplankton abundance was also higher (Fig 3). Nutrient levels directly influence the phytoplankton community as phytoplankton absorbs these nutrients from water for their growth. During pre-GF period, their low abundance was recorded due to stressful altering physicochemical parameters that caused many phytoplankton to perish. Also during monsoon, the flow of river elevates that causes a majority of the phytoplankton community to vanish into the Bay of Bengal. Our findings matched with those of Mandal et al. (2012). Pennate diatoms were predominant during Post-GF period whereas Centrales during GF period. Similar observations were noted down by Bhattacharjee et al. (2013) at Chemagari creek. Certain taxa such as *Hyalodiscus* sp., *Navicula* sp., *Nitzschia* sp., *Pleurosigma* sp., *Cylindrotheca* sp. and *Coscinodiscus* sp. were found to prevail in all the sampling stations whereas some other species were restricted to their native water body such as *Pinnularia* sp., *Thalassionema* sp., *Cocconeis* sp. indicating their low adaptability with changing environmental conditions. During the GF period, pollution being one of the probable reason for enhanced availability of nutrients into the water body than Pre-GF and Post-GF periods (Fig 3), phytoplankton especially dinoflagellates absorb them for their growth and multiplication, excessive of which can even cause an algal bloom.

Immediately after Gangasagar, species of Dinophyceae such as *Noctiluca* sp., *Dinophysis* sp., *Ceratium* sp. etc. were recorded in huge numbers which were not noticed otherwise in considerable amounts throughout the year. Dinoflagellates are the most common causal agents for an algal bloom in saline water. They act as indicators of eutrophication and pollution (Dale 2000). Their sudden escalation as a whole after the Gangasagar event was a clear indication of the pollution pressure in the waterbody that may be due to high nutrient input in the coastal water as a consequence of mass bathing by the pilgrims during this time (Bhattacharjee et al. 2013).

CONCLUSION

Gangasagar festival which is the second largest gathering of mankind possesses a religious outlook as pilgrims from all over India gather during this time for taking a holy dip at the Ganges. This directly influences the water quality of Sagar as more pollution leads to more nutrient assimilation further impacting the growth of phytoplankton. In nutrient-rich water, there is always a prevalence of diatoms. Lower abundance of phytoplankton could be due to less availability of nutrients whereas enhanced nutrient condition might cause eutrophication as an effect of pollution, varying fixation of phytoplankton, also planktonic detritus decomposition by bacterial agents. Hence, it is immensely important to keep the nutrient concentration under check. While performing this study, it was observed that immediately after Gangasagar festival when there was a surge in the nutrient content of water owing to mass-bathing and gathering, a considerable augmentation in the population of dinoflagellate members were recorded. Hence from this study, it is clearly evident that phytoplankton (dinoflagellates) acts as indicators of pollution pressure as well as water quality since phytoplankton dynamics changed drastically according to varying physicochemical parameters. So, to maintain a balanced ecosystem, it is very important to regulate the levels of phytoplankton who act as primary producers in almost all aquatic food webs.
In order to combat this, certain preventive measures can be undertaken. The brick-paved embankments can be repaired and reveted in order to reduce the process of leaching. Also, anthropogenic activities in the water bodies should be regulated which will in turn limit the percolation of excess nutrients into the waterbody, thus preventing eutrophication and pollution, henceforth maintaining a balanced ecosystem.

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