Variations in Seasonal Phytoplankton Assemblages as a Response to Environmental Changes in the Surface Waters of Minicoy Island, Lakshadweep

Geethu Mohan¹*, R. Aravind², P. Anjaneyan¹, S.M. Raffi³, K.S. Swathy¹, S. Athul¹, T.M. Sreenath¹

¹Faculty of Ocean Science and Technology, Kerala University of Fisheries and Ocean Studies, Kochi, India
²Central Institute of Brackishwater Aquaculture, Chennai, India
³University of Kerala, Karyavattom, Thiruvananthapuram, India
*Corresponding author: geethumohan76@gmail.com

Received November 13, 2021; Revised December 19, 2021; Accepted December 27, 2021

Abstract Phytoplankton, the primary producers in all aquatic systems, play an important key role in biogeochemical processes that are linked to higher trophic levels and climate variability. The spatio temporal composition and abundance of micro phytoplankton species was examined in relation to physical and chemical surface water variables (i.e., Salinity, temperature and nutrients). The primary objectives of the study were to observe the variations in phytoplankton species assemblages as a response to environmental variables. Hierarchiel cluster analysis and non-metric multidimensional scaling were used to find out distinct seasonal groups based on the composition of phytoplankton. The results indicate that several key environmental factors like temperature, salinity and nutrients like nitrate, nitrite, phosphate and silicate influenced seasonal phytoplankton assemblages within the lagoon waters. The distribution of phytoplankton population showed main groups where the blue green algae populations favored the warmer conditions of pre-monsoon period, whereas the diatom population primarily flourished in the post monsoon and monsoon period. The present study deals with the phytoplankton community structure in the Indian Ocean, Lakshadweep Archipelago, Minicoy Island, particularly in the surface water with respect to environmental variables to understand the region-specific dominant community and its governing environmental settings.

Keywords: phytoplankton, lagoon, nutrients, seasons, environmental factors

Cite This Article: Geethu Mohan, R. Aravind, P. Anjaneyan, S.M. Raffi, K.S. Swathy, S. Athul, and T.M. Sreenath, “Variations in Seasonal Phytoplankton Assemblages as a Response to Environmental Changes in the Surface Waters of Minicoy Island, Lakshadweep.” Applied Ecology and Environmental Sciences, vol. 9, no. 12 (2021): 1024-1032. doi: 10.12691/aees-9-12-6.

1. Introduction

Phytoplankton are important primary producers and are at the base of the food chain. They are also recognized as bio indicator organisms in the aquatic environment due to their short generation time and fast response to changes in aquatic environment such as nutrient enrichment and they can be used as early warning indicator [1,2]. Phytoplankton composition and abundance are considered as natural bio indicators of water quality variations because of their sensitivity and rapid responses to changes in environmental conditions such as pH, temperature, salinity, turbidity and nutrients [3]. The species composition, relative abundance, spatio temporal distribution of this aquatic biota are an expression of the environmental health or biological integrity of a specific water body. The environment was characterized as oligotrophic, trending towards mesotrophic in the premonsoon season. The high number of taxa associated with high evenness was indicative of environmental balance. Continental interference was perceived due to the variation of abiotic parameters and of the variation of the phytoplankton community structure. Marine ecosystems are particularly vulnerable to environmental changes and many are at present, severely degraded [4]. The availability of good quality water is an indispensable feature for preserving biodiversity. It is important to evaluate the role of the physical and chemical processes on the biological properties of water most often leads to the production of phytoplankton, while their assemblages (composition, distribution, diversity and abundance is also structured by these factors. Since phytoplankton community structure and diversity changes can sensitively reflect impact of environmental changes on ecosystems, its success characteristics can record impact of natural variations and human activities on coastal ecosystems. Therefore, the study of phytoplankton community structure is of extremely important theoretical and practical value for understanding of the impact of environmental change on marine ecological system.
2. Materials and Methods

Minicoy Island (08°17’ N, 73°04’E), the southernmost Island in Lakshadweep, is located 215 nautical miles southwest off Kochi. The lagoon with an area of about 25 Km² has two ecologically distinct habitats. The coral shoals with occupy about 75% of the area and the sand flat in the southern part of the lagoon. The average depth is 4m with maximum depth of about 15m. During high tide water exchange takes place between the lagoon and open sea over the reef. From the entrance, that serves as water exchange points, as migratory passage for fishes and also sailing points between open sea and lagoon. The lagoon is varying depth, and has distinct physical features. The South western region is enriched with coral reefs and sea grass beds. The lagoon is deepest in its central and scattered big boulders along the North western shore of the Island. Extensive sea grass beds are usually spread towards the landward side. A total of 12 stations were selected with the help of GPS, of which 8 are randomly selected inside the lagoon (Stn 1 to Stn 8) and the remaining 4 are selected (Stn 9 to Stn 12) towards the eastern side of the island in the coastal waters of Minicoy (Figure 1).

The surface water samples were collected using Niskin water sampler with the help of a motorized boat. The temperature in the atmosphere and surface water was measured using a portable thermometer at the time of sample collection. The salinity was measured using DIGI AUTO, TS salinometer (MODEL 5; accuracy ± 0.001) and the pH using an ELICO LI 610 pH meter (accuracy ± 0.01). Dissolved oxygen was estimated according to Winkler’s method [5]. Samples for nutrient concentrations were analysed following standard methods [5,6]. For chlorophyll a estimation, 250 ml of water sample was filtered through GF/F filters (nominal pore size, 0.7µm), extracted with 90% acetone for 24h, and kept in freezer. Chlorophyll a concentration was determined fluorometrically (Turner Designs, Model 7200) after acidification. For quantitative and qualitative studies of phytoplankton, 1 L of water samples was taken and fixed with 10 drops of Lugol’s iodine solution. After the settling and siphoning procedure, 1ml of the aliquot of the sample were taken in a Sedgwick – Rafter counting cell in duplicate under the inverted microscope (Leica DFC- 450), for identifying and counting the phytoplankton cells [7]. To compare phytoplankton communities during the three seasons, non – parametric cluster analysis was used in accordance with the Bray- Curtis similarity Index using Plymouth Routines in Multivariate Ecological Research (PRIMER 7). The Bray – Curtis similarity index determines percentage similarity between three seasons.

3. Results

The variability seasonal cycle in oceanographic parameters includes water temperature recorded minimum during monsoon and maximum during pre-monsoon period (Figure 2). Thermal stratification started in the month of December and pronounced during March-April period. During the monsoon season the water temperature was decreased with lowest value 26°C recorded at the surface and then increased through post and premonsoon period. The salinity also showed a clear seasonality with minimum recorded in monsoon and maximum during premonsoon period (Figure 3). Generally, salinity values range between 32-35 ppt. However, low values (< 34 ppt) were occasionally detected at the surface water in the month of May, June, July and August (33 and 32 respectively). pH and Dissolved Oxygen didn’t show any significant variation during the study period (Figure 4 & Figure 5).
Figure 2. Season wise variation in temperature (°C) recorded in all the stations of Minicoy island

Figure 3. Season wise variation in salinity (ppt) recorded in all the stations of Minicoy island

Figure 4. Season wise variation in pH in all the stations of Minicoy island
The nutrient enrichment of coastal waters is generally the main factor driving the succession and composition of phytoplankton communities [8]. The most important nitrogen sources for the phytoplankton growth are the nitrate and ammonium salts [9]. The consideration of Nitrite concentrations in seawater is useful due to its intermediate oxidation state between ammonia and nitrate, but it has the highest toxicological significance of human health. During the premonsoon season maximum nitrite concentration of 0.74 µM was recorded in station 8. The minimum value of nitrite being 0.56 µM occurred in station 3 during premonsoon season (Figure 4). In monsoon season the highest concentration in station 8 (1.48 µM) and in post monsoon season 0.78 µM in station 8. Nitrate considered as the most stable and predominant in organic nitrogen form in the seawater and it is in one of the main nitrogen sources for phytoplankton [10]. The maximum nitrate concentration 0.33 µM at station 12 followed by monsoon concentration was high in station 12 but in post monsoon the highest concentration in station 7 and minimum concentration was 0.04 µM at station 2 (Figure 6). Phosphorus is an important element for the growth and primary production of phytoplankton in the aquatic systems [9]. The dissolved inorganic phosphate was fluctuated between a maximum of 0.89 µM at station 12 (pre monsoon season) and 0.19 µM at station 11 in monsoon season and in post monsoon 0.37 µM station 6. Silicate maximum of 6.3 µM in monsoon season and minimum of 3.04 µM in premonsoon season (Figure 7).
Applied Ecology and Environmental Sciences

The phytoplankton species are identified as 44 species of diatoms, 14 species of dinoflagellates, one of silicoflagellates and one of cyanobacteria. The diatoms were the leading and most dominated group, forming about 73.33% of the total counts followed by dinoflagellates that represented about 23.33% and the other phytoplankton were collectively formed about 1.66% of silicoflagellates and 1.66% of cyanobacteria of the total counts of phytoplankton. In relative high abundance of phytoplankton during premonsoon period was associated with high flourishing of the diatoms, Coscinodiscus spp, Coscinodiscus essenticus, Odontella mobilinies (Figure 8) as well as a relative high occurrence of Ceratium furca, Ceratium breve, Ceratium declinatum and Dinophysis miles (Figure 9).

Among the silicoflagellates only one species comes under the genus Dictyocha sp. were identified in all seasons. Trichodesmium spp. bloom occurs during premonsoon season shows the higher phytoplankton abundance on April-May month (Figure 10), which does not have any significant effect on fish mortality due to its fast disintegration. The dendrogram derived from cluster analysis using Bray Curtis Similarity Index depicted that class Bacillariophyceae and Dinophyceae found to be linked at highest similarity level (Figure 11) Multidimensional and scaling indicators the highest similarity of phytoplankton abundance was observed during premonsoon period compared to another season (Figure 12).

**Figure 7.** Season wise variation in Phosphate and Silicate (µM) in all the stations of Minicoy island

**Figure 8.** Monthly abundance of phytoplankton species under class Bacillariophyceae in 2018
Figure 9. Monthly abundance of phytoplankton species under class Dinophyceae in 2018

Figure 10. Monthly abundance of Phytoplankton species under different classes

Figure 11. Cluster diagram indicating percentage similarity of phytoplankton under different classes
4. Discussion

Phytoplankton composition and density varied from coast to coast, season to season and year to year [11]. Analysis of phytoplankton composition is useful in determining the degrees of fertilization among different seasons [12]. In the present study, 44 species of Bacillariophyceae, 14 species of Dinophyceae, one of silicoflagellates and one of the cyanobacteria were recorded from the lagoon and open sea. Diatom species were more diverse and abundant compared to dinoflagellates. The phytoplankton composition in the lagoon and open sea was dominated by diatoms. The peak in diatom abundance occurred during the southwest monsoon, whereas dinoflagellates were more abundant during the spring inter monsoon [13]. To date, no information has been reported about the phytoplankton composition and abundance in the lagoon and open sea of Minicoy Island, Lakshadweep. Therefore, the present study observations form a baseline for future study in this area of the Island. Two periods of elevated phytoplankton productivity, one during the north- east monsoon (November – February) and the other during the south west monsoon (June – September), were reported on the west coast of India [14]. In the marine ecosystems, the nutrient stoichiometry of the water column and in turn the bioavailability of the major nutrients play a crucial role in shaping the abundance and community composition of the phytoplankton [15]. In the present study, the lower concentration of nutrients in the reef waters during both the sampling periods reveals the oligotrophic characteristics of the reef ecosystem. The inputs from both new and regenerated production contribute towards the nutrient nourishment of the reef waters [16]. The input from river discharges also can be a potential nutrient source in reef ecosystems. However, as the Minicoy atoll is lacking any river system, the nutrient supply through river discharges unlikely. As rainfall and associated terrestrial runoff are considered to influence the nutrient nourishment of the reef community. Their role in the nutrient dynamics of the Minicoy reef waters was also assessed. Being geographically located along the south eastern coast of Indian subcontinent, the Lakshadweep Sea and associated coral Islands come under the strong influence of Indian summer monsoon [17]. Advection of nutrient rich oceanic water is also considered as a primary nutrient source of reef waters [18]. The oligotrophic condition reported in the Lakshadweep Sea during the spring inter monsoon period [19], reduces the possibility of nutrients nourishment of reef waters through oceanic water advection. Lateral advection of nutrient enrichment upwelled waters in concurrence with thermomesoscale physical process like upwelling is also considered as an important process through which reef ecosystems get nourished [17].

Nutrient rich waters, characteristics of upwelling and cold core eddy regions are often predominated by large sized phytoplankton community [20]. The competitive disadvantage faced by the larger phytoplankton under oligotrophic condition usually results in their replacement by smaller nano plankton which is considered best in utilising the low nutrient levels of oligotrophic waters [21]. As the nutrient uptake sites are more concentrated in smaller surface areas, the nano plankton with the higher surface area to volume ratio has significant contribution in the total phytoplankton biomass in the nutrient deficient waters of the Arabian Sea [22]. In oligotrophic regions, the nutrient stoichiometry of the water column often plays a major role in the size structure of the phytoplankton community [21]. Synechococcus and Prochlorococcus are picoplanktonic cyanobacteria great contribution towards the primary production in the nutrient enrich regions, including reef ecosystem [23]. Though species level analysis of the picoplankton was not carried out in the present study, these two species have been reports to dominate in the near reef region of the Arabian Sea [24]. Cyanobacteria exhibits a strong preference for grow exclusively on ammonia as their chief nitrogen source [25]. Relatively high ammonia was observed in the study region, a corresponding increase was not evident in picoplankton. Besides nitrogen, the concentration of phosphorus in oceanic waters also forms a major limiting factor determining the phytoplankton preponderance and community structure [26]. The study region evidenced a lower phosphate concentration during the sampling period. In addition to phosphate, the nano and microplankton
exhibited a positive relation with silicate concentration of silicate in the study region. Diatoms form the dominant taxa contributing chiefly to the nano and microplankton size fraction in the tropical Indian waters [27]. The conspicuous relation of silicate with the biomass of nano and microplankton during both the sampling periods can be thus validated. In the oligotrophic oceanic waters of tropical and subtropical regions, the cyanobacterium, *Trichodesmium erythraeum* plays a critical role in the atmospheric nitrogen fixation process and thus gains dominant position in the oceanic nitrogen cycle [28]. The low nutrient availability throughout the sampling area might have a led to less variable community structure dominated by diazotrophic *Trichodesmium erythraeum* capable of proliferating in the oligotrophic environment. Besides the status of coral reefs is also known to have a profound influence on the abundance and community structure of the phytoplankton community of the reef ecosystem [29]. The variation evidence in the physical environment, changes in the water chemistry of the reef waters and intern the altered coral status of the reef ecosystem resulted in the significantly distinguishable phytoplankton community between composition. The El Nino induced changes in the phytoplankton composition, biomass and community structure has been reported in reefs [30] signify the imperative effect of this climate event on the reef ecology. The phytoplankton grazers interaction also plays an important role in controlling abundance and diversity of microalgae. Plankton is a food source for a range of grazers which influence their diversity and their abundance [31].

5. Conclusion

The present study underlines the use of phytoplankton assemblages as general indicators water quality and it was clear that there is no anthropogenic disturbance occurred the lagoon water remains oligotrophic condition. Seasonal variation in the species assemblage pattern was clearly observed which were primarily regulated by environmental variables like nutrient availability and temperature variations. The premonsoon period were well suited for the flourishing of cyanobacteria and diatoms. The seasonal succession patterns were less pronounced, instead the populations responded mainly to temperature gradients. Preference of diatom population to flourish under the condition of silicate availability was in contrast to the dinoflagellates and cyanobacteria population. The physico chemical parameters play a major role for the spatio temporal distribution of phytoplankton inside and outside the lagoon waters.

Acknowledgements

We wish to express our deep sense of gratitude towards the authorities of Department of Science and Technology, Kavaratti, Union Territory of Lakshadweep, Indian Meteorological Department, Trivandrum and Faculty of Ocean Science and Technology, KUFOS for the facilities, encouragement and support.

Conflict of Interest

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

References

[1] Hessen, D.O, Elser, J.J, Sterner, R.W. and Urbø, J. Ecological Stotimetry: An elementary approach using basic principles. Limnology and Oceanography, 58(6), 2219-2236. 2013.
[2] Agnieszka, P. Phytoplankton in the ecological status assessment of European lakes – advantages and constraints. Environmental Protection and Natural Resources, 27: 26-36. 2016.
[3] Stanca, E, Cellamare, M and Basset, A. Geometric shapes as a trait to study phytoplankton distributions in aquatic ecosystems. Hydrobiologia, 701, 99-116. 2013.
[4] Smaida, T. J, Borkman, D. G, Beaugrand, G. and Belgrán, A. G. “Ecological effects of climate variation in the North Atlantic: phytoplankton,” in Ecological Effects of Climate Variations in the North Atlantic, N. C. Stenthus, G, Ottersen, J. Hurrell, and A. Belgrano., Eds., Oxford University Press. 2004.
[5] Grasshoff, K, Ehrhard, M. and Kremling, K. Methods of Seawater Analysis, Chemie GmbH, Weinheim, Germany. 1983.
[6] Zhang, J.Z, Fischer, C.J. A simplified resorcinol method for direct spectrophotometric determination of nitrate in seawater. Marine Chemistry 99(1-4): 220-226. 2006.
[7] Tomas, C. R. Identifying Marine Phytoplankton. New York: Academic Press. 1997.
[8] Leterme, S. C, Jendry, J. G, Ellis, A. V, Brown, M. H. and Kidley, T. Annual phytoplankton dynamics in the gulf saint Vincent, South Australia, in 2011. Oceanologia, 56(4): 757-778. 2014.
[9] Nassar, M. Z. Phytoplankton community structure in relation to some water characteristics in Temsah Lake, Suez Canal, Egypt. International Journal of Oceans and Oceanography, 8(2): 113-120. 2014.
[10] Al-Qatob, M, Hase, C, Tizier, M. M. and Lazar, B. Phytoplankton drives nitrite dynamics in the Gulf of Aqaba, Red Sea. Marine Ecology Progress Series, 239, pp. 233-239. 2002.
[11] Prabhahar, C, Saleshrani, K. and Enbarasan, R. Studies on the ecology and distribution of phytoplankton biomass in Kadalar coastal zone Tamil nadu, India. Current Botany, 3, 26-30. 2011.
[12] Paul, J. T, Ramaiah, N, Gauns, M. and Fernandes, V. Preponderance of a few diatom species among the highly diverse microphytoplankton assemblages in the Bay of Bengal. Marine biology, 152, 63-75. 26. 2007.
[13] Sabetta, L.A, Fiocca, L, Marginetti, F, Vignes, A, Bassett,O. and Mann,C. Body size abundance distributions of nano- micro phytoplankton guilds in coastal marine ecosystems. Estuarine, coastal and shelf science, 63: 645-663. 2005.
[14] Parab, S, Prabhu, M.S.G, Helga do, R.G. and Joaquim Goes. Monsoon driven changes in phytoplankton populations in the eastern Arabian sea as revealed by microscopy and HPLC pigment analysis. Continental Shelf Research, 26 (20): 2538-2558. 2006.
[15] Heil, C. A, Revilla, M, Gibert, P. M. and Murasko, S. Nutrient quality drives differential phytoplankton community composition on the southwest Florida shelf. Limnology and Oceanography, 52(3), 1067-1078. 2007.
[16] Szamant-Frolich, A. S. Functional aspects of nutrient cycling on coral reefs. In M. L, Reaka (Ed.), The ecology of deep shallow coral reefs (133-139). Pennsylvania: Forgotten Books. 1983.
[17] Kusum, K.K, Vineetha, G, Madhup, N.V, Anil ,P, Dayana, M, Shihab, B.K, Muhsin AI, Riyas, C, Raveendra, T.V. Variability in coral reefs (133-139) during peak and waning periods of El Nino 2016. Environmental Monitoring Assessment, 189: 653. 2017.
[18] Zhang, Y, Lin, S, Qian, X, Wang, Q, Qian, Y, Liu, J. and Ge, Y. Temporal and spatial variability of chlorophyll concentration in lake Taihu using MODIS time series data. Hydrobiologia. 661(1): 235-250. 2011.
[19] SenGupta, R, Mores, C, Kureishy, T. W, Sankaranarayanan, V. N, Jana, T. K, Naqvi, S. W. A. and Rajagopal, M. D. Chemical oceanography of the Arabian Sea: part IV-Laccadive Sea. Indian Journal of Geo-Marine Sciences, 8, 215-221. 1979.

[20] Chisholm, S. W. Phytoplankton size, Primary productivity and biogeochemical cycles in the sea. In P. G. Falkowski, & A. G. Woodhead (Eds.), New York: Plenum Press, 213-237. 1992.

[21] Sommer, U. Scarcity of medium-sized phytoplankton in the northern Red Sea explained by strong bottom-up and weak top-down control. Marine Ecology Progress Series, 197, 19-25. 2000.

[22] Garrison, D. L, Gowing, M. M, Hughes, M. P, Campbell, L, Caron, D. A, Dennett, M. R, Slappeynok, A, Olson, R. J, Landry, M. R, Brown, S. L. and Liu, H. B. Microbial food web structure in the Arabian Sea: a US JGOFS study. Deep Sea Research II, 47(7), 1387-1422. 2000.

[23] Lindell, D. and Post, A. F. Ultraphytoplankton succession is triggered by deep winter mixing in the Gulf of Aqaba (Eilat), Red Sea. Limnology and Oceanography, 40, 1130-1141. 1995.

[24] Mithavkar, S. and Anil, A. C. Tiniest primary producers in the marine environment: an appraisal from the context of waters around India. Current Science, 100(7), 986-988. 2011.

[25] Ruckert, G. V. and Giani, A. Effect of nitrate and ammonium on the growth and protein concentration of Microcystis viridis Lemmermann (Cyanobacteria). Brazilian Journal of Botany, 27, 325-331. 2004.

[26] Smith, S. V. Phosphorus versus nitrogen limitation in the marine environment. Limnology and Oceanography, 29, 1149-1160. 1984.

[27] Madhu, N. V, Balachandran, K. K, Martin, G. D, Jyothibabu, R, Thottathil, S. D, Nair, M, Joseph, T. and Kusum, K. K. Short-term variability of water quality and its implications on 20 phytoplankton production in a tropical estuary (Cochin backwaters—India). Environmental Monitoring and Assessment, 170, 287-300. 2010.

[28] Capone, D. G, Burns, J. A, Montoya, J. P, Subramaniam, A, Mahaffey, C, Gunderson, T, Michaels, A. F and Carpenter, E. J. Nitrogen fixation by Trichodesmium spp.: An important source of new nitrogen to the tropical and subtropical North Atlantic Ocean. Global Biogeochemical Cycles, 19, 2005.

[29] McKinnon, A. D, Richardson, A. J, Burford, M. A. and Furnas, M. J. Vulnerability of Great Barrier Reef plankton to climate change. In J. E. Johnson & P. A. Marshall (Eds.) Climate change and the Great Barrier Reef(pp. 122-152). Australia: Great Barrier Reef Marine Park authority and Australian Greenhouse office. 2007.

[30] Tada, K, Sakai, K, Nakano, Y, Takemura, A and Montani, S. Size-fractionated phytoplankton biomass in coral reef waters off Sesoko Island, Okinawa, Japan. Journal of Plankton Research, 25(8), 991-997. 2003.

[31] Sarnelle, O, Kratz, K. W. and Cooper, S. D. Effects of an invertebrate grazer on the spatial arrangement of a benthic microhabitat, Oecologia, 96, (2), 208-218. 1993.

© The Author(s) 2021. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).