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Ecological observations on the phytoplankton of Nethravati - Gurupura estuary, south west coast of India

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Original Article

Abstract

The species composition, abundance and diversity of phytoplankton including diatoms, cyanobacteria, dinoflagellates and planktonic green algae, were studied in the Netravathi-Gurupura estuarine waters near Mangalore, west coast of India. Water samples were collected from three different sampling sites during three different seasons over a period of one year from June 2010 to May 2011 and physico-chemical parameters of water were recorded. A total of 80 species of phytoplankton were identified out of which 54 were diatoms (67.5%), 15 were cyanobacteria (18.75 %), 6 were planktonic green algae (7.5%) and 5 belonged to dinoflagellates (6.25 %). The density of total phytoplankton ranged between 16.94x10^3 cells/l^{-1} and 28.64 x10^3cells/l^{-1}. The maximum density of phytoplankton was observed during post monsoon season coinciding with most stable hydrological conditions. Phytoplankton species diversity was also detected in different sampling stations. Shannon-Wiener's (H') diversity index of phytoplankton population ranged from 1.52 to 2.69. In addition, the species richness index (d') ranged between 0.42 and 1.98 and evenness index between 0.67 and 0.95 (J'). The diversity indices show the instability of the system particularly during monsoon because of dominance of single species. The diatoms were found to be dominant in these waters.

Keywords: *Phytoplankton, Nethravathi-Gurupura estuary, diversity, south west coast of India.*

Introduction

Estuaries are physiologically unique aquatic systems where the process of mixing of fresh and marine waters brings considerable changes in the physico-chemical properties and biological processes (Patterson and Ayyakkannu, 1991; Senthilkumar *et al.*, 2002; Prasanna and Ranjan, 2010). They are very important from the ecological and biological points of view. These ecosystems show high levels of productivity which is due to the input of nutrients by rivers and the effective mixing between sediment and surface waters. Hence estuaries act as an important natural source for studying the interactions and adaptations of organisms to wide range of environmental changes including climatic and man-induced changes. Understanding the productivity of these ecosystems will help to reduce the constraints imposed on their threatened biological resources (Badsi *et al.*, 2012). The concept of biodiversity has an important role in ecological studies because of the direct dependency of ecosystem stability on biodiversity and also these studies are essential for proper ecosystem management and conservation. The distribution and the population dynamics of phytoplankton has been reported by several workers (Dakshini and Soni, 1982; Brown, 1998; Geetha Madhav and Kondalarao, 2004; Sushanth *et al.*, 2011).

Phytoplankton is one of the basic biological components from which the energy is transferred to higher organisms through food chain. The species composition, density, relative abundance, spatial and temporal distribution of these aquatic organisms is the indication of the environmental health or biological integrity of an aquatic system. This is important in coastal ecosystems because despite their relatively small total area as compared to that of the global ocean, they play an important role in the aquatic carbon cycle (Borges, 2005). Moreover coastal ecosystem is extensively exposed to industrial and anthropogenic pollutants. Since in India, nearly 25% of the human population is living in the coastal areas, the impact of human activities on aquatic biodiversity cannot be ignored as they can influence the phytoplankton community structure. The density and the diversity of phytoplankton are also the biological indicators for evaluating water quality and the degree of eutrophication (Chaturvedi *et al.*, 1999; Shekhar Shashi *et al.*, 2008) There are evidences to show that human activities are changing the distribution and movement of major nutrient elements in the landscape resulting in increased nutrient loading to receiving waters (Dakshini and Soni, 1982; Sladecek, 1986; Onyema, 2007; Shruthi *et al.*, 2011). Earlier, studies on the variation of phytoplankton in some selected rivers and estuaries of Karnataka coast was made by Bopaiah and Neelakantan (1982), Naik *et al.* (1990), Ramesh *et al.* (1992), Andrade *et al.* (2011), Karolina *et al.* (2009) and Kaladharan *et al.* (2011). Changes in nutrient loading can alter the species composition of primary producers (Roelke *et al.*, 1999). Such changes in the primary producer community can alter the entire food web and thus the carbon and energy flow through a system. In the aquatic systems, disturbances such as changes in pollution levels, break-up of thermal stratification and changes in predation pressure modify the species composition and its diversity (Figueredo and Giani, 2001). It is therefore important to monitor the relation between changes in coastal water quality and the ecosystem response. The study include ecological parameters like species abundance, diversity index, species richness and evenness of phytoplankton such as diatoms, cyanobacteria, dinoflagellates and planktonic green algae observed in the Nethravathi-Gurupura estuary, one of the principal estuary near Mangalore in the west coast of Karnataka which could offer a scientific basis for maintaining the good health of the ecosystem and conservation of biological resources.

Material and methods

Study area

The Nethravathi-Gurupura estuary is formed by the union of the rivers Nethravathi and the Gurupura which merges into the Arabian Sea near Mangalore, Karnataka at latitude 12° 51 north and 74° 50 east. The estuary has connection with the sea throughout the year. The bottom soil is muddy and the excess siltation raises the river bed. The anthropogenic and organic wastes from Mangalore city is added to the estuary. Apart from the pollution, habitat destruction is also a major problem in the estuaries during the study period due to high degree of economic development and population density in the coast.

Sample collection and analysis

Three sampling stations were identified in the estuary. The station 1 is located at the mouth of the estuary, station 2 is at Gurupura river which is about 3 kilometers away from the mouth of estuary and station 3 is in the upstream of Nethravathi river at a distance of 2 kilometers from the mouth of the estuary (Fig. 1). Phytoplankton samples were collected by filtering 5 liters of surface water using plankton net with mesh size of 20 μm. Later it was preserved in 4% formalin, quantified by using a Neubar counting chamber and identified by referring standard manuals (Desikachary, 1987; Subrahmanyan, 1959). Sampling was made during three seasons namely, monsoon (June 2010 to September 2010), post-monsoon (October 2010 to January 2011) and pre-monsoon (February 2011 to May 2011) periods based on the southwest monsoon which is prevalent in the study area.

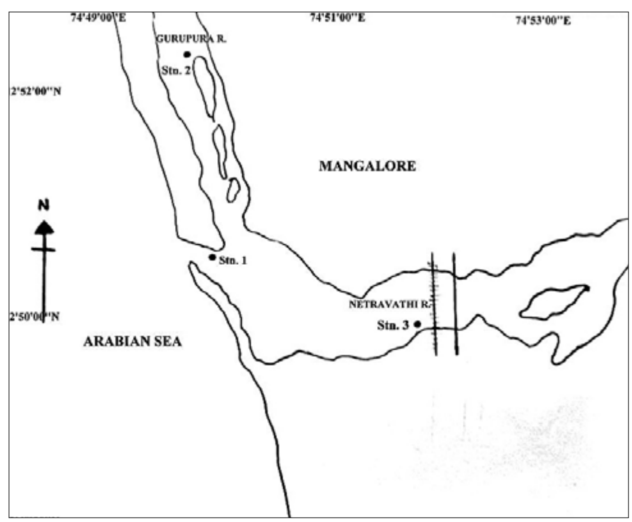

Fig. 1. Map of Nethravathi-Gurupura estuarine system showing the sampling stations.

Temperature of surface water was recorded on the spot using Centigrade thermometer. The pH, salinity and conductivity of the water samples were measured using Systronics water analyzer. The dissolved oxygen, nitrate, phosphate, silicate and sulphate concentration of the sample were analyzed according to standard methods (APHA, 1998).

Biodiversity indices such as density, species diversity, richness and evenness were calculated. For species diversity, Shannon-Wiener diversity index (H') and Margalef's species richness (d') and Pielou's Evenness Index (J') were calculated with the following standard formulae.

The diversity index was calculated by using the Shannon - Wiener diversity index H' (Shannon - Wiener, 1949).

$H = -\sum (Pi \times \ln Pi)$, Where $Pi = S / N$
s = number of individuals of one species
n = total number of all individuals in the sample
ln = logarithm to base e

Margalef's index was used as a simple measure of species richness (Margalef, 1958).

Margalef's index, $d = (S - 1) / \ln N$
s = total number of species
n = total number of individuals in the sample
ln = natural logarithm

For calculating the evenness of species, the Pielou's Evenness Index (J') was used (Pielou, 1966).

$J' = H / \ln S$
h = Shannon - Wiener diversity index
s = total number of species in the sample.

Results and discussion

The seasonal variation in the physico-chemical characteristics of water of the Nethravathi-Gurupura estuary during the study period is given in Table 1. Surface water temperature ranged from 27.5ºC to 31.5ºC during the study. The highest temperature was recorded in dry season which is influenced by the high intensity solar radiation coupled with evaporation. Lowest surface water temperature recorded in wet season may be due to the cloud over and reduction in solar radiation. The pH in the sampling stations remained slightly alkaline during the study period (7.75 - 8.50) which may be due to buffering effect of tidal sea water in the study site. Dissolved oxygen values ranged between 4.3 and 8.21 mg l^{-1}. Season-

Table 1. Seasonal variation in the physico-chemical characteristics of water of the Nethravathi–Gurupur estuary during the study period.

Season	Parameters	Station1	Station2	Station3
Pre-monsoon	Temperature (°C)	31.5±0.02	30±0.00	29±0.01
	pH	7.8±0.16	8.2±0.54	7.9±1.2
	Salinity (ppt)	28±0.26	24.5±0.5	26±0.88
	DO (mg L^{-1})	6.66±0.88	6.04±0.5	6.32±0.16
	Conductivity (mS)	25.4±1.2	36.0±5.2	29.1±3.2
	Silicate (mg L^{-1})	20.6±2.5	15.2±3.6	18.4±1.5
	Nitrate (mg L^{-1})	0.12±2.1	0.054±3.5	0.1±0.6
	Phosphate (mg L^{-1})	0.2±0.88	0.031±1.2	0.01±1.6
Monsoon	Temperature (°C)	28±0.02	27.5±0.05	28±0.00
	pH	7.75±0.9	7.9±0.02	8.16±0.5
	Salinity (ppt)	8.6±0.25	3.5±0.36	5.6±0.5
	DO (mg L^{-1})	8.02±0.04	7.82±0.45	8.21±0.08
	Conductivity (mS)	44.1±0.2	40.5±2.1	38.0±1.5
	Silicate (mg L^{-1})	32.00±2.5	48±0.45	28±3.2
	Nitrate (mg L^{-1})	2.6±1.5	0.24±2	1.02±3.1
	Phosphate (mg L^{-1})	4.02±0.8	0.5±1.6	0.15±1.5
Post-monsoon	Temperature (°C)	28±0.01	28±0.02	30±0.00
	pH	8.14±0.06	7.96±0.02	7.94±0.06
	Salinity (ppt)	19.9±0.45	18.5±2.3	20±1.5
	DO (mg L^{-1})	4.62±0.06	4.3±0.02	5.4±0.04
	Conductivity (mS)	3.84±4.2	8.65±2.5	5.16±1.6
	Silicate (mg L^{-1})	0.93±2.5	0.05±3.6	1.02±0.45
	Nitrate (mg L^{-1})	0.2±2.2	0.01±0.45	0.061±0.6
	Phosphate (mg L^{-1})	1.2±0.9	0.06±0.75	0.42±1.2

wise observation of dissolved oxygen showed an inverse trend against temperature and salinity. It is well known that temperature and salinity affect dissolution of oxygen in seawater (Vijayakumar *et al.*, 2000). Higher values during the monsoon season may be due to the combined effect of increased turbulence, agitation, higher wind velocity coupled with heavy rainfall and the resultant freshwater mixing. A low value of DO was observed during post monsoon when the temperature and salinity was high and also phytoplankton was abundant. A high degree of variation was observed in the salinity in three different seasons, which was high in premonsoon (between 24.5 and 28 ppt) and decreased considerably with the onset of monsoon (between 3.5 and 8.6 ppt). The recorded variation in the salinity values could be attributed to the influx of fresh water and dilution of estuarine waters during monsoon season which causes decrease in salinity, whereas the low rainfall, increased solar radiation causing high rate of evaporation, and the dominance of neritic water leads to increased salinity in premonsoon and postmonsoon seasons. However Karolina *et al.* (2009) have recorded salinity of water between 32-36 PSU during their study period.

Nitrate levels ranged between 0.01 and 2.6 mg/l. Levels for phosphate ranged between 0.01 and 4.02 mg l^{-1}. A similar trend in seasonal variation of physico-chemical parameters was observed by Andrade *et al.* (2011) and he recorded 9.46 mg l^{-1} of nitrates during monsoon season. High nitrate and phosphate during monsoon season may be due to fresh water influx and increased organic matter input to the system (Santhanam and Perumal, 2003). The highest phosphate and nitrate values recorded during monsoon season which may be attributed to heavy rainfall, land runoff and weathering of rocks liberating soluble alkali metal phosphates, the bulk of which are carried into the mangrove waters (Gowda *et al.*, 2001). Lower values of nutrients during other seasons may be due to the utilization of these nutrients by the phytoplankton. Silicate concentration ranged between 0.05-32.00 mg l^{-1}. Silicate concentration was very high during monsoon season reaching up to 32.00 mg l^{-1} in site 1 and it decreased considerably during post monsoon. High values during monsoon may be because of heavy influx of freshwater carrying silicate and also from bottom sediments exchanging with overlying water due to the turbulence. Low values during post monsoon suggest that silicate is actively removed from water column by diatoms.

The diatoms, cyanobacteria, dinoflagellates and planktonic green algae recorded at Netravathi-Gurupura estuary during the study period are listed in Table 2. Diatoms were the dominant organisms in all the stations throughout the study period, which could be related to the fact that diatoms could thrive well in varying environmental changes. Similar trend was also observed during the study of Kaladharan *et al.* (2011). Diatoms were followed by cyanobacteria, whereas dinoflagellates and planktonic green algae were represented by very few species during the study period.

Taxonomic distribution of phytoplankton observed in the Netravathi-Gurupura estuary during the study period is

Table 2. List of phytoplankton species recorded in Nethravathi-Gurupura estuary during the study period (+++, indicates highly abundant (> 10000 cells/l); ++, moderately abundant; (100-10000 cells/l); +, present (1-100 cells/l); -, absent)

Species	Pre monsoon	Monsoon	Post monsoon
DIATOMS			
Achnanthus brevipes	++	+	++
A. inflate	+	-	++
Amphiprora sp.	-	-	+
Amphora costata	+	+	-
Asterionella japonica	++	-	+
Bacillaria paradoxa	+	-	-
Bacteriastrum varians	-	-	+
Camphoradiscus sp.	+	+	+
Chaetoceros curvisetus	+	+	+
C. peruvianus	-	-	+
Climacosphaenia moniligera	+	-	-
Cocconies littoralis	++	-	++
Coscinodiscus curvatulus	+	-	-
Cyclotella sp.	+	+++	+
Cymbella tumida	+	+	+
Diploneis splendica	-	-	-
D. subordiculoris	+	+	+
D. lendica	+	-	+
Fragilaria oceanic	+	+	++
Gamphonema parvulum	+	+++	-
Gramatophora undulate	-	++	+
G. elongatum	+	+	-
G. balticum	-	+	+
Leptocylindricus sp.	-	-	-
Licmophora gracillis	+	-	+
Licmophora sp.	-	-	-
Mastogloia splendia	-	+	-
Melosira numuloides	++	+++	+
Melosira striata	+	+	-
Navicula inflexa	-	+++	+
N. smithii	+	+++	-
Navicula sp.	-	+	+

Nitzchia frigid	+	+	-
N. lanceolata	-	+++	-
N. paleacea	+	+	++
N. panduriformis	-	+	+
N. pungens	-	-	+
N. sigma	+	-	-
Nitzschia sp1	-	+++	+
Nitzschia sp2	-	-	-
Pinularia viridis	+++	-	+
Pinularia sp.	-	-	+
Pleurosigma anqulatum	+	+++	+
P. elongatum	+	-	+
P. delicatum	+++	+	-
Pleurosigma sp.	+	++	+
Progonoia sp.	+	-	-
Pseudo-nitzschia sp.	+	++	+
Raphoneis sp.	+	-	+
Rhizosolania alata	-	-	+
R. robusta	-	-	+++
Rhizosolenia sp.	+	+	-
Skeletonema costatum	+	-	++
Synedra sp.	-	-	-
Thallassiothrix longissima	+	-	+
Thalassiosira sp.	-	+	+
Triceratium sp.	+	-	+
CYANOBACTERIA			
Anabaena sperica			
Chroococcus sp.	-	-	++
Lyngbya martensiana	++	+	+
Merismopedia sp.	+	-	+++
Microcystis aureginosa	-	++	-
Oscillatoria animalis	+	-	-
O. cortiana	-	-	+
O. lemnetica	+	-	+
O. limosa	+	-	+
Oscillatoria pseudogeminata	+	-	-
O. brevis	-	++	-
Oscillatoria salina			
Oscillatoria tenius			
Phormidium angustissimum	+	-	+
Phormidium lucidu	-	-	+
P. tenue			
Plectonema boryanum	++	+	+
Synechocystis salina	+	+	+
DINOFLAGELLATES			
Cerecium minutum	+	-	+
Cerecium sp.	+	-	-
Dinophysis coudata	-	-	+
Noctiluca scintillans	-	+	+
Prorocentrum micans	+	-	+
PLANKTONIC GREEN ALGAE			
Chlamydomonas sp.	-	-	+
Chlorella sp.	-	++	-
Pediastrum boryanum	+	+	-
Pediastrum sp.	-	+	+
Spirogyra sp.	+	-	+
Ulothrix sp.	-	+++	-

shown in Table 3. Of the total 85 species of phytoplankton identified during the study period, 56 (67.66%) were diatom species, 18 species (32.14 %) belonged to cyanobacteria, 6 speceis (7.85%) were planktonic green algae and 5 species (5.88 %) belonged to Dinophyta. The distribution of these phytoplankton varied considerably with seasonal changes. The distribution and abundance of phytoplankton in tropical waters varied remarkably due to seasonal fluctuations and these variations are well pronounced in sheltered systems of estuarine waters (Perumal *et al.*, 2009). Phytoplankton was abundant in each site during pre-monsoon and post-monsoon season which may be due to the stability of the water column. When the salinity and other hydrological parameters are in stable condition, the phytoplankton production will be more which was observed by Rajesh *et al.* (2002). Palnktonic green algae were abundant during monsoon which may be due to the prevalence of fresh water (EKWU and SIKOKI, 2006). Abundance of other phytoplankton were lowest during monsoon season which may be because of abrupt changes in the environmental conditions, decreased salinity and temperature i.e., increase in volume, dilution with river discharge and hence the scattered distribution. (Perumal *et al.*, 2009). Also during rainy season the phytoplankton community might have been collapsed due to heavy flood; on the other hand cloudy weather and low transparency of water column during this period might be the reason for decline in phytoplankton number. Among diatoms, *Achnanthus brevipes, Cymbella tumida, Navicula smithii, Gyrosigma elongatum, Rhizosolania robusta, Nitzschia* sp and *Skeletonema costatum* were most abundant in nonmonsoon seasons, while *Cyclotella* sp., *Gamphonema parvulum, Navicula* sp., *Nitzschia paleacea* and *Pleurosigma anqulatum* were found abundantly during monsoon. Among cyanobacteria, *Oscillatoria tenius, Merismopedia* sp and *Plectonema boryanum* were found in large numbers during premonsoon and postmonsoon seasons. During monsoon,

Table 3. Taxonomic distribution of phytoplankton in the Nethravathi-Gurupura estuary

Groups	Diatoms	Cyanobacteria	Dinoflagellates	Green algae	Total
Order	20	6	4	5	35
Family	26	6	4	5	41
Genera	33	9	4	5	51
Species	54	15	5	6	80

planktonic green algae like *Chlorella* and *Ulothrix* were found in abundance. Dinoflagellates were represented by very few numbers in all the sites throughout the study period.

Among all the stations, maximum density was recorded at station 3 ($28.64x10^3$) during monsoon season and minimum density of $16.94x10^3$ was seen at station 3 during pre-monsoon season (Table 4). The highest density during monsoon at station 3 may be due to the prevalence of few species of diatoms including *Gamphonema parvulum, Navicula* sp., *Nitzschia paleacea* and *Pleurosigma anqulatum* and planktonic green algae like *Chlorella* sp. and *Ulothrix* sp. conditions and such species could grow well and dominate the phytoplankton community. Diversity decreases when one or a few groups dominate in a community, when individuals of a more common group replace individuals of a rare group or when one or a few groups rapidly reproduce. (Robin *et al*., 2010). Among the stations, highest diversity, species richness and the evenness was recorded in station 1 and lowest was recorded in station 2. According to the data presented by Robin *et al*. (2010), the highest phytoplankton species richness, species diversity and species evenness are the characteristic feature of the Karnataka coastal waters.

Table 4. Diversity index, species richness, evenness and density of phytoplankton population in different sampling stations during different seasons. N density, cells/l; H', Shannon-Wiener diversity index; d, species richness; J, Pielou's evenness

Season	Pre-monsoon			Monsoon			Post-monsoon		
	Station								
	1	2	3	1	2	3	1	2	3
N	$21.30x10^3$	$19.25x10^3$	$16.94x10^3$	$18.25x10^3$	$18.58x10^3$	$28.64x10^3$	$22.36x10^3$	$20.14x 10^3$	$21.56x 10^3$
H'	2.35	1.82	2.05	2.08	1.52	1.62	2.69	2.09	2.22
d	1.55	0.53	1.52	0.69	0.42	0.82	1.98	0.57	1.16
J	0.92	0.85	0.88	0.82	0.76	0.67	0.98	0.89	0.95

The high diversity index was observed during post monsoon and it was low in the monsoon (Table 4). The low index value might be the indication of lack of species richness. A high value of diversity index generally implies healthy ecosystem, while a low value indicates degraded state (Manna *et al*., 2010). The diversity index and the species richness showed least values during monsoon season but were higher in the other seasons in all the stations. This may be due to the stable hydrographical condition during non monsoon seasons which support the growth and survival of most of the species. Rajagopal *et al*. (2010) reported that the low value of Shannon's index of phytoplankton population in rainy season is due to dilution of water in the vicinity. Species diversity would be low following the disturbances such as flood (Bajpai and Agarkar, 1997). In our study, some of the diatoms like *Cytocella* sp., *Navicula* sp., *Nitzschia paleacea* and *Pleurosigma anqulatum* were dominant during monsoon season. This may be because of some species of diatoms which are highly resistant to abrupt changes in environmental

In conclusion, phytoplankton abundance, density, diversity and distribution are subjected to changes because of variation in the hydrological conditions in coastal waters. Generally, large variations in phytoplankton species composition are often a reflection of significant alteration in ambient conditions within an ecosystem. Therefore a frequent monitoring of the coastal ecosystem with respect to its hydrological conditions and biological composition is essential to know the health of the ecosystem. The present study could provide baseline information on phytoplankton abundance and diversity and its response to seasonal changes which could be a useful tool for further ecological assessment and monitoring of the coastal waters of estuary.

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