

Monsoonal Variability in Abiotic Parameters in Coastal Waters off Trivandrum Evokes Press and Pulse Response in Biotic Variables **

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Abstract

*Trivandrum Coast experiences coastal upwelling during south west monsoon, which is accompanied by abiotic changes in physio-chemical parameters. The resultant biotic responses could range from an instantaneous pulse to a sustained press reaction. In order to understand the type of biotic responses at primary and bacterial level, temporal variation in physico-chemical and biological parameters were measured at 4 depths off Trivandrum coast during monsoon and compared to non monsoon seasons. One way ANOVA showed significant variation in environmental parameters with time during monsoon. Principal component analysis of the abiotic variables revealed salinity, nitrite and nitrate to be the three driving attributes of the coastal waters during the upwelling period whereas during the post monsoon period nitrate was the only attribute. Nitrate concentration ranged from 7.5 to 15.3 μM and 0.7 to 14 μM in the monsoon and post monsoon seasons respectively. During the monsoon season, chlorophyll *a* and phaeophytin concentrations were 1.5 ± 1.2 and 1.3 ± 0.9 mg l^{-1} respectively. These concentrations were 11 and 16 fold higher than the pre monsoon reflecting a pulse response. Canonical correspondence analysis (CCA) showed that the factors responsible for this pulse response were nitrate, nitrite and silicate. However, unlike chlorophyll, bacterial variables showed both short term pulse and long term press reaction off Trivandrum coast.*

Introduction

The surface water of the Somalian coast, eastern edge of Arabian Peninsula and the southwest coast of India are pushed away by the winds from southwest to northeast during the south west monsoon. The west

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coast coastal waters off Trivandrum are the most affected by the monsoonal coastal upwelling during south west monsoon as the process starts from this region and moves northward. The coastal waters are displaced off the shore by the cool nutrient rich water from the bottom layers (Prasanna Kumar *et. al.*, 2001). This causes a turbulent mixing of water masses which alters the stability of the system which brings change in physical and chemical variables which is accompanied with changes in the biotic parameters. Biotic parameters primarily show two types of responses. The pulse response is a brief relatively instantaneous response in a system which may subside later. In contrast, press response is gradual and sustained for a while in a system (Scheffer *et. al.*, 2008). Interestingly, some variables show dual response simultaneously. A quick response is followed by a reaction that lasts for a relatively longer time. Habeebrehman *et. al.*, (2008) have demonstrated that the nutrient uptake and community structure of phytoplankton exhibit both short term and long term changes during upwelling period in west coast of India (Habeebrehman *et. al.*, 2008). However, the studies on the type response of chlorophyll and bacterial parameters to abiotic parameters are limited. In this study, we assume that the *coastal system is relatively stable during pre monsoon and post monsoon seasons* and hypothesize *that upwelling events during monsoon would bring about changes in biotic parameters and the responses would be different.*

Materials and methods

The study station was off Trivandrum Coast, South West of India (N 8° 26.04', E 76° 30') in the eastern Arabian Sea. Water samples were collected from 4 depths using 10 L Niskin bottles at 6 hour interval during monsoon (June) and post monsoon (November), 2010 onboard ORV Sagar Sampada 276 and 282. Pre monsoon sampling was carried out just before the onset of monsoon in May 2010 onboard CRV Sagar Sukti.

Salinity and temperature were measured by a conductivity-Temperature-Depth CTD. Dissolved oxygen concentration was measured using the Winkler's titrimetric method (Strickland and Parsons, 1965). Samples were analyzed onboard using a Dosimeter (Metrohm 785 DMP Titrimetric). Nutrient analysis was carried out using an onboard SKALAR auto analyzer as described by Wurl (2009). For pigment analysis, one litre of water sample was immediately filtered using a glass fibre filter paper

(Whatmann GF/F, 0.7 μ M pore size). For extraction of pigments (chlorophyll *a* and phaeopigments), the thawed filters were treated with 10ml of 90% acetone and kept in dark for 24 h at 4°C. Extract was centrifuged at 5000 rpm and the clear supernatant was measured fluorometrically based on the method developed by Yentsch and Menzel (1963). For determining total count (TC), 5ml water sample was immediately fixed with formaldehyde (2.5% final concentration) and stored at 4°C until analysis. Total viable count (TVC) was estimated according to Kogure *et. al.*, (1979). For total and viable bacterial counts, fixed water samples were stained for 5 min with acridine orange (final concentration 1%) and filtered on black nuclepore membrane filters (Millipore, 0.2 μ m pore size) using the methodology of Hobbie *et. al.*, (1977). Cell counts were made using epifluorescence microscopy (Olympus Fluorescent Microscope Model BX61).

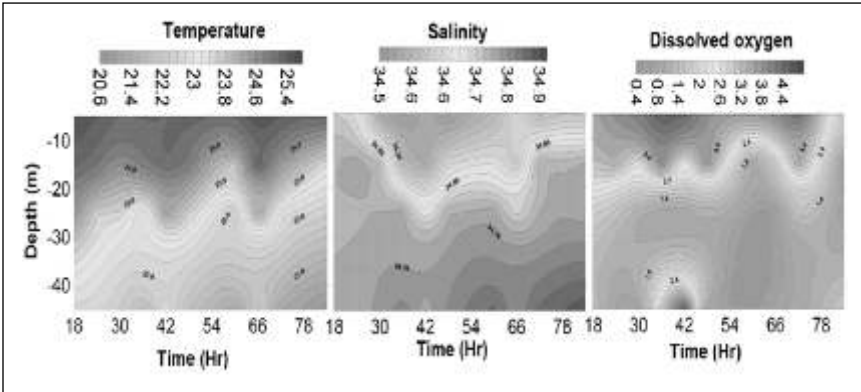
Biological data was log transformed for statistical analysis. One way ANOVA was carried out to confirm temporal variation. Principal component analysis was used to find out the major component responsible for the variation in the abiotic parameters. Canonical correspondence analysis (CCA, Multi Variant Statistical Package, Kovacs computing Services) was done to elucidate the relationships of different bacterial groups with abiotic (environmental) variables. Correlation was done using Statistica (Statsoft) to highlight the extent of significance in the relationship between the parameters.

Result and Discussion

During south west monsoon, the wind driven upwelling along the coast brings cooler nutrient rich water to surface. This causes both spatial and temporal variation in the abiotic parameters (Sharma *et. al.*, 2000). Over the 3 days period during monsoon, temperature ranged from 20.7°C to 25.6°C. Towards the end of the time series, a gradual cooling trend was noticed (Fig. 1).

Warmer surface water at the start of the sampling was found to be displaced by the cooler water from the deeper layer. Salinity also showed significant temporal variation during monsoon with an increase from 34.7 \pm 0.02 to 34.8 \pm 0.12 in three days period. Dissolved oxygen content in the water was found to decrease to low level in subsurface layer from 3.1 to

Fig 1



0.6 ml l⁻¹ as upwelling progressed. This is in accordance with reports made by Maheswaran *et. al.*, (1999). Nutrients such as nitrate, phosphate and silicate showed temporal variation relative to post monsoon season. The average values of abiotic parameters are shown in table 1.

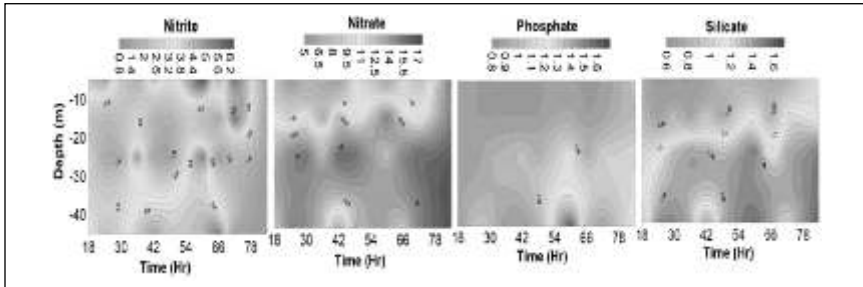
Table 1

Parameter	Mean
Temperature (°C)	23.4 ± 0.5
Dissolved Oxygen –DO (ml l ⁻¹)	2.3 ± 1.4
Salinity	34.7 ± 0.1
Nitrite - NO ₂ (μM)	2.9 ± 1.5
Nitrate- NO ₃ (μM)	11.9 ± 3.4
Phosphate- PO ₄ (μM)	0.9 ± 0.2
Silicate - SiO ₂ (μM)	1.1 ± 0.3

Average Concentration of abiotic parameters during monsoon period

Nitrite which is an intermediate in the reaction did not show any variation (Fig. 2). Nutrient concentration was higher in the deeper layer during the first day which moved to the surface in the following days (Fig. 2).

Fig 2



Surface nitrate concentration increased from 8.4 to 15.3 μM . Similar changes in nutrient concentrations were observed by several authors (Pie, et. al., 2009; Smith, 1984 and the references therein). Thus the distribution of physical and chemical parameters during monsoon season suggested coastal upwelling during the study period, an observation made as early as the sixties by Armstrong et. al., (1967). During monsoon season, nitrate, nitrite and salinity showed influence which may be due to the mixing of water masses during upwelling which would have created heterogeneity in the physical as well as chemical parameters. First two axes of PCA showed 99.1 % variation in the system (Table 2).

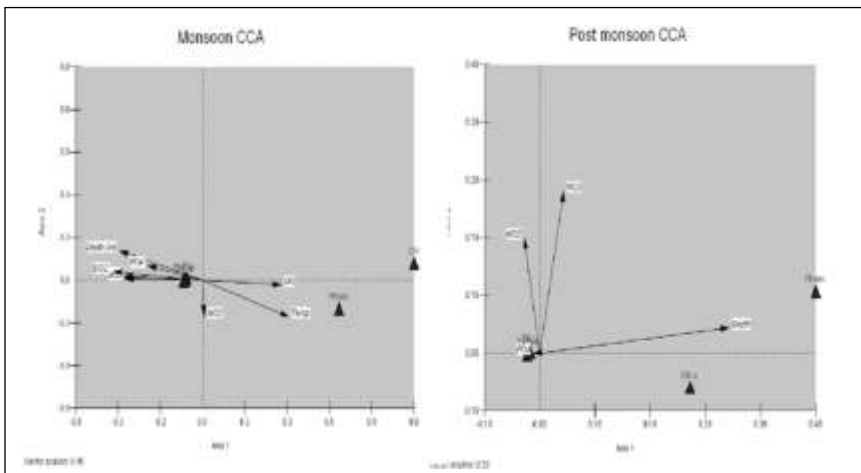
Table 2

Parameter	Monsoon		Postmonsoon	
	Axis 1	Axis 2	Axis 1	Axis 2
Depth	0.99	-0.14	1.00	-0.09
Temperature	-0.09	-0.04	-0.02	-0.01
Salinity	-0.06	-0.28	-0.02	-0.01
DO	0.01	0.00	0.00	0.00
NO ₂	0.00	-0.36	0.00	0.03
NO ₃	0.13	0.88	0.09	1.00
PO ₄	0.01	0.01	-0.00	-0.01
SiO ₂	0.02	0.04	0.00	0.00

PCA variable loading of abiotic parameters

Nitrate, phosphate and silicate showed highly significant correlation with each other ($p < 0.001$). This may be due to the same source as these nutrients are liberated by the bacterial decomposition of organic matter in the sediment and is brought to surface by the upwelled waters (Alvarez-salgado et. al., 1997). During post monsoon, depth and nitrate were the major contributing factors and the two axes of PCA contributed 99.89 % variation in the system stability. The lesser supply of nutrients in post monsoon is attributed to the relaxation in wind field which reduces the Ekman pumping of deep water to surface of coastal waters (Habebrehman et. al., 2008). Though 99.1 % variation was due to nitrate, nitrite and salinity in the system during monsoon, temperature, dissolved oxygen, and silicate also contributed upto 99.63 % of the variation for biotic parameters (Fig. 3).

Fig 3

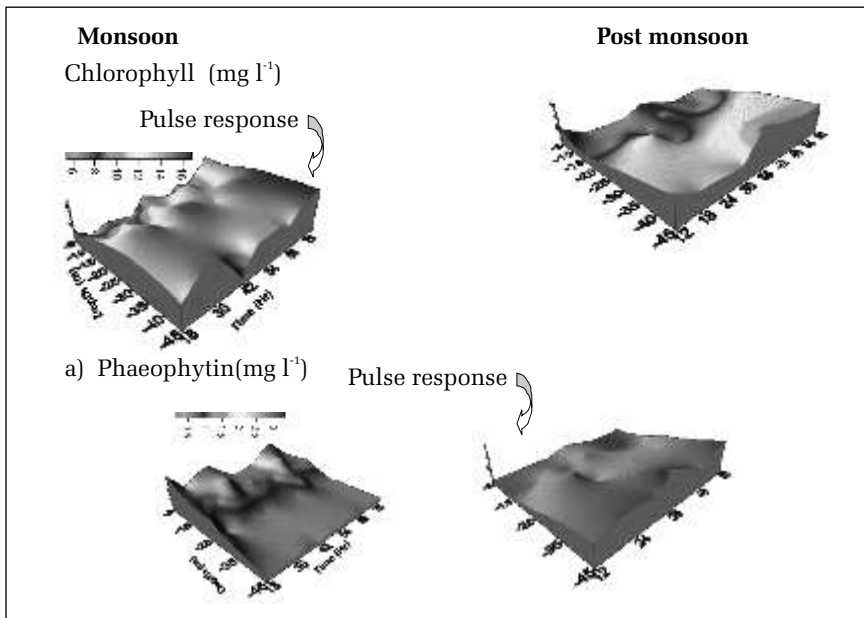


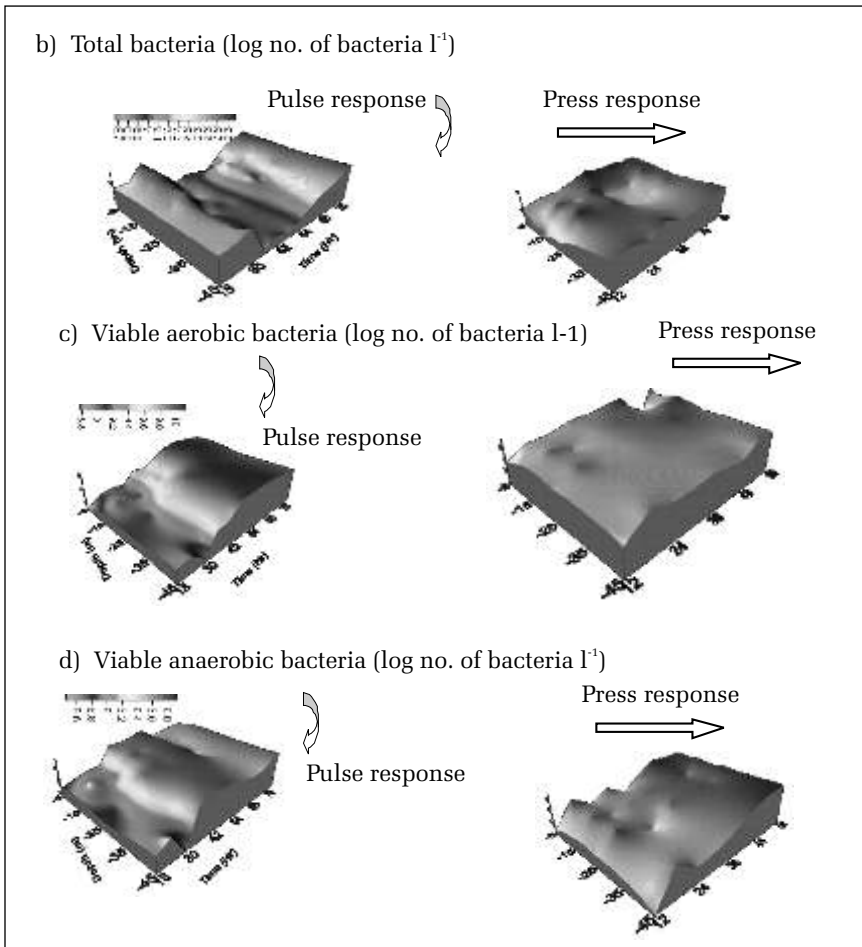
A strong relationship between chlorophyll a and nitrate has been explained by several researchers, (Qasim and Joseph, 1975; and Banse, 1987; Smith, 1984; Smith and Codispoti, 1980 and Mc Issac *et. al.*, 1985) suggesting that the physiological adjustment of phytoplankton to changing environment causes temporal changes in the nitrate uptake.

During post monsoon season, nitrite, nitrate and phosphate were the major driving force for the biotic variation (Fig. 3). These parameters contributed to 99.4 % variation in the biotic parameters. The interactions among nutrients and planktonic organisms are the keys to elucidate

biological productivity of ocean. Such Strong relationships between prevailing physical conditions and biological response in Arabian Sea have been reported earlier by Banse (1987) and Brock *et. al.*, (1994). The average values of chlorophyll and phaeophytin showed an increase from pre monsoon ($0.15 \pm 0.04 \text{ mg l}^{-1}$ and $0.1 \pm 0.04 \text{ mg l}^{-1}$ respectively) to monsoon season (1.5 ± 1.4 and $1.3 \pm 0.9 \text{ mg l}^{-1}$ respectively) and then started to decline (Fig. 4). The chlorophyll: phaeophytin ratio decreased from premonsoon (1.5) to unity in monsoon season and increased rapidly to 3.1 in post monsoon. The equilibrium state generated between chlorophyll and phaeophytin in the monsoon is shifted to chlorophyll fraction during post monsoon. This change may be attributed to the increase in nutrient concentration aided by monsoonal upwelling which favours phytoplankton growth and subsequent reproduction. Moreover, dilution of micro zooplankton caused by the vertical mixing has been reported to allow phytoplankton to escape grazing and grow (Marra and Barber, 2005). This factor also adds to the increase in phytoplankton biomass during monsoonal upwelling. The declining phase followed and the concentrations were lowest in post monsoon season (Fig. 4). With time phaeophytin started sinking and during post monsoon season, higher concentration was found at the deeper layer.

Fig 4





The total bacteria showed two order increase in their abundance from pre monsoon ($1.2 \pm 0.3 \times 10^7 \text{ l}^{-1}$) to monsoon season ($2.9 \pm 2 \times 10^9 \text{ l}^{-1}$) and showed a marginal increase from monsoon to post monsoon ($6.8 \pm 2.4 \times 10^9 \text{ l}^{-1}$). This shows that bacteria respond to the increase in nutrient concentration within a month. The bacterial abundance was found near the upper limit of 10^{7-10} l^{-1} in the sea water as reported by Azam and Smith (1991) and the further increase in bacterial abundance was reduced, perhaps due to the competition and / or antagonism among bacterial species, zooplankton grazing or viral lysis (del Giorgio and Scarborough, 1995).

In this study, phytoplankton pigments showed a sudden increase due to the changes in the system but subsided when the disturbance or the causing factor reduced. But the bacteria in the water column showed a two

order increase relative to pre monsoon season during monsoon and a gradual response even after the removal of causal effect. So phytoplankton pigments showed a pulse response and bacteria showed a pulse and press response due to the variability of abiotic parameters. The response was evident in three months but the daily observation for three days did not show any obvious response. This study suggests that high nutrient concentration and the heterogeneity in physical parameters evoke dual response in biotic variables in the coastal waters off Trivandrum during monsoon season. Further studies on inter annual comparison could be carried out to explore the mechanism of response and whether it would continue to increase the following years or revert to the original state. In addition, studies could be complemented with the identity of the organisms forming the community to appreciate inter and intra species linkages and their response.

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