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Impact of torrential rain on coastal ecosystem at kalpakkam, southeast coast of India

A.K. Mohanty*, M. S. Achary, Gouri Sahu, R.K. Padhi, M.K. Samantara and K.K. Satpathy

Environment Safety Division, Indira Gandhi Centre for Atomic Research, Kalpakkam, India

*[E-mail: ajit@igcar.gov.in]

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The present study focuses on the drastic changes observed in the coastal ecosystem at Kalpakkam during flooding event due to huge rainfall that occurred in and around northern Tamil Nadu during December 2015. A significant increase in hydrological parameters (nitrate, phosphate, silicate, total nitrogen and phosphorous) was recorded as compared to previous years (2006-2014). In the present instance, the coastal water salinity which was about 19 psu was the lowest as compared to the data available since 1979. The phytoplankton population density was severely affected by the runoff. The present observed density 1.4 x 10^4 cells l^{-1} was the lowest among the available data at this coast. Availability of green algae species in the coastal waters was significantly high (10 species, 17 % of total species) as compared to previous reports. One of the most interesting features of this study was the observation of epibiosis on zooplankton in massive numbers. A comparison of previous occurrences of epibiotic relationship in plankton community with the present observation showed a staggering increase in epibiosis to 38 % of zooplankton species as compared to 5-13 % during 2008-2014.

[Keywords: Coastal waters; Plankton; Rainfall; Epibiosis; Bay of Bengal]

Introduction

Marine coastal ecosystems are vulnerable to various natural and anthropogenic disasters. These events can impact or degrade the health and productivity of the marine ecosystem by destroying habitats, altering circulation patterns, and introducing pollutants into it. It has often been noticed that the coastal ecosystem is significantly affected either through a continuous process of anthropogenic interference or through sporadic highly intense natural events. Plethora of literatures in this regard are available which show the drastic impacts of tsunami, cyclones, industrial discharges, riverine inputs, mine discharges, sewage inputs and volcanic eruptions on physico-chemical properties, coastal productivity, plankton composition, pollutant levels, coral mortality etc have been reported following natural events of high magnitude[1,4]. During the period 30th November to 2nd December, 2015; Kalpakkam coast and many parts of the east coast of India experienced torrential rain of about 600 mm which caused a severe flooding.

Kalpakkam coast (12° 33' N Lat. and 80° 11' E Long.), an important nuclear hub of India, is situated about 80 km south of Chennai (**Fig. 1**). Edaiyur and the Sadras backwater systems are important features which are connected to the Buckingham canal that

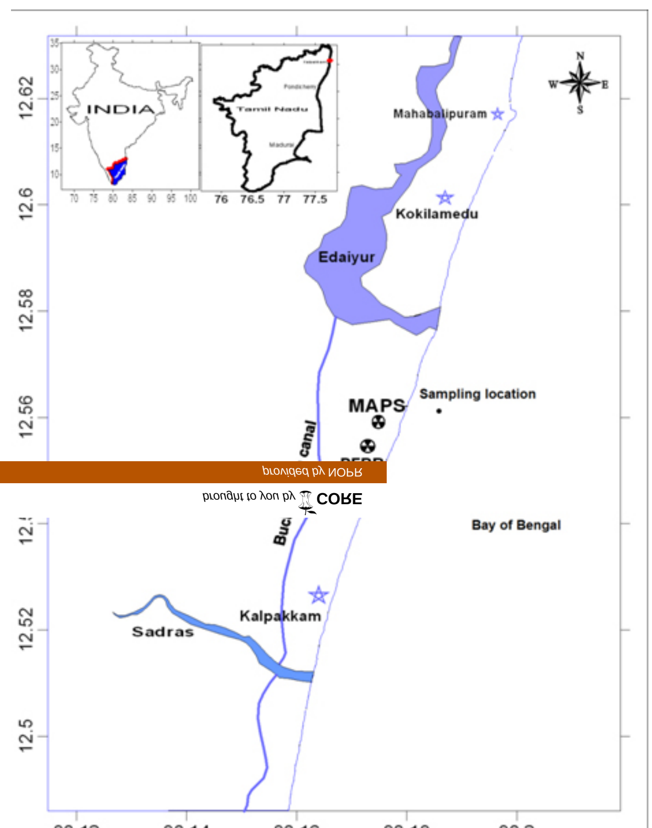

Fig. 1 — Study area showing the sampling location in the coastal waters of Kalpakkam

runs parallel to the coast. The whole year has been divided into three seasons viz: 1) Summer (February-June), 2) Southwest (SW) monsoon (July-September) and 3) Northeast (NE) monsoon (October-January)[5] based on the pattern of rainfall and associated changes in hydrographic characteristics at Kalpakkam coast. Seasonal monsoon wind reversal, a unique feature of Indian Ocean that results in subsequent changes in the coastal circulation pattern[6], is also felt at this location. The coastal current which is pole-ward during SW monsoon changes to equator-ward during the SW to NE monsoon transition, whereas, a reverse current pattern is observed during the NE to SW monsoon transition period[7,8]. The two backwaters along with Palar River (remains dry for most of the year) open into the coast discharging copius amount of freshwater to the coastal milieu for a period of 2 to 3 months during the NE monsoon period. However, the littoral drift during the post-monsoon period causes formation of sand bar between the backwaters and sea, leading to stoppage of low saline water inflow from the backwaters to sea.

Material and Methods

The present study focuses on the drastic changes observed in the coastal ecosystem during a heavy rainfall and flooding event that occurred in and around northern Tamil Nadu coast during December 2015. In general, this part of the peninsular India receives an annual rainfall of 1200 mm. About 60 % of the precipitation is received during the northeast (NE) monsoon period (October to January) and about 30 % during southwest (SW) monsoon period (June to August) and the remaining during the rest of the year. During the present study, 633 mm rainfall was received in the month of December 2015. It caused a massive flooding event that impacted the coastal population of northern Tamil Nadu, especially the Chennai region. To find out the impact of the massive quantity of freshwater discharge into the coastal waters, samples were collected from coastal waters of Kalpakkam (~70km south of Chennai) thrice in an interval of 5 days during 1st -15th December 2015.

The samples were collected about 500 m inside sea at the jetty of Madras Atomic Power Station (MAPS) (**Fig. 1**). Winkler's titrimetric method[9] was followed for the estimation of dissolved oxygen (DO). Salinity measurements were carried out by Knudsen's method[9]. Turbidity of the water samples was measured by turbidity meter (CyberScan IR TB 100) having ± 0.1 NTU (nephalometric turbidity unit) accuracy. pH measurement was carried out by a pH meter (CyberScan PCD 5500) with ± 0.01 accuracy. Samples for nutrient analysis were filtered through 0.45 µ Millipore filter paper and preserved at -20 ^{o}C and analyses were carried out within 2-3 days of collection. Dissolved micronutrients such as nitrite, nitrate, ammonia, silicate, phosphate along with TN and TP were estimated by spectrophotometric method following standard procedures[9,10]. Chlorophyll-*a* (chl-*a*) was analyzed by spectrophotometry following the method[10]. For all the spectrophotometric analyses, a double beam UV–Visible Spectrophotometer (Chemito Spectrascan UV 2600) was used. The phytoplankton density was estimated using Utermohl's sedimentation technique[11] and counted using Sedgwick Rafter cell with the aid of inverted microscope (Zeiss Axiovert 40) using magnification up to 1000 X. Phytoplankton was identified following standard taxonomic monographs[12,16]. Zooplankton samples were collected by horizontal hauling using conical plankton net (mesh size- 200 µm) fitted with a flow meter. Zooplankton samples were preserved with 5 % neutralized formaldehyde and then examined for quantitative as well as qualitative aspects using zooplankton counting chamber at magnification of 200 X under an inverted microscope. Zooplankton identification was carried out by using standard literatures[17,20]. The larger organisms were sorted out from the sample and counted separately. The zooplankton density was presented in terms of organisms per m^3. It is worthwhile to mention here that as part of our regular monitoring programme, coastal water quality and plankton dynamics has been monitored continuously since the year 2006 and thus, the previous data available were used for a comparison with the present event. For this purpose, average of parameters for 2006-2014 was used against the present observed value.

Results and discussion

Annual variations in coastal water quality

The annual coastal water temperature at Kalpakkam ranged from 25.4 to 31.5^{o} C with relatively high values observed during post-monsoon months. Water pH (7.9-8.4) did not show any specific seasonal trend. Salinity values ranged from 25.45-35.97 psu. It showed a significant seasonal trend with the minimum and the maximum salinity being observed during NE monsoon and summer period, respectively. Dilution of coastal water by addition of fresh water from the two backwaters coupled with the precipitation during NE monsoon period could be the reason for lower salinity values observed during monsoon. The DO contents varied between 4.5-7.6 mg l^{-1}. Relatively high DO contents were observed during pre-monsoon and monsoon periods as compared to post-monsoon period.

The annual variations of both nitrite (BDL-5.88μ mol l^{-1}) and nitrate (BDL to 9.18 μ mol l^{-1}) did not show any particular seasonal trend of distribution, though most of the post-monsoon observations were relatively low as compared to other two seasons. Ammonia concentration did not show any typical trend and BDL values were observed on many occasions. It ranged from BDL-11.74 μ mol l^{-1}. Total nitrogen values did not show any seasonal trend. TN concentration ranged from 3.74- 47.68 μ mol l^{-1}. Phosphate concentration ranged from BDL – 2.29. Like the nitrogenous nutrients, phosphate also did not show any seasonal trend. TP concentrations ranged from 0.14 - 3.24 μ mol l^{-1}. It showed a similar trend as that of the phosphate. Silicate concentration ranged from 2.33-25.40 μ mol l^{-1}. Fresh water input from the backwaters into the coastal water and surface runoff could be the reason for the observed higher values during monsoon period. Chl-*a* content of coastal waters ranged from 0.28- 14.46 mg m^{-3}. It showed a clear seasonal trend with relatively high values during pre-monsoon and low values during monsoon and post-monsoon periods. Chl-*a* values observed during the present study was in the following order: monsoon < post-monsoon < pre-monsoon. Its concentration decreased significantly during NE monsoon period, which could be due to unfavourable conditions for phytoplankton growth due to reduction in salinity.

Impact of torrential rain on coastal water quality

It has been reported by several studies[6,21] from this locality that coastal waters at Kalpakkam region show a significant change in its physico-chemical and biological properties during NE monsoon period. However, in the present instance changes were of high order as compared to the previous 9 years average data for the same period. Though, the variations in water temperature, pH, dissolved oxygen and chlorophyll-a showed very little difference with respect to previous year measurements (**Fig. 2**), values of salinity (18.62 ± 6.13 psu), nitrate (8.01 ± 8.69 μmol l^{-1}), total nitrogen (29.22 ± 7.71 μmol l^{-1}), phosphate (4.09 ± 8.17 μmol l^{-1}), total phosphorus (5.34 ± 10.68 μmol l^{-1}) and silicate (64.12 ± 35.23

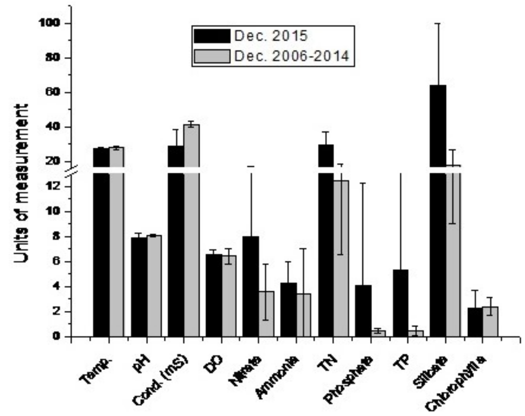

Fig. 2 — Variations in physico-chemical (temperature in °C, conductivity in mS sec-1; all nutrients in μmol l^{-1}) properties and chlorophyll-a (mg m^{-3}) concentration in the coastal waters of Kalpakkam (December 2015- average values measure during the present study; December 2006-2014: average value of parameters in the month of December during 2006-2014)

μmol l^{-1}) were significantly high as compared to 2006-2014 average values (salinity: 26.80 ± 5.82; nitrate: 3.58 ± 2.24; total nitrogen: 12.50 ± 5.96; phosphate: 0.44 ± 0.20; total phosphorus: 0.58 ± 0.37 and silicate: 17.75 ± 8.73). The most fascinating change observed was with respect to salinity, the single important parameter that affects every physico-chemical and biological process in sea. Its value decreased abysmally to 18.62 psu which of course was recorded not on the heaviest rainfall day but 3-4 days after it, clearly manifesting the freshwater discharge into the coastal milieu. Above results clearly indicated that, massive input of nitrogen, phosphorus and silica took place during the flood through land drainage and runoff. Moreover, considerably high TN and TP concentration observed during the present study also indicated the transfer of organic form of these nutrients from the terrestrial system to the aquatic ecosystem. A similar study[2] reported significant fluctuations in hydrographical parameters like salinity, dissolved oxygen, chemical oxygen demand and significant enrichment of inorganic nutrients in the coastal waters of Visakhapatanam, during the post cyclone (‘Hudhud’) event which was attributed to land runoff that included domestic and sewage wastes. Another study in this regard[1] has also revealed an increase in micronutrient concentrations in the Sundarban wetland ecosystem after the post severe cyclonic storm ‘Aila’. Moreover, similar enrichment of nutrients has also been reported during the post-tsunami (December 2004 tsunami) period by several workers[22,24], which were attributed mainly to the inundation of land adjoining the coast that carried all the contaminants into the sea.

Impact on phytoplankton community structure

The phytoplankton population density was severely affected by the runoff during December 2015 (**Fig. 3**) unprecedented precipitation. The present observed density 1.4 x 10^4 cells l^{-1} was the lowest among the available data at this coast. It was observed that, the phytoplankton density decreased with increase in rainfall (**Fig. 3**) which was further supported by the strong negative correlation ($r = 0.892$, $p \geq 0.001$) between the two. Generally the phytoplankton density at Kalpakkam varies from 2-5 X 10^5 cells l^{-1} during the non-monsoon months (February to September)[25,26]. However, during NE monsoon period the population density decreases by one order of magnitude[25,26]. Though, the coastal water at this location becomes nutrient rich during NE monsoon period, prevalence of low salinity due to dilution effect adversely impacts the phytoplankton growth and reproduction during this period[4,6]. In the present instance, the coastal water salinity which was about 19 psu was the lowest as compared to the data available since 1979. Thus, the phytoplankton population adapted to a typical coastal water salinity of about 30 psu could not have thrived at such a low salinity[6,23]. Interestingly, though the population density showed a significant variation, number of phytoplankton species did not vary considerably as compared to previous years (**Fig. 4**). This could be attributed to the fact that, the availability of green algae species in the coastal waters was significantly high (10 species, 17 % of total species) during the present study (**Table 1**) as compared to earlier observations (year 2008-2014: 1-4 species, 2-8 % of

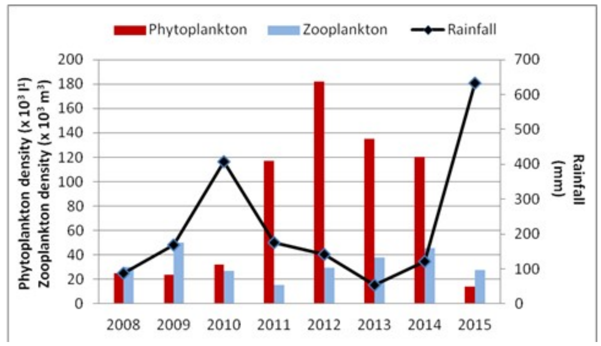

Fig. 3 — Variation in phyto- and zooplankton density in the coastal waters and rainfall at Kalpakkam in the month of December during 2008-2015

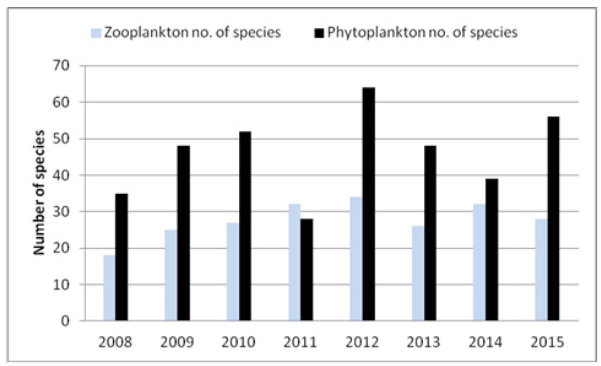

Fig. 4 — Variation in number of species in the coastal water of Kalpakkam in the month of December during 2008-2015

Table 1 — Dominant phyto- and zooplankton species, % of zooplankton species observed with epibionts and % of green algae specie (in total phytoplankton species) observed in the coastal water s of Kalpakkam in the month of December during 2008- 2015

	Dominant Phytoplankton species	**Dominant Zooplankton species**	**Abnormal observations**	
			% of zooplankton species with Epibiosis	% Green algae species
2008	*Nitzschia* sp, *Coscinodiscus* sp	*Acrocalanus longicornis*	5	2
2009	*Thalassiosira* sp	*Undinula vulgaris*	10	3
2010	*Coscinodiscus* sp, *Chaetoceros lorenzianus*	*Acrocalanus longicornis, Acrocalanus gralicilis,*	10	8
2011	*Nizschia lanceolata, Synedra* sp	*Acrocalanus longicornis*, Salpa sp.	9	4
2012	*Leptocylindrus danicus, Melosira sulcata, Thalassiosira* sp.	*Acrocalanus longicornis, Atlanta* sp, *Centropages orisini,*	9	3
2013	*Chaetoceros lorenzianus, Skeletonema costatum*	*Acrocalanus longicornis, Euterpina acutifrons*	13	2
2014	*Nitzschia* sp, *Coscinodiscus* sp *Skeletonema costatum,*	*Acrocalanus gralicilis, Bestiolina similis,*	7	
2015	*Ditylum sol, Coscinodiscus centralis, Coscinodiscus* sp, *Skeletonema costatum,*	*Acrocalanus longicornis, Acrocalanus gralicilis, Bestiolina similis, Undinula vulgaris*	38	17

total species). This indicated that the green algal species have joined the coastal ecosystem from the fresh and brackish water bodies (Sadras and Edaiyur backwaters and Palar River and tiny brackish water KKM lake present near coast) through flooding and runoff. Similar results have been reported[27], where they have observed increased green and blue green algal species in coastal lagoon environment after the cyclonic storm 'Philin'. Scrutiny of the phytoplankton community structure showed that *Coscinodiscus* spp. and *Skeletonoma costatum* were dominant in the month of December during most of the years. These two genera are cosmopolitan in nature and are generally found in tropical coastal environments throughout the year[28]. As they can withstand wide variations in salinity and can survive in oligotrhphic to eutrophic environments[25], they tend to dominate the phytoplankton community during hostile weather conditions as has been reported[29].

Impact on zooplankton community structure

Zooplankton, the primary consumer, is dependent on phytoplankton for its growth and reproduction. Zooplankton showed a similar species abundance pattern as that of phytoplankton during the present study (**Fig. 4**). A total of 28 species were encountered during the present study as compared to the observed 18-32 species during the previous years (2008-2014). Unlike the phytoplankton population, the variations in zooplankton density were not significant with respect to rainfall. The zooplankton density recorded was 27.8 X 10^3 individuals m^{-3} which was lower than most of the densities observed earlier (29.5-50.1 x 10^3 individuals m^{-3}) except 2010 (27.2 x 10^3 individuals m^{-3}) and 2011 (15.6 x 10^3 individuals m^{-3}). Despite insignificant correlation between rainfall and zooplankton, relatively low zooplankton densities coincided with comparatively high rainfall observed during 2010-2011. The insignificant variations in zooplankton community structure could be attributed to their food habit. Coastal zooplankters are of diverse feeding guilds (herbivorous, carnivorous or omnivorous) and thus can survive grazing upon any organic matter or detritus matter. Hence, in the absence of phytoplankton, which generally thrives during normal condition, zooplankton during extreme weather conditions can feed upon the organic matter transported form terrestrial and inland aquatic water bodies. Moreover, carnivorous and omnivorous species can survive easily as they graze on wide varieties of planktonic organisms rather than any specific types. Species composition showed that *Acrocalanus* spp. and *Bestiolina similis* were dominant during the study. Species belonging to *Acrocalanus* are generally found in tropical and subtropical coastal waters. They generally dominate the coastal ecosystems with a large population percentage up to 30 % of total zooplankton population despite of the seasonal succession[30,31]. The dominance of *Acrocalanus* species throughout the years of study thus can be attributed to the above reason. Similarly Bhattacharya et al.[1], have reported the dominance of *Bestiolina similis* in the Sundarban coastal ecosystem after the cyclonic storm 'Aila'.

Observations of epibiosis

One of the most interesting features of this study was the observation of epibiosis on zooplankton in massive numbers. Epibiotic interactions in marine zooplankton are common and have been reported throughout the world[32,35]. Body surface of the host organism (basibiont) serves as a suitable environment for epibionts[36,40]. This unique coupling has traditionally been regarded as a non-symbiotic and commensal relationship. However, higher number of epibionts on body surface adversely impacts the host by increasing their susceptibility to predation, by hindering their movement, growth, reproduction and by reducing food availability[36,41,42].

Most of the organism associations found from Indian waters are either between ciliate protozoans (as epibiont) and copepods/ other crustaceans (as host) or between photosynthetic micro-organisms (as epibiont) and copepods (as host)[43]. Recently published literature indicated occurrence of epibiotic relationships of *Epistyles* sp., *Vorticella* sp., *Acineta* sp., *Thecacineta* sp., *Veginicola* sp., *Tokophyra*sp., *Pseudohimntidium* sp. etc with various zooplankton and phytoplankton species from coastal waters of Tamil Nadu[43,45]. Species such as *Thecacineta calix*[44] and *Pseudohimntidium pacificum*[43] have been reported from Kalpakkam coastal waters. In the present study, epibiosis of *Acineta* sp., *Vorticella* sp. and *Pseudohimantidium* sp. with copepod species *Acrocalanus gracilis*, *Euterpina acutifrons, Corycaeus sp.,* and phytoplankton species *Chaetoceros coarctatus* was observed. Many of the epibiont species, which could not be identified immediately, are being identified with the help of experts. Interestingly, a comparison of previous occurrences of epibiotic relationship in plankton community with the present study showed a profound increase in epibiosis. During previous observations in year 2008-2014, the epibiotic relationship was recorded for about 5-13 % of zooplankton species, whereas, in the present instance it was about 38 % (**Table 1**). It indicated the presence of some triggering mechanisms in the ambient water, during the heavy surface runoff, which led to establishment of epibiosis in massive scale. It is well known that epibiosis is beneficial for the epibionts in the context of food, competition, predation, survival and transportation[45]. Mounted on the host organisms, epibionts increase their rate of survival by being transported to suitable environments, which not only facilitates their food supply and dispersal of excreta but also helps in their distribution and gene flow[46]. Though, particular mechanisms responsible for the observation of epibiosis in such a large scale could not be explained, the above survival instincts of the epibionts could have triggered the formation of the non-symbiotic relationships in a hostile and vulnerable environment that prevailed during the flooding event. One possible reason could be the availability of epibionts from different environments entering into the marine milieu having conducive situation for them to survive on the host which are possibly susceptible for epibiosis at low salinity in particular.

Despite of their sporadic occurrences, natural events like cyclonic storms, flooding, tsunami etc cause an enormous damage to the coastal ecosystem, as observed in the present study. A detailed investigation on the physico-chemical properties and their impact on structuring the plankton community during such events will be useful in assessing the ecological impacts and the subsequent changes in marine food web.

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