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The Impact of Tropical Cyclone ‘Phailin’ on the Hydrology of Chilika Lagoon, India

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Abstract

The Asia’s largest lagoon; Chilika, designated as first Ramsar site in India, was studied after a severe cyclonic storm “Phailin” in October 2013 that was coupled with heavy precipitation and flooding. Physicochemical parameters, nutrients, and salinity data were analyzed to understand the impact of Phailin on the hydrology of lagoon. Multidimensional scaling analysis of 15 years of salinity data, revealed spatial partitioning of lagoon into four distinct ecological sectors; southern, central, northern, and outer channel. Fresh water discharge from the rivers remained a dominating factor for controlling the salinity regime of the lagoon ($r= -0.2894$, $p= 0.0144$).

A significant change in the salinity regime as well as in the nutrients was observed after the cyclone compared to the pre-cyclone months. The salinity of southern, central sectors and outer channel decreased by 28.7, 29.8, and 19.1% respectively, whereas in the northern sector, it remained fairly constant compared to pre-cyclone months. There was an overall increase in silicate concentration in the lagoon after cyclone due to riverine silicate influx evidenced by a significant negative correlation between salinity and silicate concentration in the lagoon. However, there was a decline in nitrate+nitrite and phosphate concentration throughout the lagoon mostly due to dilution effect as well as adsorption to sediment in case of phosphate. The impact of cyclone was also distinctly visible on specific biota such as sea grasses, macrophytes, and benthic community which are considered as good bio-indicators.

Keywords: Chilika; Lagoon; Nutrient dilution; Phailin; River discharge; Ramsar Site; Super cyclone; Water quality

Introduction

The Bay of Bengal region of the Indian subcontinent is well known for origin of tropical cyclones, which often turn into super cyclone before hitting the continental land mass. Most tropical regions are exposed to high intensity rainfalls associated with cyclones Summer *et al.* [1]. Two of the cyclonic storms had hit the east coast state of India; Odisha during October of year 1999 (super cyclone) and in 2013 (severe cyclonic storm). A very severe cyclonic storm Phailin had landfall to south Odisha coast on 12th October 2013 with a sustained maximum surface wind speed of 200-210 kmph gusting to 220 kmph (IMD Report [2]. An ecological effect of such major storms on coastal ecosystems has been studied by many researchers Bhatacharya *et al.* [3]; Mitra *et al.* [4]; Reddy *et al.* [5]; Satpathy *et al.* [6]; Webster *et al.* [7]. Freshwater discharge can play an important role in changing the water chemistry and hydrology of the coastal estuarine ecosystem Kanuri *et al.* [8]; Muduli et al., 2012 [9], Muduli et al., 2013 [10], Worldwide many studies are focused on the influence of heavy freshwater discharge (due to flood events) on water quality of coastal ecosystems; Martinez-Mena *et al.* [11]; Steven [12]. However, such studies in context to Indian lagoon ecosystems are lacking.

Salinity is an important factor in determining the distribution of biodiversity of flora and fauna in coastal ecosystem Benjamin *et al.* [13]; Mcevoy *et al.* [14]. For instance, benthic organisms and sea grass communities have been shown to be significantly influenced by the change in salinity and turbid water flux which occurs during flood events Gaonkar *et al.* [15]; Orth *et al.* [16]. Flux of nutrients during flooding can alter the rate of primary production in the aftermath of cyclone Murrell *et al.* [17]; Sarma *et al.* [18]. Thus, monitoring of water quality assumes high priority to understand the impact of cyclone on the hydrology and biodiversity of the lagoon.

Chilika lagoon is a highly sensitive and complex ecosystem especially due to large catchment size (3500 Km2). A variety of land-derived discharge flows into the lagoon through several rivers and their distributaries. The flood after the cyclone Phailin brought a huge amount of freshwater of different chemistry into the lagoon, which could have an adverse effect on the hydrology and water quality. As salinity and nutrients are vital parameters influencing and determining the ecology and biodiversity in coastal lagoon, these two parameters were studied in great details in relation to Phailin. The specific objectives of this study are to understand

i. The effect of Phailin on the nutrients inputs from major rivers that drain into Chilika lagoon and the influence of this input on the water quality of different sectors of the lagoon.

ii. The impact of Phailin on the salinity regime of the lagoon.

Materials and Methods

Study Area

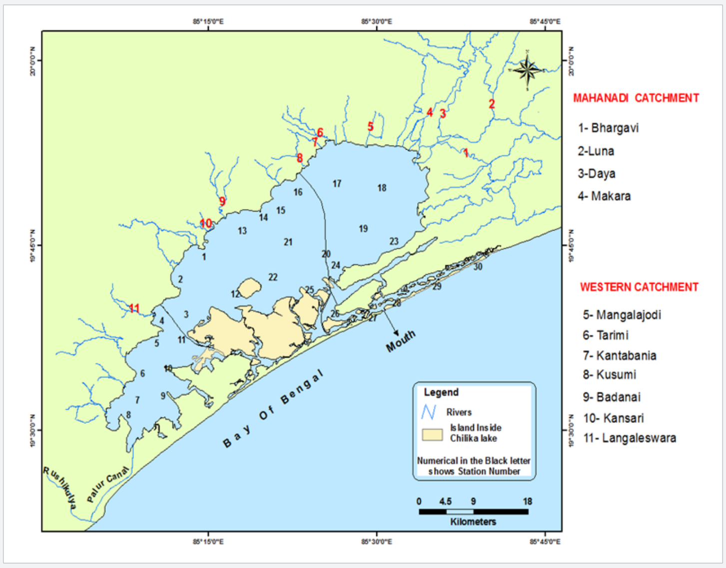

Figure 1: Map of Chilika lagoon with 30 sampling locations and 11 rivers.

Chilika lagoon (Figure 1) is a largest brackish water lagoon in Asia located on the east coast of India (19 28' 19 54' N and 85 06' 85 35' E). It is one of the most dynamic shallow ecosystems (average depth: 2m), about 65 km long and spreading parallel to the coastline in north east to south west direction with a varying width (reaching to average 20 km). There are 52 rivers and rivulets that drain fresh water and sediment into the lagoon. There are three inlets (showed as one in the figure, due to very small spatial distances ~300m) connected to sea through which saline water enters into the lagoon. Apart from this, lagoon through the Palur Canal (Figure 1) at the southern part of the lagoon connected to the sea, through Rushikulya estuary.

Sampling and Analysis

Sampling was carried out during September and October months of year 2013 from 30 different stations covering all four sectors: Southern (SS), Central (CS), Northern (NS) and outer channel (OC) (Figure 1). Simultaneously, samples were also collected from 11 major rivers streams that drain into Chilika lagoon. Surface water samples were collected using a 5L Niskin bottle. Nutrients [nitrate+nitrite (NO_3+NO_2), phosphate (PO_4), and silicate (SiO_2)] were estimated by nutrient auto analyser (SKALAR SANplus ANALYZER) following SKALAR methodology with the precisions of nitrate+nitrite ±0.02, 0.01, and 0.02 µmol, respectively. Temperature and pH and salinity were measured using water quality Checker (TOA DKK, WQC24). Chlorophyll-a, dissolved oxygen and turbidity data were recorded using optical sensor in the sondes of data buoys (Multi-parameter water quality sonde; 6 Series; DATA BUOY; YSI, USA) deployed at each sector set to provide real-time water quality data at 15-minute intervals. Data of 30 days before and after Phailin were considered for correlation analysis.

Qualitative and quantitative assessment of the benthic community was made by adopting stringent methods described earlier Gosner *et al.* [19]; Holme *et al.* [20]. Sea grasses and freshwater macrophyte survey was carried out after three months of the cyclone, and identifications were made using taxonomic keys described earlier Campbell *et al.* [21]; Kanan *et al.* [22]. Using float method, long-term river discharge data was recorded everyday between years 2004-2013. Average discharge data of each month was considered for calculation of nutrient flux (discharge x nutrient concentration), as samples for nutrient analyses were collected only twice a month and average values were used for all calculations.

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Result and Discussion

Phailin caused a drastic change in salinity gradient and nutrients status of Chilika lagoon. The extent of which varied depended on the flow rate and concentration of nutrients in the riverine inputs.

Physico-chemical parameters

Transparency of the entire lagoon decreased by 31% except SS of the lagoon where it remained almost same due to least freshwater inflow to this sector. The transparency decreased 1.35, 1.50 and 1.41 times in CS, NS, and OC, respectively. However, such significant change between the months (September and October) was not observed during 2012 (Tables 1a & 1b). This could be attributed to the inflow of turbid water from rivers as well as mixing of bottom sediment due to wind-induced wave action caused by Phailin. Since the turbid water, inflow was highest in NS (Tables 1a & 1b) (Figure 2), this sector also experienced the lowest transparency Nixon *et al.* [23]. The pH in SS and CS was observed to increase significantly (Figure 2), which could be due to dominating primary production though there was a decrease, in transparency (Table 1b).

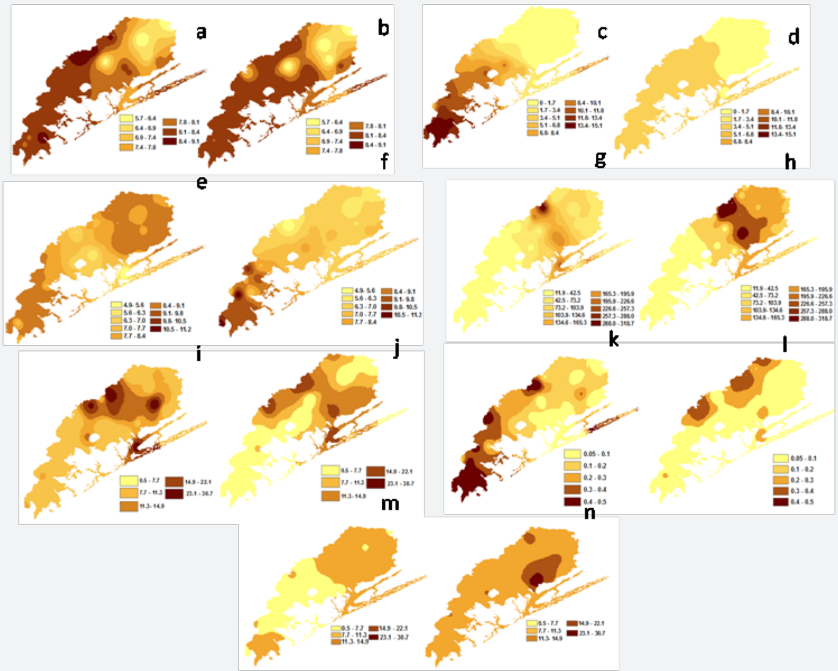

Figure 2: Spatial distribution of water quality parameters before and after the Phailin.

a. pH: September-2013 b. pH: October-2013 c. Salinity: September-2013 d. Salinity: October-2013
e. DO: September-2013 f. DO: October-2013 g. Turbidity: September-2013 h. Turbidity: October-2013
i. Nitrite+Nitrate: September-2013 j. Nitrite+Nitrate: October-2013 k. Phosphate: September-2013
l. Phosphate: October-2013 m. Silicate: September-2013 n. Silicate: October-2013.

Table 1a: Variation of Physico-chemical parameters during September and October 2012.

	12-Sep					12-Oct				
Para meters /Sector	Southern sector	Central Sector	Northern sector	Outer Channel	Average	Southern Sector	Central sector	Northern sector	Outer channel	Average
Depth(m)	1.8-3.3	1.0-2.1	1.3-1.8	2.5-6.4	1.0-6.4	2.3-3.0	1.3-2.4	0.9-1.6	2.6-6.3	0.9-6.3
	2.6±0.38	1.7±0.31	1.5±0.17	3.9±1.80	2.42±0.67	2.5±0.21	1.7±0.34	1.3±0.27	4.1±1.61	2.4±0.61
Trans(m)	1.7-2.4	0.2-1.7	0.2-0.8	0.4-1.0	0.2-2.4	0.9-1.9	0.4-1.4	0.1-0.66	0.5-1.0	0.1-1.9
	2.0±0.22	0.9±0.46	0.5±0.23	0.7±0.23	1.02±0.29	1.4±0.29	0.9±0.35	0.34±0.17	0.8±0.24	0.86±0.43

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Turbidity (NTU)	3.00-7.00	2.50-156.00	21.00-176.60	17.00-86.00	2.50-176.60	7.30-28.90	8.00-37.00	34.50-320.00	16.50-33.10	7.30-320.00
	3.93±1.20	33.13±47.69	82.94±68.06	52.13±35.40	43.03±38.09	12.33±6.89	20.98±10.52	156.14±105.08	24.15±8.16	53.40± 32.66
pH	8.48-8.66	8.23-8.85	8.1-8.78	8.3-8.63	8.1-8.85	8.43-8.57	8.41-9.06	8.17-9.30	8.49-8.56	8.17-9.30
	8.57±0.06	8.56±0.19	8.44±0.23	8.43±0.14	8.5±0.16	8.51±0.04	8.72±0.22	8.74±0.4	8.52±0.03	8.62 ±0.17
Salinity	9.6-13.6	0.4-7.9	0-0.2	2.8-12.1	0-13.6	9.2-13.2	1.1-8.6	0.1-0.4	13.7-19.1	0.1-19.1
	11.43±1.55	3.93±2.69	0.11±0.11	7.18±4.65	5.66±2.25	11.19±1.33	4.65±2.32	0.25±0.14	16.88±2.38	8.24± 1.54
DO (mg L-1)	5.39-7.6	5.4-9.5	5.17-10.63	6.83-8.10	5.17-10.63	5.46-7.39	5.98-8.48	5.84-9.86	7.29-7.92	5.46-9.86
	6.61±0.75	7.5±1.21	8.08±2.02	7.35±0.61	7.39±1.15	6.42±0.64	7.07±0.87	7.53±1.31	7.57±0.26	7.15± 0.77
NO3+ NO2 (μM)	0.59-2.82	1.01-7.90	1.28-8.97	1.42-3.58	0.59-8.97	0.11-0.51	0.05-4.67	1.07-5.19	0.61-1.46	0.05-5.19
	1.26±0.69	3.47±1.93	4.67±2.79	2.45±1.06	2.96±1.62	0.33±0.14	1.90±1.30	2.82±1.63	1.03±0.42	1.52± 1.07
PO4 (μM)	0.23-0.50	0.05-0.87	0.55-3.42	0.50-1.05	0.05-3.42	0.55-1.51	0.23-2.60	1.28-2.87	0.27-0.50	0.23-2 .87
	0.33±0.08	0.47±0.25	1.36±1.02	0.75±0.23	0.72±0.4	1.05±0.31	1.28±0.66	1.94±0.57	0.40±0.09	1.16± 0.41
Silicate (μM)	51.40-77.82	27.65-112.88	65.87-141.54	61.99-121.09	27.65-141.54	77.32-118.28	50.40-140.46	96.47-173.29	29.30-55.79	29.30-173.29
	64.20±9.56	62.91±29.89	118.60±28.21	91.22±24.82	84.23±23.12	98.46±13.63	97.48±35.18	138.84±35.06	43.45±13.25	94.55 ± 24.28

Table 1b: Variation of Physico-chemical parameters before and after *Phailin*

13-Sep						13-Oct				
Parameters /Sector	Southern sector	Central sector	Northern sector	Outer channel	Average	Southern sector	Central sector	Northern sector	Outer channel	Average
Depth(m)	2.1-2.72 2.31±0.19	0.88-1.67 1.41±0.23	1.17-2.59 1.75±0.46	1.18-5.1 1.19±.2.1	0.88-2.59 1.67±0.75	2.81-3.85 3.37±0.35	1.9-3 2.48±0.41	1.5-2.42 2.02±0.38	2.10-4.9 3.37±1.4	1.5-4.9 2.81±0.6424
Trans(m)	0.51-1.65 1.25±0.39	0.22-1.23 0.8±0.34	0.13-0.74 0.42±0.23	0.43-2.87 1.17.±1.15	0.13-2.87 0.91±0.53	0.37-1.82 1.09±0.39	.18-.62 0.41±0.16	0.15-0.6 0.23±0.16	0.15-0.5 0.34±0.18	0.15-1.82 0.48±0.22
Turbidity(NTU)	4.4-13.9 7.72±3.12	9-154 32.73±44.24	38-183 92.09±58.16	19.5-40 31.13±8.53	4.4-183 40.92±28.51	11.9-42 20.64±9.09	23-205 68.67±65.93	47-319 135.86±99.42	36-178 86.75±62.52	23-319 77.98±59.24
pH	8.12-8.65 8.32±0.16	6.12-9.11 8.12±0.82	6.73-8.55 7.88±0.61	8.03-8.31 8.21±0.13	6.12-9.11 8.13±0.43	8.46-8.75 8.57±0.11	7.2-8.85 8.29±0.49	6.1-8.42 7.65±0.78	7.33-8.4 7.88±0.6	6.1-8.85 8.10±0.5
Salinity	8.7-15.1 12.02±3	0.4-10.4 4.83±3.56	0.1-1.2 0.26±0.41	2.7-9.3 5.35±3.2	0.1-15.1 5.62±2.54	2.1-4.5 3.5±0.84	0.4-3.3 2.03±0.85	0-0.2 0.07±0.06	0.3-2 1.02±0.71	0-4.5 1.66±0.62
DO(mg L-1)	5.67-8.29 7.2±0.95	4.06-6.62 5.63±0.8	6.14-8.35 7.08±0.75	5.44-8.64 6.33±1.55	4.06-8.64 6.56±1.01	7.1-11.26 9.19±1.3	4.93-8.03 6.69±0.87	5.8-7.26 6.67±0.51	6.75-7.74 7.07±0.46	4.93-11.26 7.41±0.79
NO3+NO2(μM)	6.81-16.45 12.2±2.9	6.05-30.77 17.41±7.86	11.87-27.03 17.04±5.56	7.14-23.75 13.57±7.31	6.05-30.77 15.06±5.91	4.18-8.33 5.88±1.24	0.83-22.15 11.81±7.68	0.5-17.25 11.96±5.62	1.57-14.34 7.84±5.35	0.5-22.15 9.37±4.97

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PO4(µM)	0.17-0.49 0.35±0.09	0.05-0.48 0.23±0.15	0.09-0.28 0.15±0.07	0.08-0.32 0.95±1.53	0.05-0.49 0.23±0.12	0.02-0.12 0.05±0.03	0.01-0.38 0.12±0.11	0.04-0.26 0.1±0.08	0.03-0.04 0.04±0.01	0.01-0.38 0.08±0.05
Silicate(µM)	4.83-173.72 54.08±68.05	25-129.77 78.06±35.55	68.43-143.36 117±0.05	101.51-122.13 113.78±8.69	4.83-173.72 90.73±28.09	109.88-172.1 130.82±18.79	87.99-167.35 141.23±23.36	116.62-258.87 174.85±46.29	117.73-134.44 122.12±8.22	87.99-258.87 142.26±24.17

The production might have contributed by re-suspended benthic algae, which have better production than the pelagic algae Annual report [24]. This phenomenon was also evidenced with concurrent increase in chlorophyll-a and dissolved oxygen. Overall pH of the lagoon remained almost same however there was a significant decrease in DO concentration observed, could be attributed to surfing of lagoon water. This observation is unlike to that observed in other ecosystem affected by cyclonic events Bhatacharya *et al.* [3]; Mitra *et al.* [4]. Before Phailin, the Chlorophyll-a concentration was 3.2 µg L-1 which increased to 4.1 µg L-1 after Phailin. chlorophyll-a also showed a positive correlation with dissolved oxygen (r=0.28, p=0.0001) indicating that increase in oxygen was due to primary production rather than by surfing of water due to heavy winds Hull *et al.* [25]. A strong positive correlation (r=0.71, p=0.0001) between chlorophyll-a concentration and turbidity further supported the fact that suspended particulates mostly contained Chlorophyll-a during the study period.

Salinity Variation in Chilika during the Monsoon

The salinity of the Chilika lagoon is predominantly controlled by the sea water exchange and river water discharge. Apart from these, Palur canal, which is connected to the sea through Rushikulya estuary, also raises salinity of the lagoon (Figure 1). Depending upon the freshwater influx of rivers, the salinity regimes were significantly different in each sector, which was evident from the multi-dimensional scale (MDS) plot (Figure 3). River discharge during the high-flow period was compared with average salinity of the whole lagoon recorded between years 2004 to 2013. There was a significant influence of river discharge on water quality of Chilika as evident from the regression analysis (r=0.2894, p=0.0144) (Figure 4). It was found that during the high river discharge period in years 2006, 2008 and 2013, the average salinity of the lagoon decreased, considerably.

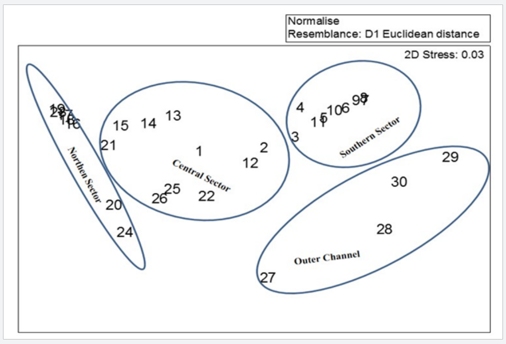

Figure 3: MDS plot of Sectoral division of Chilika lagoon based on Salinity.

The salinity recorded in monsoon (July to October) was examined and compared with recent observation from different sectors (Figure 5). Since 1999, during monsoon, the salinity of the lagoon varied between 4.6 to 11.9 with an average of 8.3, whereas during the non-monsoon period the salinity varied between 9.1 to 15 with an average of 12.7. The lowest salinity value observed during 2006 could be attributed to flood events that brought heavy freshwater discharge (Figure 3). Higher salinity of >11 during 2002, 2004 and 2005 could be due to late arrival of monsoon. The lowest salinity during 1999 was the indication of poor exchange of sea water with lagoon, which led to an opening of a new mouth during September 2000 Jayaraman *et al.* [26].

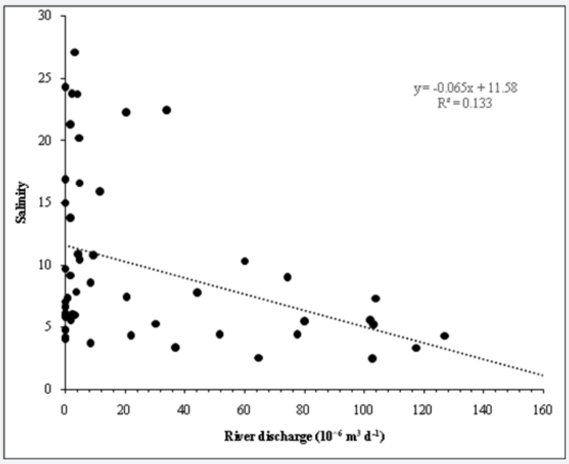

Figure 4: Variation of salinity with respect to riverine discharge during 1999 to 2013.

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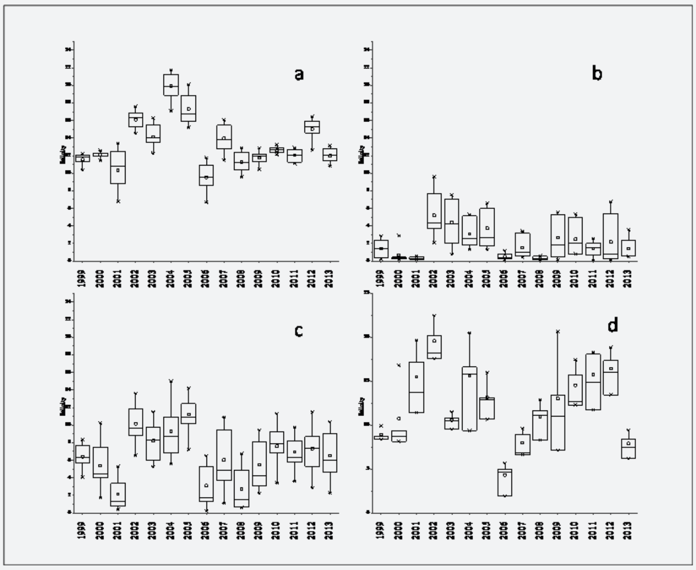

Figure 5: Variation of salinity since 1999 to 2013 during monsoon (July to October) in

a. Southern sector,

b. Northern sector,

c. Central sector and

d. Outer channel.

Spatial variation in salinity due to Phailin

The results of the present study revealed that during October 2013, the average salinity of the entire lagoon reached to a level of 1.72, which was the lowest ever recorded since 1999 for October month. After Phailin, the salinity of the lagoon decreased by 3.3 times and 4.8 times as compared to previous month i.e. September 2013 and previous year October 2012, respectively. Comparison of salinity of October 2013 with September 2013 indicated that the salinity of the NS remained almost same, whereas in OC maximum decrease in the salinity was observed. The decrease in salinity of SS, CS and OC was observed to be 7.1, 2.3, and 8 times respectively (Figure 2) (Table 1b). The decline in salinity was not only due to the freshwater riverine discharge but also from the massive rainfall after Phailin. The level of salinity decreased in October 2013 in following order: OC>SS> CS> NS as compared to the average values of October months of last 14 years (since 1999 to 2012) and the magnitude were 7.95, 2.47, 1.93, and 1.29 times, respectively. Since last 14 years, during October, average salinity in the OC, SS, CS and NS were 8, 8.8, 2.4, and 1.4 respectively. However, after Phailin, average salinity in the in the OC, SS, CS and NS decreased to 1.02, 3.56, 1.24, and 1.08, respectively. After Phailin, the salinity in SS and OC was found to be the lowest ever recorded in last 15 years, though there was a natural opening of a new mouth during the Phailin (Forest beat house) about 1 km northward to an earlier existing mouth at Gabakunda. The resultant all time low salinity in the lagoon could be attributed to unidirectional freshwater flow (from lagoon to sea) at the mouth.

Effect of Nutrient Flux from Major Rivers

There was a significant decrease in river nutrient concentration (except silicate) which caused dilution of nutrient concentrations in the lagoon (Table 1b) (Figure 2). A number of studies have reported high variability in the concentrations of these nutrients due to freshwater discharge Acharya *et al.* [27]; Bond *et al.* [28]; Sarma *et al.* [29]. After the Phailin, PO4 concentration in the lagoon showed 2.9 times decrease whereas silicate concentration increased by 2.94 times; being highest in NS and lowest in CS. There was a decrease in nitrate concentration (Table 1) observed after could be due to dilution effect however the increase in nitrate concentration has been reported for other ecosystems such as, Kannada coast Reddy *et al.* [5], Kalpakam Satpathy *et al.* [30], southwest coast of India and Sunder ban mangrove wetland (Bhattacharya *et al.* [3]. In contrast, few studies have also reported no significant changes in the concentration of dissolved P with change in environmental conditions Meyer *et al.* [31]. However, the total fluxes of all nutrients were found to be increased 3.8 fold due to Phailin induced heavy rainfall. Total nutrient flux from the Mahanadi catchment contributed ~85% as compared to the western catchment (Table 2). During 2012, the variation in nutrient concentrations between September and October months was not significant (ANOVA, $p > 0.05$) but in 2013 it was found to be highly significant (ANOVA, $p<0.05$) indicated drastic changes in water chemistry due to cyclone.

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Table 2: Variation of nutrient fluxes before and after *Phailin*

Sl.No.	Name of river	Before Phailin (influx: $\times 10^4$mol d^{-1})			After Phailin (influx: $\times 10^4$ mol d^{-1})		
		NO_2+NO_3	PO_4	SiO_2	NO_2+NO_3	PO_4	SiO_2
1	Bhargavi	2	0.003	60	15	0.2	294
2	Luna	4	0.03	287	2	0.1	548
3	Daya	11	0.03	308	43	1	737
4	Makara	90	0.1	2502	508	4	9398
5	Mangaljodi	5	0.004	90	5	0.03	252
6	Tarimi	0.2	0.001	45	0.4	0.01	106
7	Kantabania	1	0.003	84	1	0.03	199
8	Kusumi	0.2	0.003	19	0.1	0.01	39
9	Badanai	0.03	0.01	13	0.2	0.01	93
10	Kansari	1	0.003	61	19	0.2	1501
11	Langaleswar	1	0.1	22	0.3	0.01	36

Consequences of changes in water quality on biodiversity

Due to sudden fall in salinity decomposition and decrease of rich sea grass meadows of *Halophila ovalis* was observed. While, the appearance of freshwater weeds such as *Chara* sp. and *Naja* sp. in most parts of the SS could be considered as an effect of changes in salinity regime of the lagoon due to cyclone. *Halophila ovalis* is highly productive over a salinity range of 15 to 35 and can withstand salinity <10 up to one month Benjamin *et al.* [13]. Thus, the reduction in salinity after Phailin did not favour *Halophila ovalis* growth but promoted the proliferation of freshwater weed species. A significant variation in the macro benthic group composition and decrease in abundance were also observed after the Phailin which could be due to sudden drop in salinity and increase in turbidity in the water column Alongi *et al.* [32]; Murrel *et al.* [17] (Table 1b).

Among the macro benthic groups, benthic amphipod was found dominant in November 2013 while during the previous year, polychaetes group were dominant [33]. There were number of small juveniles of polychaetes and amphipods were noticed and their biomass was comparatively higher than the previous year (October 2012). This could be due to the presence of more molluscan species. Overall the benthic biomass and abundance was decreased from 44 to 40 gm m-2 and 365 to 241 nos. m-2 respectively after Phailin. Change in the dominant group indicated the possible influence of super cyclone Phailin on the bottom substratum of the Chilika lagoon.

Conclusion

The present study reported the immediate changes in water quality of lagoon due to Phailin such as increasing silicate concentration and dilution of PO4 and NO3+NO2. The salinity of the lagoon, remained lowest in SS and OC compared to last 15 years of record. The overall decrease in salinity and turbidity resulted in loss of sea grass meadows and proliferation of freshwater weeds as well as changes in benthic communities. The present study could be treated as baseline information for further research especially on the changes in water quality and diversity of zooplankton, phytoplankton, and benthic macro fauna after the cyclonic storm. The long-term study on these aspects will be helpful for understanding the recovery period and resilience of the coastal lagoons from such extreme weather events. This data and knowledge would be useful in modelling studies to predict the health of an ecosystem and accordingly management action could be planned to restore the ecosystem balance. As due to climate change the frequency of the extreme weather events like cyclone are likely to be exuberated.

Recommendations

Chilika lagoon, a shallow brackish water lagoon with an average depth of ~1.5 m is influenced by high seasonal fluctuation in water inflows and evaporation, changing its volume, significantly. This decides the residence time of water with nutrients influencing the biogeochemistry of the entire lagoon. High precipitation induced by severe cyclonic storm suddenly changes the water quality which ultimately has an adverse effect on the balance of an ecosystem. The change in water level is likely to affect important littoral macrophytes-lined fish spawning and nursery zones and important habitat for benthic fauna and pelagic component. Water quality of an aquatic ecosystem is a crucial indicator to understand the ecological health. The change in water quality has an immediate effect on the phytoplankton followed by zooplankton and fisheries. Hence, studies must be extended to plankton and their influence on the productivity and fishery diversity. In shallow ecosystem, during cyclonic events, heavy precipitation with river discharge also change the sediment texture and composition which might affect the benthic community structure. Thus long-term studies to understand the recovery period of the ecosystem (in terms of salinity, nutrient level, plank tonic structure, sea grass, benthic

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communities and fishery) is essential for the sustainable management, lake productivity, perpetual ecosystem services and biodiversity of the lagoon.

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References

1. Sumner G, Bonnell M (1986) Circulation and daily rainfall in the North Queensland wet Seasons 1979-1982. Int J Climatol 6: 531-549.
2. IMD Report (2013) Very severe cyclonic storm, Phailin over the Bay of Bengal (08-14 October 2013): a report. Earth system science organisation, India meteorological department, Ministry of earth sciences, Government of India.
3. Bhatacharya BD, Bhatacharya A, Rakshit D, Sarkar SK (2014) impact of the tropical cyclone storm 'Alia' on the water quality characteristics and mesozooplankton community structure of sunderban mangrove wetland India Ind j of geo mar s 43(2): 216-223.
4. Mitra A, Halder P, Banerjee K (2011) Changes of selective hydrological parameters in Hooghly estuary in response to a severe tropical cyclone (Aila). Ind J of Geo-Mar Sc 40: 32-36.
5. Reddy HRV, Katti RJ, Chandrashekara KPR, Vikas SJ, Nagendra RS, *et al.* (2005) Coastal water quality off Dakshina Kannada before and after tsunami. Curr sc pp. 88.
6. Satpathy KK, Mohanty AK, Prasad MVR, Natesan U, Sarkar SK, *et al.* (2008) Post-Tsunami changes in water quality of Kalpakkam coastal waters, east coast of India with special references to nutrients. Asian J Water Environ Pollut 5: 15-30.
7. Webster IT, Ford PW, Tillman P (2005) Estimating nutrient budgets in tropical estuaries subject to episodic flows. Marine Poll Bull 51(1-4): 165-173.
8. Kanuri VV, Muduli PR, Robin RS, Subamanian B R (2013) Plankton metabolic processes and its significance On dissolved organic carbon pool in a tropical brackish water lagoon. Cont shelf res 61-62, 52-61.
9. Muduli, Pradipta R, Vishnu Vardhan, Charan Kumar B, Robin RS, *et al.* (2012) Spatio-temporal variation of CO_2 emission from Chilika Lake, a tropical coastal lagoon, on the east coast of India. Estuary Coast Shelf S 113: 305-313.
10. Muduli, P.R., Kanuri, V.V., Robin, R.S., Charan, B.K., Patra, S., Raman, A.V., Rao, G.N., Subramanian, B.R., 2013. Distribution of dissolved inorganic carbon and net ecosystem production in a tropical brackish water lagoon, India. Cont. Shelf Res. 64, 75–87.
11. Martínez-Mena M, Garcia AJ, Barberá GG, J Albaladejo, VM Castillo, *et al.* (2005) Effects of flush floods on nutrient loads to a semiarid coastal lagoon: Mar Menor. Geophysical Research Abstracts, Murcia, Spain.
12. Steven A (1994) Cyclone Sadie Flood Plumes in the Great Barrier Reef Lagoon: Composition and Consequences. Proceedings of a workshop held in Townsville Queensland, at the Australian Institute of Marine Science (AIMS), Australia.
13. Benjamin KJ, Walker DI, Mccomb AJ, John Kuo (1999) Structural response of marine and estuarine plants of *Halophila ovalis* (R . Br .) Hook f to long-term hyposalinity Aquat Bot 64: 1-17.
14. Mcevoy P, Goonan P (2003) Salinity is not necessarily bad for biodiversity: case studies of invertebrates from South Australian streams and River Murray wetlands. Rec Aust Mus 7: 131-134.
15. Gaonkar UK, Sivadas SK, Ingole BS (2013) Effect of tropical rainfall in structuring the macrobenthic community of Mandovi Estuary, west coast of India J r Biol Assoc 93: 1727-1738.
16. Orth Robert J, Carruthers TJB, Dennison WC, Carolas MD, James WF, *et al.* (2006) A Global Crisis for Seagrass Ecosystems. Bio Sc 56: 987-996.
17. Murrell, James DH, Emile ML, Richard M, Greene, *et al.* (2007) Phytoplankton production and nutrient distributionsin a subtropical estuary: Importance of freshwater. flow Estuar Coast 30(3): 390-402.
18. Sarma VVSS, Kumar NA, Prasad VR, Acharya T, Harikrishnachari, *et al.* (2009) Influence of river discharge on plankton metabolic rates in the tropical monsoon driven Godavari estuary, India, Estuarine, Cont. Shelf Res 85: 515-524.
19. Gosner K (1974) Guide to the identification of marine and estuarine invertebrates. Cape Hatteras and the Bay of Fundy New York, John Wiley & Sons Ltd Int Re Hydrobiol 59 (2): 303.
20. Holme NA, McIntyre AD (1984) (eds), Methods for the study of marine benthos. Blackwell Scientific Publications, Oxford, UK.
21. Campbell S, Higman P, Slaughter B, Schools Ed (2010) Field Guide to Invasive Plants of Aquatic and Wetland Habitats for Michigan, USA, pp. 91.
22. Kannan L, Thangaradjou T (2005) Sea grasses.
23. Nixon SW (1988) Physical energy inputs and the comparative ecology of lake and marine ecosystems. Limnol. Oceanogr 33 (4): 1005-1025.
24. Annual Report Ecosystem Modelling-Chilka Lake (2009-10) ICMAM-PD, Ministry of Earth Sciences, India.
25. Hull V, Parrella L, Falcucci M (2008) Modelling dissolved oxygen dynamics in coastal lagoons. Ecol Mod 211: 468-480.
26. Jayaraman G, Rao AD, Dube A, Pratap KM (2005) Numerical Simulation of Circulation and Salinity Structure in Chilika Lagoon J Coastal Res pp. 22.
27. Acharyya T, Sarma VVSS, Sridevi, Venkataramana V, Bharathi MD, *et al.* (2012) Reduced river discharge intensifies phytoplankton bloom in Godavari estuary, India Mar Chem 132: 15-22.
28. Bond H.W (1979) Nutrient concentration patterns in a stream draining a montane ecosystem in Utah. Ecology 60(6): 1184-1196.
29. Sarma VV, Prasad VR, Kumar BSK, Kumar MD (2010) "Intra-Annual Variability in Nutrients in the Godavari Estuary, India." Cont Shelf Res 30 (19): 2005-2014.
30. Satpathy KK, Mohanty AK, Prasad MVR, Natesan U, Sarkar SK (2010) Seasonal variation in physicochemical properties of coastal waters of Kalpakkam, east coast of India with special emphasis on nutrients. Environ Mon Ass 164: 153-171.
31. Meyer JL, Likens GE (1979) Transport and transformation of phosphorus in a forest stream ecosystem. Ecology 60(6): 1255-1269.
32. Alongi DM (1990) The ecology of tropical soft-bottom benthic ecosystems. Oceanogr Mar Biol Annu Rev 28: 381-496.
33. Kumar HS, Pandit Rao, Baliarsingh SK, Srinivasa Kumar T (2014) Consequence of cyclonic storm Phailin on coastal morphology of Rushikulya estuary : an arribada site of vulnerable Olive Ridley sea turtles along the east coast of India. Curr Sci India 107(1): 28-30.

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