Table 1. Fresh vegetable yield of safflower, fenugreek and spinach

Crop	Season		
	Winter (2014–15)	Summer (2015)	Monsoon (2015)
	Fresh vegetable yield (kg/ha)		
Safflower	656–4744	427–7767	5175–8331
Fenugreek*	10,000–12,900	1800–2100	5000–7000
Spinach*	11,600–14,000	8000–9000	9000–12,000

*Source: Data provided by local farmer irrigated fields (single cutting @ 35–40 DAS).

Table 2. Nutritional parameters of vegetable safflower, fenugreek and spinach in summer 2015

Crop	Fat (%)	Protein (%)	Vitamin C (mg/100 g)	Phenolic compounds (mg/100 g of GAE)
Safflower (range)	1.15–2.85	21.00–29.75	8.06–18.99	76.00–234.87
Safflower (general mean)	2.01	26.27	12.66	146.12
Fenugreek (general mean)	1.27	21.83	18.25	218.58
Spinach (general mean)	1.12	23.84	10.91	99.91

during the rosette stage (30–40 DAS) without adversely affecting the productivity of the crop as an oilseed[10,11]. Thus the income generated from thinned plants and removal of the lower 3–4 leaves/plant at 30–40 DAS can meet the entire cost of production of the crop in advance. This can help the farmers in meeting all future input needs of the crop. The earnings likely to be obtained from the seeds and flowers would be a net income in his hands. However, in order to achieve this it is important to promote safflower as a nutritious leafy vegetable among the masses. This will not only enhance income of safflower farmers, but would also help in ensuring nutritional security of the consumers.

High vegetable yield under summer and monsoon conditions has revealed the suitability of safflower for two growing situations in which it is conventionally not grown. The promotion of safflower as a leafy vegetable will provide an additional nutrient source to the consumers and a source of remuneration to the farmers.

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Temporal variation of phytoplankton assemblage in estuarine waters: implication of cyclone *Phailin*

Physical forcing of cyclonic phenomenon on water quality often exerts stress on marine and estuarine ecosystems due to their unpredictability. The post-cyclonic changes in phytoplankton biomass have been reported in the Bay of Bengal[1]. In addition, cyclones also intensify physical processes resulting in entrainment of nutrient-rich water from deeper depths into surface leading to regional phytoplankton blooms[2]. These blooms can bring out either positive or negative responses in the phytoplankton community which in turn exert effects on the food chain. However, changes in water quality parameters largely depend on cyclone intensity along with residence period.

A very severe cyclonic storm, *Phailin*, was developed in the Bay of Bengal and made landfall at Gopalpur coast of Odisha on 12 October 2013 (ref. 1). The present study area, Rushikulya estuary, was in close proximity (~20 km) to the landfall point. The Rushikulya estuary is a shallow aquatic ecosystem influenced by semi-diurnal tides and experiences tropical monsoonal climate[3]. The present study was carried out to decipher the phytoplankton community structure in Rushikulya estuary with reference to the cyclone *Phailin*.

The Rushikulya estuary has been seasonally monitored. Hence, water quality parameters of pre-*Phailin* phase (April 2013) were compared with post-*Phailin* phase-1 (November 2013) and post-*Phailin* phase-2 (April 2014). During each survey, water samples were collected from a fixed station (Figure 1).

Surface water samples were collected to determine inorganic nutrients (nitrite, nitrate, phosphate and silicate), dissolved oxygen (DO), total suspended matter (TSM) and chlorophyll-*a* (Chl-*a*). DO was estimated by adopting Winkler's method[4]. TSM concentration was measured by gravimetric analysis. Salinity was measured following Knudsen's titration method. Nutrients were analysed following standard methodology[4]. Chl-*a* was estimated spectrophotometrically using 90% acetone extraction method[5]. Phytoplankton samples (1 litre) were collected from surface, preserved with standard fixatives and subjected for taxonomy using a trinocular research microscope (Make: Labomed; Model: Lx 400). The phytoplankton abundance was represented as cell numbers per litre (cells l^{-1}).

The total abundance of phytoplankton cells was highest during post-*Phailin* phase-2 (23.91×10^4 cells l^{-1}) followed by pre-*Phailin* phase (12.66×10^4 cells l^{-1}). Post-*Phailin* phase-1 (5.56×10^4 cells l^{-1}) was observed with lowest abundance of phytoplankton cells. During pre-*Phailin* phase, diatom was found to be the dominant phytoplankton group (99%) wherein a bloom-forming species, *Asterionellopsis glacialis* (AG) shared >75% (9.35×10^4 cells l^{-1}) of the total population (Figures 2 and 3 *c*). In corroboration to earlier report[6], the study area was observed with diatom dominancy and AG as the bloom forming diatom. Total phytoplankton abundance during post-*Phailin* phase-1 was two times lower than pre-*Phailin* phase and four times lower than post-*Phailin* phase-2. However, diatom dominated the phytoplankton community in post-*Phailin* phase-1 despite changing physico-chemical conditions due to their euryhaline and eurythermal nature[7]. During post-*Phailin* phase-2, dinoflagellate was observed as the most dominant group (95%) of phytoplankton with predominating species *Noctiluca scintillans* (NS). NS contributed >80% (21×10^4 cells l^{-1}) to the total phytoplankton population (Figures 2 and 3 *a*, *b*). As NS is not a toxin producer, its blooming condition can act as a vector for toxigenic phytoplankton and killing agent for fishes. Concomitant to the present study, pre-monsoon NS bloom was also reported earlier in this region and upwelling induced nutrient nourishment was presumed as a possible driving force for bloom event[8]. In view of NS preponderance during post-*Phailin* phase-2, the low turbulence and availability of nutrients brought into the ambient medium as an effect of cyclone *Phailin* might have favoured dinoflagellate proliferation[9].

Despite decline in total abundance, maximum species diversity of phytoplankton was observed during post-*Phailin* phase-1 (32 diatom, 10 dinoflagellate, 2 blue green algae) in comparison to pre-*Phailin* phase (21 diatom, 2 dinoflagellate, 1 blue green algae) and post-*Phailin* phase-2 (6 diatom, 6 dinoflagellate). The decline in species diversity during pre-*Phailin* and post-*Phailin* phase-2 was due to the predominance of AG and NS respectively. The very sharp dwindle of species diversity during post-*Phailin* phase-2 could be attributed to the fact that heterotrophic NS feed on other phytoplankton[10]. During pre-*Phailin* phase, Chl-*a* (proxy of phytoplankton biomass) was 16.46 mg m^{-3} whereas during post-*Phailin* phase-1 and phase-2, the concentration was 4.47 and 15.37 mg m^{-3} respectively (Figure 4). High Chl-*a* values during pre-*Phailin* phase and post-*Phailin* phase-2 were ascribed to the predominance of AG and NS respectively. Although total phytoplankton abundance was highest in post-*Phailin* phase-2 (NS preponderance period), Chl-*a* concentration was relatively lower in comparison to pre-*Phailin* phase (AG preponderance period). This may be attributed to the low contribution rate of quantified phytoplankton fraction to total Chl-*a* during post-*Phailin* phase-2 (ref. 11). In the context of lower phytoplankton abundance during post-*Phailin* phase-1, it is worth mentioning that the instantaneous increment in nutrient concentration did not seem to trigger phytoplankton abundance

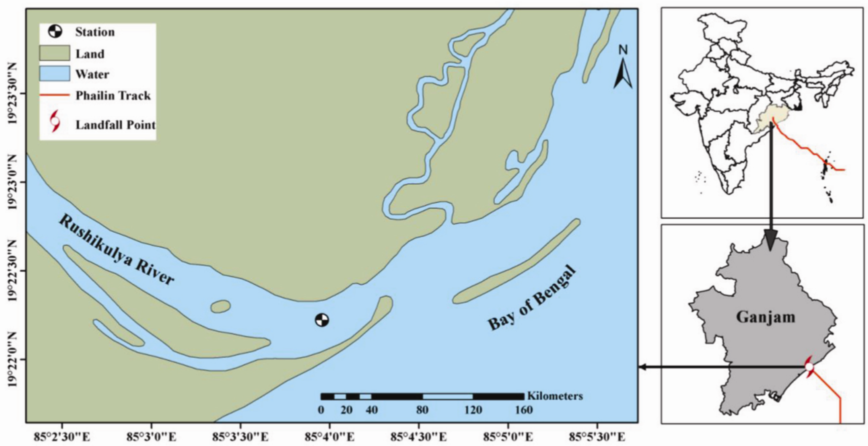

Figure 1. Map showing sampling location in Rushikulya estuary and track-landfall point of cyclone *Phailin*.

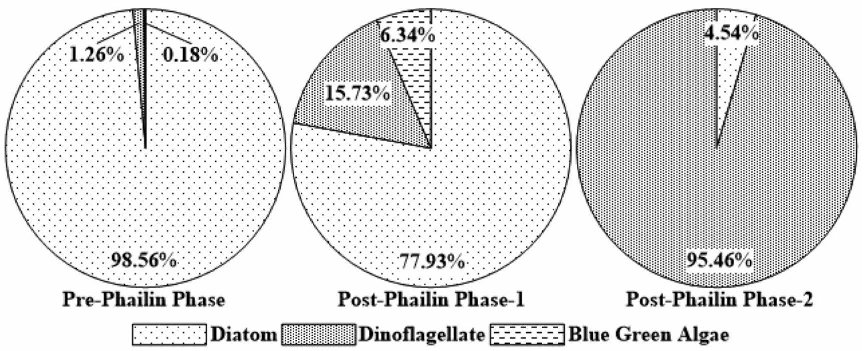

Figure 2. Relative abundance of phytoplankton groups during pre and post phases of cyclone *Phailin* in Rushikulya estuary.

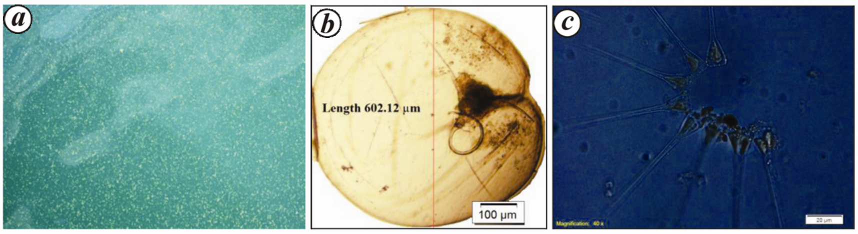

Figure 3. ***a***, Field photograph showing aggregation of *Noctiluca scintillans* in Rushikulya estuary. ***b***, Micrograph of *Noctiluca scintillans*. ***c***, Micrograph of *Asterionellopsis glacialis*.

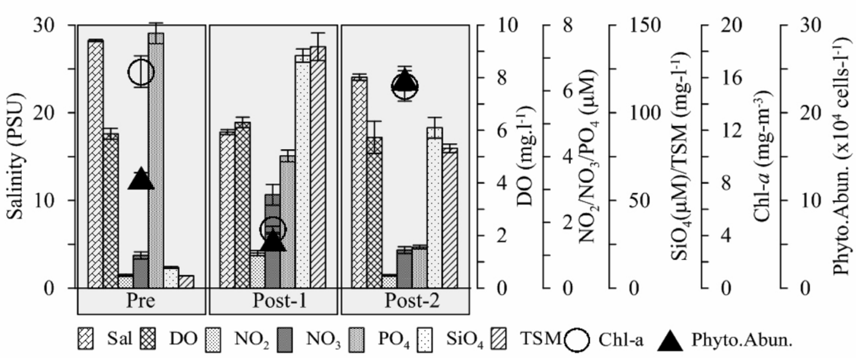

Figure 4. Distribution of physico-chemical and biological parameters during pre and post phases of cyclone *Phailin* in Rushikulya estuary (Sal, Salinity; DO, Dissolved oxygen; NO_2, Nitrite; NO_3, Nitrate; PO_4, Phosphate; SiO_4, Silicate; TSM, total suspended matter; Chl-*a*, chlorophyll-*a*; Phyto. Abun., Phytoplankton abundance). The vertical lines with cap in each bar represent standard deviation.

leading to bloom[12]. Moreover, lower phytoplankton abundance might be due to change in hydrographic parameters attributed to precipitation-induced river influx, terrigenous run-off and turbid water column.

Higher magnitude of nutrients during post-*Phailin* phase-1 was attributed to cyclone *Phailin*-induced heavy precipitation resulting in nutrient-rich river influx and terrigenous runoff. TSM concentration was also found highest during this phase which could be attributed to the suspension and re-suspension of sediments as a result of breach of a sand bar (part of estuary) due to scouring effect of cyclone *Phailin*[13] (Figures 1 and 4). Silicate concentration was lower during pre-*Phailin* phase (diatom was the dominant phytoplankton group) and higher during post-*Phailin* phase-2 (dinoflagellate was the dominant phytoplankton group). Further, it was also noted that a significant amount of silicate (128.21 µM during post-*Phailin* phase-1) entered into this ecosystem that might be due to the dilution of silicate rich silt as a result of cyclone *Phailin*-induced river influx and terrigenous runoff (Figure 4). The observation signifies active utilization of silicate by diatoms (predominance of AG) during pre-*Phailin* phase and non-utilization by dinoflagellates (predominance of NS) during post-*Phailin* phase-2 (refs 6, 8). During the study period, DO concentration fluctuated within a narrow range and remained as ~6 mg l^{-1}. The magnitude of nitrogenous nutrients and phosphate was lower during post-*Phailin* phase-2 in comparison to post-*Phailin* phase-1, which might be due to grazing by other phytoplankton species on which heterotrophic NS feeds (Figure 4).

In summary, the present study infers the following in Rushikulya estuary: (1) there is a recurrence of pre-monsoon phytoplankton bloom; (2) instantaneous increment in nutrient concentration aftermath of cyclone *Phailin* does not promote phytoplankton abundance; and (3) NS infested estuarine waters may act as a vector for toxigenic phytoplankton and killing agent for fishes.

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