Biological implications of cyclone *Hudhud* in the coastal waters of northwestern Bay of Bengal

A very severe cyclonic storm, *Hudhud,* equivalent to a category-4 hurricane on the Saffir–Simpson hurricane wind scale (SSHWS), originated in the Andaman Sea on 6 October 2014. The cyclone propagated west-northwestward and made landfall near Visakhapatnam, northern coast of Andhra Pradesh on 12 October 2014. The study area, Gopalpur (southern coast of Odisha) was in the active influence zone of *Hudhud* and in close proximity (~260 km north) to the landfall point (Figure 1). This region is an important mass nesting rookery for vulnerable olive ridley sea turtles, which aggregate for breeding in the coastal waters off Odisha from November to May[1]. This region is also identified as a time-series station under the SATellite Coastal and Oceanographic REsearch (SATCORE) programme coordinated by the Indian National Centre for Ocean Information Services (INCOIS); it is being monitored since 2009.

Tropical cyclones are known to be important episodic events for injecting nutrients into the euphotic layer for enhancement of phytoplankton through disturbance induced by physical processes[2]. It has been observed that productivity changes with the occurrence of cyclones in the Bay of Bengal (BoB)[3]. However, the degree of enhanced productivity largely depends upon the intensity of the cyclone along with its residence period.

Recent studies using satellite data have reported a significant increase in chlorophyll *a* (Chl *a*) concentration and decrease in sea-surface temperature (SST) in the coastal waters off Gopalpur, subsequent to the passage of cyclone *Phailin*[3]. The reported increase in Chl *a* was 710% with a positive anomaly of 4.35 mg/m^3 with respect to ten years of climatology. SST showed a significant negative anomaly of 2.5°C (ref. 3). Anticipating the possible effect of cyclone *Hudhud* on water quality, pre- (8–11 October) and post-*Hudhud* (14–20 October) field campaigns were conducted in the coastal waters of Gopalpur (Figure 1). During each survey water samples were collected from three locations and analysed for inorganic nutrients [nitrite + nitrate ($NO_2 + NO_3 = NO_x$), phosphate (PO_4) and silicate (SiO_4)], total suspended matter (TSM), dissolved oxygen (DO), Chl *a* and phytoplankton (qualitative and quantitative). Nutrients and DO were analysed using spectrophotometric method and Winkler's titrometric method respectively[4]. TSM was measured gravimetrically. Spectrophotometric analysis of Chl *a* was carried out following acetone extraction method[5]. Water sample (1 litre) for the phytoplankton study was collected in pre-cleaned plastic bottles and preserved with 1% Lugol's iodine–2% neutral formalin until analysis. Standard taxonomic keys were referred for identification and species were enumerated under a Sedgewick–Rafter counting chamber.

The result of the analysis showed highest abundance of total phytoplankton during post-*Hudhud* phase (81.97×10^4 cells l^{-1}) in comparison with pre-*Hudhud* phase (34.20×10^4 cells l^{-1}) (Figure 2). During the pre-*Hudhud* phase, diatoms were observed as the most dominant group (70–79%) of phytoplankton, wherein *Asterionellopsis glacialis* predominated (Figure 3). During post-*Hudhud* phase, a shift in species dominance was noticed with predominance of *Thallassiothriox longissima*. However, diatoms remained as the dominant phytoplankton group during both phases, with a marginal increase in contribution to the total phytoplankton population.

During pre-*Hudhud* phase, nitrogenous nutrients (NO_x) were observed at a concentration of ~ 1 μmol/l, which increased fourfold subsequent to the passage of the cyclone. NO_x is one of the major environmental factors regulating primary productivity in the study area[6]. Similar to NO_x, a twofold increase in PO_4 concentration was recorded during post-*Hudhud* phase. PO_4 ranged from 0.79 to 1.35 μmol/l and 1.49 to 2.53 μmol/l respectively, during pre- and post-*Hudhud*. The silicate concentration ranged between 2.99 and 3.77 μmol/l during the pre-*Hudhud* phase (Figure 2). After the passage of the cyclone, SiO_4 concentration varied between 4.82 and 11.38 μmol/l. SiO_4 is the most important nutrient that promotes phytoplankton, specifically diatom growth and is reported to be one of the limiting nutrients in the study area[7,8]. Hence, this twofold increase in SiO_4 concentration during the post-*Hudhud* period might have fueled diatom growth, preferably for *T. longissima* to preponderate. The predominating

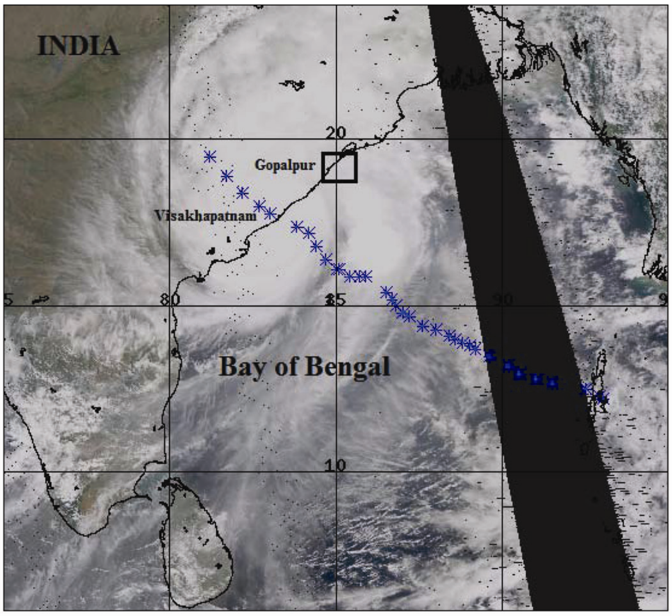

Figure 1. A true colour composite image from MODIS-Aqua overlaid with the track of cyclone *Hudhud* (star). The rectangular box shows the *in situ* sampling area.

chain-forming diatom, *T. longissima* might have contributed significantly to the increased Chl *a* during the post-*Hudhud* phase[9].

The high values of nutrients observed during the post-*Hudhud* phase could be attributed to strong winds and heavy precipitation-induced freshwater influx as well as suspension and re-suspension of nutrients in the water column. The daily precipitation peaked at 80 mm during the landfall period (11–13 October 2014) (source: http://as.ori.nic.in/rainfall/Pub-RainChart.asp). This was also evident from the concentration of TSM which increased from 5.98 ± 1.57 to 19.43 ± 8.12 mg/l during the pre- and post-*Hudhud* phases respectively (Figure 2).

There was significant increase in Chl *a* from pre- (1.58–2.28 mg/m^3) to post-*Hudhud* (2.57–6.62 mg/m^3) phase (Figure 2). This increase was linearly correlated with variability in the nutrients. A strong positive correlation was observed between Chl *a* and NO_x (Pearson's r = 0.73) and PO_4 (0.71), whereas SiO_4 was found to be limiting phytoplankton growth because of rapid consumption of elevated SiO_4 by diatoms[8]. In consonance with the increase in Chl *a*, phytoplankton abundance was also high after the passage of *Hudhud* compared with before. The increase in Chl *a* concentration during the post-*Hudhud* phase may have been due to the combined effect of nutrient entrainment from river influx and mixing resulting from the cyclone. This proliferation in phytoplankton productivity may lead to blooms. On the other hand, cyclone-induced new production may also boost fisheries in this region by enriching the food chain.

After witnessing a significant elevation of Chl *a* in nearshore coastal waters, further attempts were made to map Chl *a* to understand its spatial extent. The level-2 data of Ocean Colour Monitor-2 (OCM-2) were acquired from INCOIS ground station. The pre- (2–11 October 2014) and post-*Hudhud* (13–21 October 2014) composite images of Chl *a* revealed a significant increment in concentration along the track of the cyclone subsequent to its passage in BoB (Figure 4). Coastal waters in its vicinity also showed enhanced Chl *a* during the post-*Hudhud* period. A similar pattern of enhanced Chl *a* along the track of tropical cyclone *Phailin* was also observed earlier in this Bay[3].

The above analysis provides evidence that cyclone *Hudhud* exerted an effect on primary productivity in the coastal waters of northwestern BoB. The cyclone-induced changes in primary producers and water quality may alter the feeding grounds of migratory olive ridleys in BoB. Sea turtles may change their remigration intervals in response to food availability, which may be affected by cyclone-induced changes in surface current and thermohaline circulation patterns[10–12]. A shift in phytoplankton species dominance after the passage of *Hudhud* may result in changes in the community structure in the study area. Cyclone-influenced biogeochemistry of the study area needs to be further monitored to understand its possible effect on fisheries and marine communities.

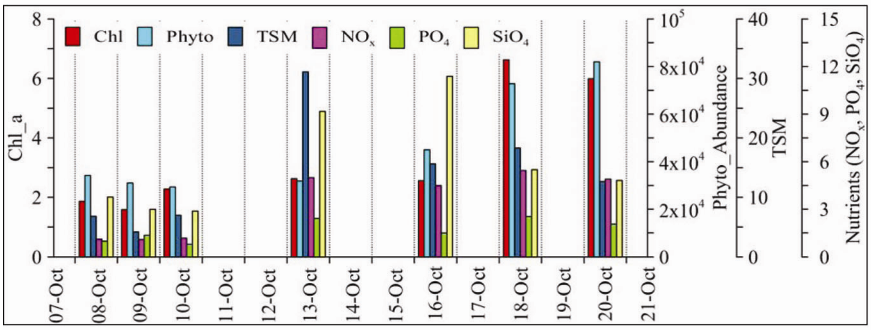

Figure 2. Average distribution of Chl *a* (mg/m^3), phytoplankton abundance (cells/l), TSM (mg/l), NO_x (µmol/l), PO_4 (µmol/l) and SiO_4 (µmol/l) during pre- and post-phases of cyclone *Hudhud*.

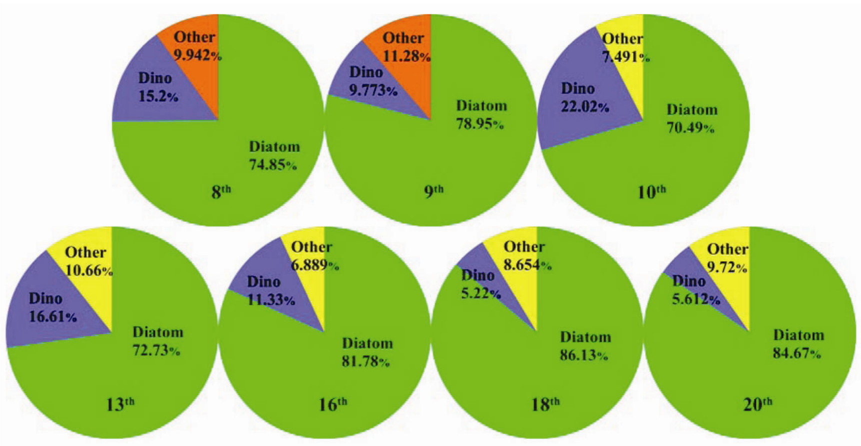

Figure 3. Relative abundance of phytoplankton groups during pre- and post-*Hudhud* phase.

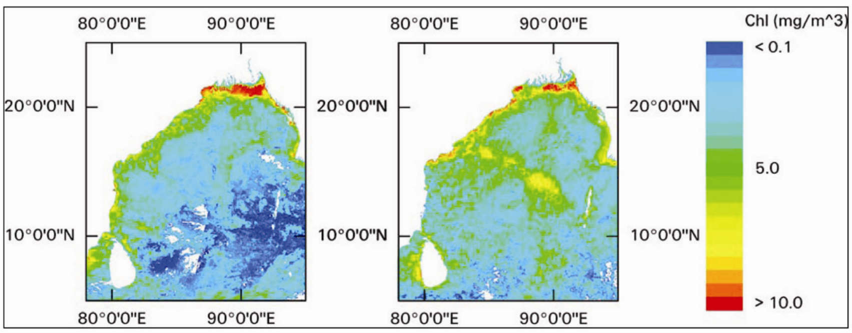

Figure 4. Composite images of Chl *a* generated from OCM-2 data for the period of pre-*Hudhud* (left panel) and post-*Hudhud* (right panel).

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Spider feeding on a Vespertilionid bat from Kerala, South India

Insectivorous bats occupy a relatively safe position in the food web, usually being predated upon only by owls, hawks and snakes[1–3]. Bats predated upon by spiders is a rare phenomenon and reports on the same in the Oriental region are rare[4,5]. Only a few chiropterologists and arachnologists have ever seen a bat being predated upon by a spider in the field[6–9]. Many field biologists and ecologists with special interest in such an ecological relationship between the two taxa have spent decades in the field with little success. There have been only 52 reports on bats being predated by spiders from across the globe over the past hundred years[10]. The infrequency of such reports implies that mortality of bats due to spiders is an extremely rare event, or it may be rarely observed and/or reported.

Of the 52 published reports mentioned earlier, only 2 are from India[4,5], including one from Chinnar Wildlife Sanctuary in Kerala. Here we report an additional record of bat predation by a spider from the Kerala Agricultural University main campus, Thrissur district, Kerala, South India.

The first report of bat being caught in a spider web was in 1842 by Cantor[11]. The earliest report from India was by Bhattacharya[4] in which a pipistrelle, *Pipistrellus* sp., was caught in the web of a Sparassid spider, *Heteropoda venatoria*, but the spider failed to feed on the bat. The second report from India was from Chinnar Wildlife Sanctuary; a Theraphosid spider, *Poecilotheria rufilata* fed on *Pipistrellus ceylonicus*[5].

Giant golden silk orb weavers of genus *Nephila* feed primarily on small insects like jewel beetles. However, they have been observed to go for large catches like cicadas, moths, grasshoppers, dragonflies, damselflies, large beetles, bats, fish, frog, lizards, snakes and rats as well[10]. There was an unsuccessful attempt of a *Nephila* spider trying to feed on a Grey-breasted Prinia, *Prinia hodgsonii*[12] (size 110 mm), at the Kerala Agricultural University main campus, Thrissur district (S. Sarath, 2011, pers. commun.).

On 25 November 2013, during the course of a regular bird-watching trail at the Botanical Garden of Kerala Agricultural University, Thrissur district, Kerala, India (Figure 1) (10°32′52.4″N, 76°17′12.4″E, altitude ~50 m), we made an interesting observation. At around 12:30 h, we saw a Giant Wood Spider (*Nephila pilipes*, family Nephilidae) feeding on a prey, which initially looked like a dry leaf to us. The spider web was on a *Lagerstroemia*

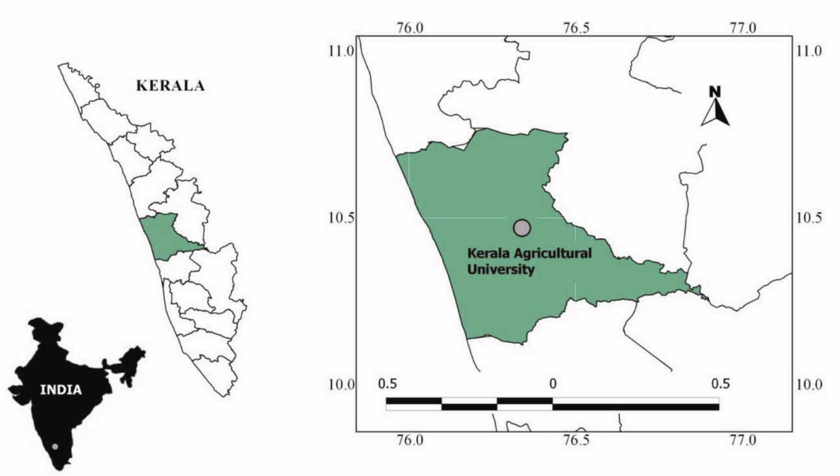

Figure 1. Location map of the Kerala Agricultural University main campus at Thrissur.