

Preliminary results on the influence of river discharges on biogeochemical processes in Godavari estuary and Bay of Bengal

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The Bay of Bengal is known to receive globally significant freshwater discharges from rivers of the subcontinent. However, the influence of river discharges on the biogeochemical processes of estuaries and the Bay of Bengal are not clearly known. In order to understand changes in circulation and biogeochemical processes, studies have been made earlier in different (mostly in the middle of) seasons. The seasonal coverage was usually done in wet and dry seasons with some studies covering winter and summer monsoons and non-monsoon seasons. Such a sampling strategy was made with the presumption that different seasons would have maximal diverse conditions of significance to ecosystem and biogeochemical turnover.

As most of the Subcontinent Rivers are in full flow following the summer monsoon (June-September) rain fall estuarine sampling during the maximal discharge is expected to reflect the influence of freshwater discharge on the ecology and biogeochemical processes of the estuarine and adjoining coastal waters. However, there is no published evidence on the evolution of fine-scale temporal variability of ecosystem and biogeochemical variables in an estuary to conclude that studies in peak seasons would yield results of maximal variability or how these properties systematically change in time. During the summer monsoon, discharges of many rivers are regulated through dams. Such a controlled discharge would alter the periodicity of natural estuarine circulation pattern and the associated biogeochemical processes compared to those of free flowing rivers without dams.

Biogeochemical studies along the west coast have confirmed prevalence of hypoxic waters following the southwest monsoon that has been attributed to high biological production triggered by natural upwelling and anthropogenic fertilizer discharges. If later to be the

reason for high productivity in coastal waters then it should be a major factor for biological production along the east coast of India. There is no systematic study to quantify the fluxes of anthropogenic nutrients into the estuary and/or into coastal waters, and find the influence of such discharges on the productivity and biogeochemical processes of these aquatic bodies.

Keeping the factors (a) flushing of the estuary, (b) temporal variability in mixing processes, (c) discharge of nutrients, (d) evolution of biological productivity patterns, and (e) associated biogeochemical processes in mind, we have planned and carrying out systematic studies in the Godavari estuary with daily sampling since 11 September 2007. Having fixed one station near Yanam, known (based on our earlier studies) to experience near zero salinity in summer monsoon to high saline conditions in dry seasons we also identified another at Kotipalli, to represent freshwater conditions in all seasons. Results from the station at Kotipalli are expected to indicate the signatures of characteristics of water transported from upstream regions. While the sampling at Kotipalli is only at the surface, it was done at surface, 5 m and 10 m at Yanam. Sampling at these two locations was carried out simultaneously at 1100 AM. A field laboratory is set up at Yanam where the daily samples collected from Yanam and Kotipalli stations were analyzed soon after the sampling. Vertical profiles of temperature and salinity were obtained using a portable Sea Bird CTD system. Oxygen was estimated by Winkler's titration and nutrients (nitrite, nitrate, ammonia, phosphate and silicate) were analyzed spectrophotometrically. Total and size fractionated Chlorophyll was analyzed following DMF extraction. Discharge data were obtained from Irrigation Department, Dowleswaram Barrage, Rajahmundry.

The entire water column at Yanam was filled with river water up to the end of September after which salinity recovery started from bottom. A weak salt wedge type circulation prevails up to the end of December. From July to September the freshwater discharge was at a minimum of $5 \times 10^4 \text{ ft}^3 \text{ sec}^{-1}$ (or $\sim 0.12 \times 10^9 \text{ m}^3 \text{ d}^{-1}$). With an average area (downstream of Kotipalli) of 65 km^2 and average depth of 5 m the volume of the Gautami Godavari estuary amounts to $0.325 \times 10^9 \text{ m}^3$. At the minimal discharge rate the entire estuary would be flushed

in <3 days during summer monsoon. Alternately, at the maximal discharge rates at 8 to 12 times that of minimal during monsoon, the entire estuary could be flushed a few times a day.

Oxygen concentrations were high in September-October and in December-January, reaching concentrations above 200 μM during the latter period. Nutrient concentrations decreased from September onwards, coinciding with the beginning of the salinity recovery phase, due to reduced discharge and increased utilization by photosynthetic activities. Total chlorophyll reached maximal levels during October-November with somewhat a funnel shape vertically. The productivity during this period appears to have been favored by the brackish water conditions associated with salinity recovery. Size fractionated chlorophyll distribution suggested the dominance of small sized chlorophyll particles (<10 μm sized plankton). Brackish water conditions at Yanam with salinity <15, as occurred in recovery period, favored proliferation of small (mostly 2-10 μm) sized plankton whereas salinities >15, as found in January, promoted large (>10 μm) sized plankton groups.

The second chlorophyll peak in January at Yanam, in fact, is largely contributed by plankton of size >2 μm . The second peak coincides with peak in ammonia concentration, the source of which is in the upstream since the surface water at Kotipalli recorded much higher levels. Whether agricultural fertilizer or other industrial discharge contributed to high ammonia and chlorophyll production (inadvertent fertilization) in January is unclear. Results at Kotipalli revealed sporadic discharges of ammonia into the upper reaches. Nevertheless, higher biological production resulted in utilization of nutrients and production of highest levels of oxygenated conditions in winter.

Nutrient distributions between Kotipalli and Yanam clearly indicate significant losses downstream between the two stations, even in September when the monsoon discharge is still high, implying that their concentrations are significantly reduced before entering the estuary. For instance, nitrate concentrations of 120-160 μM at Kotipalli are reduced by 4-5 times (to <30 μM) at Yanam. Nutrients

are most likely diluted by freshwater directly draining across the banks from the basin since no significant production of chlorophyll in September was found at both the places. Data from Kotipalli and Yanam suggest, despite the higher abundances of nutrients in September, that there was minimal chlorophyll production that appears to be primarily controlled by high turbidity. Reduced suspended material towards the second half of October favored the proliferation of plankton as the light penetrated water column promoting the photosynthetic activity.

Productivity estimates based on changes in oxygen indicated shifting of the ecosystem of Yanam from heterotrophy in September to autotrophy by January. This is essentially because of dominant bacterial activity supported by dissolved and particulate carbon loads transported by the river discharges. As the heterotrophic processes were still significant, even when peak biological production occurred, the oxygen levels remained lower in October than in January. The same mechanism is also responsible to make the Bay of Bengal a net heterotrophic system during July that slowly shifts to a net autotrophic ecosystem later on.

These preliminary investigations have posed several questions to be addressed by the experiments being planned in the XI Plan period.