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Comparative accounts of biological productivity characteristics and estimates of carbon fluxes in the Arabian Sea and the Bay of Bengal

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Abstract

The Arabian Sea and the Bay of Bengal are tropical basins experiencing monsoonal wind forcing that reverses semi-annually. This brings changes in physics, chemistry and biology of the upper water column on a seasonal scale and ultimately regulates the sinking fluxes of the region. An attempt is made here to focus on factors responsible for fluxes of carbon from the upper layers to the deep sea. Higher fluxes are observed during southwest and northeast monsoon season in both the regions. In contrast to the Arabian Sea, an immense quantity of freshwater runoff together with warmer SST (~30 °C) makes the northern bay strongly stratified. The runoff also brings in billions of tonnes of fluvial matter as well. Stratification constrains subsurface nutrient input into the surface waters thereby reducing the primary production in the Bay of Bengal. The total living carbon content in the Bay of Bengal is much lower than in the Arabian Sea. Higher downward fluxes associated with deep mixed layer and high production in the Arabian Sea during summer and winter pinpoint importance of strong winds causing mixing and upwelling during summer and evaporative cooling and convection during winter. Inability of the low-speed winds to break the stratification in the Bay of Bengal keeps the region low productive throughout the year. Therefore, river water associated with the terrigenous material due to ballast effect appears to swipe off surface producers to the deep, thereby increasing the downward fluxes of total particulates, which are sometimes even higher than that of the more productive Arabian Sea.

1. Introduction

The Indian Ocean in the north comprises the Arabian Sea (AS) and the Bay of Bengal (BOB), encompassing the Laccadive and the Andaman

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Seas. Although the geographical settings of these two basins are somewhat similar, the hydrographic and hydrochemical characteristics differ widely. The AS receives lower volumes of river runoff ($0.3 \times 10^{12}\,m^{-3}\,yr^{-1}$) compared to BOB ($1.6 \times 10^{12}\,m^{-3}\,yr^{-1}$). Rivers Tapti and Narmada are two of the very few major rivers draining into the AS. On the other hand, a large number of rivers such as the Irrawady, Brahmaputra, Ganges, Godavari, Krishna and Cauvery discharge into the BOB (Subramanian, 1993). As a result, BOB surface waters are 3–7 psu less saline than the AS surface waters (Prasanna Kumar et al., 2002). Contrastingly, excessive evaporation over precipitation leads to the formation of higher surface salinities in the AS—Arabian Sea high salinity water (ASHSW, ca. 36 psu), which sink and renew deep-waters (Dietrich, 1973). Strong south-westerly winds during southwest monsoon (SWM) result in coastal and open-ocean upwelling in the AS. Both seas experience atmospheric forcing over seasons leading to regular intra-annual oscillations in biological productivity. These result in seasonal as well as yearly variations in fluxes from the upper ocean to the deep (Haake et al., 1993; Lee et al., 1998; Unger et al., 2003). However, the relationships between primary producers, consumers and flux rates of the AS and BOB are not completely understood. The purpose of this paper is determine (1) the pathways of transport of organic carbon in the two seas and (2) the reasons why the observed productivity in the two basins and particle fluxes to the deep do not often match. To address these questions, data sets collected from 1994 onwards under the programmes —Joint Global Ocean Flux Study (JGOFS-India), Bay of Bengal Process Studies (BOBPS) and Marine Research on Living Resources (MRLR)—were used. Data collected under the Indo–German sediment trap programme (AS—May 1986–May 1987 and BOB—October 1987–October 1988 (Ittekkot et al., 1991; Nair et al., 1989; Ramaswamy and Nair, 1994)) were also used for substantiating the fluxes. Though these data sets have come from various years, an attempt is made to rationalize the observations with the prime idea of realizing the fluxes in these basins with quite contrasting productivity patterns.

2. Materials and methods

Based on the regional monsoonal cycles, the AS and BOB were sampled seasonally during the JGOFS and BOBPS. In the AS, collections were made during northeast monsoon (NEM, February 1995), southwest monsoon (SWM, July–August 1995 and August 1996) and spring intermonsoon (SPIM, April–May 1994) under JGOFS. BOB measurements under BOBPS were limited to SWM (July–August 2001) and fall intermonsoon (FIM, September–October 2002). We used the data set from the BOB collected under the MRLR project for NEM.

Locations of sampling from the coastal and open ocean areas in the AS and BOB are shown in Fig. 1. Essentially, JGOFS protocols (UNESCO, 1994), were followed for collection and analyses of the samples. Many details regarding the collection and processing of samples of parameters measured are given in Krishnaswamy and Nair (1996). Cruise details are shown in Table 1. Procedures

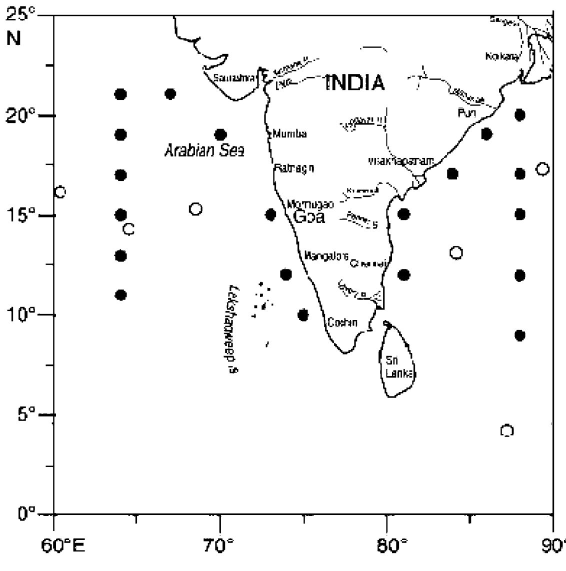

Fig. 1. Sampling locations. Filled circles indicate stations covered under the JGOFS in the AS and Bay of Bengal process studies programme in the BOB. Open circles denote sediment trap mooring locations. Stations covered for MRLR project were at 11°N along 80.1–84°E; 13°N along 80.4–84°E; 15°N along 80.2–85°E; 17°N along 83–87°E; 19°N along 86–89°E; and 20.5°E along 87.3–89°E. A very limited data set was made use of from MRLR project.