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Evaluation of changes in macrobenthic standing stock and polychaete community structure along the south eastern Arabian Sea shelf during the monsoon trawl-ban

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ABSTRACT

The south eastern Arabian Sea is characterized by moderate coastal upwelling, high biological production and subsurface oxygen depletion during the southwest monsoon (June–September). Concurrently, a seasonal closure to trawling activities (15th June–31st July) is implemented here, as a sustainable ecosystem management practise. The effects of monsoon driven environmental changes and consequences of trawling cessation on macrofauna were assessed, based on surveys at 12 sites (30–200 m) preceding and during different phases of the southwest monsoon. Macrofaunal density and biomass increased considerably towards the mid and late monsoon along the inner shelf (30–50 m) where trawling is intense, while no temporal changes were observed along the outer shelf (100–200 m). Density increased four-folds at the 30 m contour and three-folds at 50 m, while biomass nearly doubled at both depths, reflecting a marked increase in density of polychaetes (61–87% of macrofauna). The disproportionate increase in faunal density and biomass along the inner shelf (30–50 m) was due to abundance of juvenile polychaetes and dominance of small-sized opportunists towards late monsoon (August–September). A concurrent hike in nominal species count of polychaetes was also observed in the study area. The increase in polychaete standing stock and high density of planktonic larvae during onset and peak monsoon, coupled with occurrence of juveniles as well as gamete-bearing adults in sediments, indicates that the southwest monsoon is a peak breeding season for the dominant polychaetes in the region. The trawl-ban during this period facilitates the recoupment of benthos by maximising spawning success and larval settlement, thereby enhancing overall ecosystem integrity.

1. Introduction

Benthic communities, composed of complex assemblages of organisms living in association with sea-floor sediments, play a central role in the functioning of marine ecosystems (Koho et al., 2013). Benthic fauna are of primary importance in the assimilation of the substantial quantities of organic matter settling on the seafloor, which are transferred to benthic and pelagic food webs via trophic interactions. Soft bodied benthic fauna are important sources of food for diverse demersal fishes and shellfish; and in most cases, economically exploited fishery resources are supported in regions with high benthic biomass (Crisp, 1984; Snelgrove, 1998). Bioturbation by benthic fauna increases oxygen penetration in sediments and enhances the degradation of organic matter (Mermillod-Blondin, 2011). The integrity of the benthic realm is critical in overall ecosystem functioning as well as in supporting fishery resources. Being sessile or with limited mobility, benthic fauna are particularly vulnerable to physical, chemical and ecological disturbances.

The continental shelf off Kerala state in the southwest coast of India is known for its commercially exploited finfish and crustacean resources. Bottom trawling is the most common fishing activity, with ~4000 trawlers operating along the state's coastline (595 km), resulting in high fishing pressure (Naomi et al., 2011). Scientific evaluations have raised concerns about the presumed damages to benthic habitats by trawling gears (Bergman and Hup, 1992; Collie et al., 2000; Kaiser et al., 2006; Queirós et al., 2006; Tillin et al., 2006). Direct effects of bottom trawling include scraping and ploughing of the substrate, sediment resuspension and destruction of benthic assemblages. Indirect effects include

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post-fishing mortality of benthos and long-term trawl-induced changes in benthic community structure. Such long term changes may affect food availability for commercially important fishes and may also modify demersal food webs (Jennings and Kaiser, 1998; Jennings and Reynolds, 2000; Kaiser et al., 2006; Kumar and Deepthi, 2006). A handful of experimental studies have been undertaken to understand immediate changes in benthos after trawling off Kerala and other parts of the Indian coast (Thomas et al., 2006; Zacharia et al., 2006; Bhagirathan et al., 2014).

Concern over the ecosystem effects of fishing has led several countries to close parts of the sea bottom to mobile fishing gear for preserving ecosystem function and fish production (Kaiser et al., 2002). A closed fishing season for mechanised trawling vessels is implemented in all coastal states of India as well, with the view of reducing fishing effort during peak spawning periods of commercially important species, and also to reduce stress on the benthic fauna (Vivekanandan et al., 2010). The ban period along the Kerala coast, in the South Eastern Arabian Sea (SEAS) is between 15th June and 31st July (Kerala Marine Fishing Regulation Act, 1980) each year and coincides with the onset of the southwest (summer) monsoon, during which moderate to intense coastal upwelling occurs in the region (Smitha et al., 2008), resulting in enhanced biological production (Habeebrehman et al., 2008) and sub-surface hypoxia (Banse, 1959; Naqvi et al., 2009).

The trawling ban off Kerala during the monsoon season is generally considered to be an effective practise from the perspective of sustainable resource management (Vivekanandan et al., 2010). Though the quantitative and qualitative distribution of macrobenthos of the SEAS shelf is well described (Jayaraj et al., 2008; Joydas and Damodaran, 2009, 2014), reports on the impacts of trawling cessation on benthos are limited (Thomas et al., 2006). The temporal change in macrobenthic standing stock and composition during the monsoon upwelling, when the region is characterized with high production, increased organic matter (OM) flux and bottom water hypoxia, has not been addressed in an integrated manner for the sizeable SEAS shelf as a whole.

Based on surveys preceding (May, pre-monsoon and June, monsoon onset) and following the trawl-ban (August, peak monsoon and September, late monsoon) in the SEAS shelf (~7–9°N, 30–200 m), this investigation aims to: (i) study changes in standing stock and composition of benthic macrofauna, as well as community structure of polychaetes during the southwest monsoon, and (ii) determine whether breeding of polychaete taxa in the region coincides with the monsoon (through examination of meroplankton). The changes in quantum and composition of macrofauna across the monsoon season are considered from the perspective of the trawl-ban.

2. Materials and methods

2.1. Study area

The present study focuses on the continental shelf (30–200 m) of the southern part of the SEAS, between ~7° and 9°N latitudes. The SEAS is subjected to seasonal wind reversal associated with the southwest (summer) monsoon (June–September) and northeast (winter) monsoon (November–February), which influences the hydrography and oceanography of the upper water column (Smitha et al., 2008). As a result of constant influences from the equatorial Indian Ocean and the less saline Bay of Bengal, salinity is relatively low in the study area, when compared to the rest of the eastern Arabian Sea (Prasannakumar et al., 2004). During the southwest monsoon, moderate to intense coastal upwelling occurs in the SEAS, with isotherms tilting upwards from around April (Smitha et al., 2008). This causes nutrient enrichment in the upper water column, which results in enhanced biological production in the euphotic zone (Madhupratap et al., 2001). The high production and terrestrial runoff during this season, coupled with strong stratification, results in rapid utilisation of dissolved oxygen and formation of seasonal sub-surface hypoxia over the SEAS shelf (Naqvi et al., 2009).

The high seasonal production also enhances finfish and crustacean resources in the SEAS, which are subject to intense year-round fishery (Silas, 1977; Suseelan and Pillai, 1993), except during the 45-day trawl-ban period (June–July). Intense prawn fishery (using otter trawls) is practiced in the grounds lying between Kayamkulam (near Kollam) and Anjuthengu (near Trivandrum) and off Cape Comorin (Naomi et al., 2011). Single-day trawling operations in the region are restricted to ~30–50 m water depth, while multi-day operations are focused even beyond 100 m depths (Naomi et al., 2011). In general, the smooth topography of the mid-shelf region of the SEAS proves ideal for trawling. There is considerable concern about the extremely high fishing pressure in the SEAS shelf (Vijayan et al., 2000).

2.2. Sampling

Four surveys were undertaken in the study area on board Fishery Oceanographic Research Vessel *Sagar Sampada* – during June 2009 (FORVSS 267: pre-ban, monsoon onset phase/OP), August 2009 (FORVSS 270: post-ban, monsoon peak phase/PP), May 2010 (FORVSS 275: pre-ban, pre-monsoon/ PM) and September 2011 (FORVSS 289: post-ban, monsoon late phase/LP) to assess macrofaunal standing stock and composition.

During the first two surveys (OP and PP 2009), samples and data were collected at 12 sites (Fig. 1), located at 4 depths (30, 50, 100 and 200 m) in 3 transects along 77 °30′E (N–S off Cape Comorin, CAP), 8 °30′N (E–W off Trivandrum, TVM) and 9 °N (E–W off Kollam, KLM). A modified Smith–McIntyre Grab (0.2 m^2) was deployed to collect surface sediment samples at each site in duplicate. A sub-sample for sediment texture and organic matter analyses was collected from the grab and oven-dried (at 55 °C). The remaining sediments from the grab were sieved on-board, through a 500 μm mesh, and the retained materials were preserved in 5% buffered formaldehyde solution containing Rose Bengal stain. Sampling was rendered impossible at the 200 m station off Cape Comorin during the first survey, owing to bad weather. The sites between 30–100 m along TVM and KLM transects were revisited during the PM and LP surveys (while operational limitations made sampling at 200 m impossible). The above procedure was followed to collect macrofauna, with the use of a 300 μm mesh instead of 500 μm. Since smaller-sized fauna were found to dominate in the OP and PP samples and are reported to be important components of macrofauna below upwelling systems including SEAS (Abdul Jaleel et al., 2014), the smaller sieve was used in the latter surveys (PM and LP), so as to better quantify changes in standing stock across the southwest monsoon, including the contribution of smaller individuals. A total of 60 grab samples were collected during the entire study. A conductivity temperature depth (CTD) profiler (SBE 911-Plus) was used to record salinity and temperature at all sites, and water samples were collected in the attached rosette sampler for estimation of dissolved oxygen in near-bottom water following Winkler's Method (Strickland and Parsons, 1972).

In order to examine quantitative and qualitative composition of polychaete larvae in the water column, zooplankton samples were also collected during three cruises in June, August and September 2009 (FORVSS 267, 270 and 272), which corresponded to onset (OP), peak (PP) and late phases (LP) of the southwest monsoon. During each cruise an oblique surface Bongo net (300 μm mesh) haul at the surface and a vertical Multiple Plankton Net (MPN,