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Conclusion
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The present study was carried out with special reference to the following:

To understand and correlate changes in physical (sea surface temperature, wind speed) and biological (chlorophyll \(a\)) parameters in Arabian Sea.

To study the effects of physical and biological parameters on zooplankton biomass and develop zooplankton biomass algorithms for Arabian Sea.

To study the primary and secondary production rate and energy transfer from primary to secondary trophic level in Arabian Sea.

To investigate the influence of \(N. \text{scintillans}\) bloom on zooplankton and determine the relationship between \(N. \text{scintillans}\) and zooplankton in Arabian Sea.

Studies on Physical (Sea Surface Temperature, wind speed) and biological (chlorophyll \(a\)) environment of Arabian Sea

The analysis of the satellite derived physical (Sea Surface Temperature, wind speed) and biological (chlorophyll \(a\)) parameters for the period 1999-2009 were carried out to decipher the seasonal cycle of the physical process in the Arabian Sea and associated changes in chlorophyll Biomass.

Sea surface Temperature (SST) is one of the key oceanographic parameters, exerting an influential role in many of the meteorological and oceanographic processes. Climatological mean (1999-2009) of SST showed a prominent north south variation. Along the northern region, SST was characterized by low temperature (between 24.7 to
Maximum climatological wind speed was observed in central Arabian Sea during Southwest Monsoon (SWM). Climatological wind speed of July month in central western Arabian Sea (15-17°N & 61-63°E) showed maximum wind speed (12.44 m/s). During northeast monsoon in northern Arabian Sea comparatively low wind speed (~ 3-5 m/s) was observed.

This spatial heterogeneity in the SST and wind speed was reflected in the biological parameters. The chlorophyll a concentration was highest in northern Arabian Sea during Northeast monsoon (NEM) (1.19 to1.50 mg/m³). In the central Arabian Sea, highest chlorophyll a was observed during Southwest Monsoon instead of Northeast Monsoon.

In conclusion, the above analysis showed that during Northeast Monsoon the weak northeast trade wind brings cool, dry continental air reduced temperature in northern Arabian Sea and enhances the chlorophyll a concentration, which was about two times higher than that seen in the region outside the winter cooling. During Spring Intermonsoon, incoming short wave radiation and SST was maximum in Arabian Sea (29.5°C in open ocean Arabian Sea) and along with weak wind speed were unable to break the stratification and induce mixing of subsurface waters with the surface waters. As a result, chlorophyll a concentration decreased (< 0.4 mg/m³) and showed an oligotrophic condition. During Southwest Monsoon, incoming short wave radiation was decreased and wind speed showed a 3-fold increase from its Spring Intermonsoon values. Thus, both increased wind speed and reduced solar insolation led to the observed cold
SST (~25°C) in central Arabian Sea resulted in high chlorophyll $a$ concentration in this area.

Annual standardized anomalies were observed from 1999-2009, where the SST showed a clear-cut warming signal in the Arabian Sea. Seasonal differences in SST were also found with respect to increasing temperature. During Northeast Monsoon, seasonal standardized anomalies showed an insignificant decreasing trend of SST in open ocean Arabian Sea. The observed weak decreasing trend in open ocean Arabian Sea is due to decreased SST in northwestern Arabian Sea during Northeast Monsoon. Annual wind speed was found to decrease in open ocean Arabian Sea and in different domains, wind speed showed different magnitude of increasing and decreasing trend. During Northeast Monsoon, wind speed increased, while during Southwest Monsoon an insignificant increasing trend was observed in the open ocean Arabian Sea. During Spring Intermonsoon and Fall Intermonsoon wind speed was decreased in open ocean Arabian Sea. In different domains of the Arabian Sea, wind speed showed different magnitude of increasing and decreasing trend. In open ocean Arabian Sea and all the domains of the Arabian Sea; showed decreasing trend of chlorophyll $a$, in annual as well as seasonal analysis for the period 1999-2010. Moreover, it is important to note that there may be some uncertainty in chlorophyll $a$ data for the last few years due to ageing of the SeaWiFS sensor.

From the analysis of standardized anomaly index for SST and wind speed for open ocean Arabian Sea it can be concluded that from 1999 to 2009 there has been an annual increase in the SST and an annual decrease in the wind speed resulting in a
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decrease in chlorophyll $a$ concentration. However, the magnitude of the change and the periods of significant change are different in the different domains of the Arabian Sea.

Studies on effects of physical and biological parameters on zooplankton biomass and development of zooplankton biomass biophysical algorithms for Arabian Sea

Effect of physical (Sea Surface Temperature) and biological (Chlorophyll $a$) parameters on zooplankton was studied using data collected during US Joint Global Ocean Flux Study. Microzooplankton and mesozooplankton biomass indicated a linear relationship with chlorophyll $a$ and exponentially with SST. Empirical biophysical models for microzooplankton and mesozooplankton biomass were developed. The biophysical models of microzooplankton and mesozooplankton biomass were used to generate microzooplankton and mesozooplankton biomass images using remotely sensed chlorophyll $a$ and SST. Microzooplankton and mesozooplankton biomass values are accurate (low RMSE and % bias) when assessed with available data. Microzooplankton and mesozooplankton biomass images provides information that is useful for comparison with any future and past changes in biomass.

Microzooplankton and mesozooplankton biomass for the period 1999-2009 was calculated using SeaWiFS derived chlorophyll $a$ and NOOA-AVHRR derived SST. Monthly climatological mean of microzooplankton and mesozooplankton biomass showed pronounced seasonality and formed spatial patterns. During, Southwest and Northeast monsoon, the microzooplankton and mesozooplankton biomass in the epipelagic zone increased compared to the relatively calm intermonsoon periods.
Studies on the primary and secondary production rate and energy transfer from primary to secondary trophic level in Arabian Sea

MODIS derived epply VGPM model showed an annual decreasing trend in Arabian Sea (-0.24/year). In all the domains, decreasing trend of primary productivity was observed, only in northeastern Arabian Sea domain insignificant increasing trend was observed. Secondary production rate (mesozooplankton production rate) was calculated using an in-house developed mesozooplankton biophysical model and temperature dependent growth rate models viz., the Huntley and Lopez model (1992) and Uye et al. model (1996). Huntley and Lopez (1992) equation estimates high growth rate value as compared to published growth rates (0.80 – 1.04 d⁻¹). The range of estimated growth rates for the different domains using the Uye et al. (1996) equation are reasonable when compared to published growth rates at near temperatures (0.35– 0.41 d⁻¹). Annual mesozooplankton production rate was calculated using mesozooplankton biomass and growth rate derived using the Uye et al. (1996) growth rate equation for the period 2003 to 2012. Annual secondary production rate was decreased from 2003 to 2012 with a decreasing rate 0.1 per year. In the domains of the northern and central Arabian Sea an insignificant change in mesozooplankton production rate was recorded, in southern Arabian Sea mesozooplankton production rate was decreased. Furthermore, study of energy transfer from primary to secondary production showed that proportionally less energy is transferred from primary productivity when primary productivity is high, a than when primary productivity is low. The spatial variability of transfer efficiency is important and cannot be ignored if accurate zooplankton biomass is to be extrapolated. Transfer efficiency map of Arabian Sea showed energy transfer from
primary to secondary (mesozooplankton) production rate was high in open ocean Arabian Sea as compared to coastal area of Arabian Sea.

Studies on the influence of *N. scintillans* bloom on zooplankton and determination of the relationship between *N. scintillans* and zooplankton in Arabian Sea

Green *N. scintillans* bloom is found in the northern Arabian Sea every year during the Northeast monsoon. During Northeast monsoon cool dry continental air brought by the northeast trade winds intensify evaporation and sea surface cooling and the consequent sinking of the surface water (convection) results in an increase of the MLD. Entrainment occurs in northern Arabian Sea after January owing to an increase in surface water density and transport nutrients in the euphotic zone and it results in increase in productivity. Moreover, it is found that there is high biomass of zooplankton in *N. scintillans* bloom area as compared to non bloom area. This indicates that *N. scintillans* does not have an adverse effect on zooplankton biomass in northern Arabian Sea during the winter monsoon.