

Unusual mass shoreward movement of bivalve (Mollusca) *Donax scortum* Linnaeus along the coastal waters off Calicut - South Eastern Arabian Sea

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Eutrophication and oxygen depletion are the major factors influencing the responses of benthic organisms in coastal ecosystems. Along the coastal waters of South Eastern Arabian Sea a mass shoreward movement of bivalve *Donax scortum* (locally referred as “*eranthu*”) occurred during end phase of summer monsoon upwelling. Possible reasons for this shoreward movement points to the low dissolved oxygen (0.25 ml L^{-1}) in the bottom waters. Intense blooms of large dinoflagellate species, *Noctiluca scintillans* were observed a week prior to this event along these coastal waters and the crashing related decaying might have resulted in lower DO values in the region. The study discuss on the deleterious effects of hypoxic conditions caused by summer monsoon algal blooms on benthic fauna of South Eastern Arabian Sea.

[**Keywords:** Hypoxia; *Donax scortum*; Harmful algal blooms; *Noctiluca scintillans*; Arabian Sea]

Introduction

Coastal benthic ecosystems are highly influenced by alterations in physico-chemical factors of the water column and benthic-pelagic interactions are prominent in these systems. Habitat destruction by natural and anthropogenic activities such as dredging and mining, eutrophication, decrease in dissolved oxygen (DO) levels etc. are some among factors negatively affecting benthic ecosystems¹. Dissolved oxygen is considered to be an important factor in these aspects owing to the stress caused by hypoxic and anoxic conditions². Decrease in water column dissolved oxygen can result in various responses among the benthic organisms such as avoidance, growth irregularities, reproductive and behavioural changes^{3,4} etc. In general the DO levels of $<1.42 \text{ ml L}^{-1}$ is considered to be hypoxic condition³. Hypoxia induced alteration in behavioral characteristics of benthic fauna have been documented in various coastal bays and estuarine environments around the world⁵⁻⁸.

Hypoxia along the South Eastern Arabian Sea (SEAS) is directly or indirectly linked to the biannually reversing monsoons and the coastal upwelling during the summer monsoon season. High and sustained production along the coastal waters of SEAS results in higher organic matter input in the region. Coastal blooms are a regular phenomenon

during the summer monsoon upwelling which can possibly reduce the dissolved oxygen concentrations during the death and decay⁹. The occurrences of intense blooms in near shore waters thus have either direct or indirect effects on the benthic fauna. The erratic movements of invertebrates and fishes were previously reported from the Alabama coast of Gulf of Mexico and were reported as Jubilee phenomenon¹⁰ where the local fisherfolk effortlessly collected edible marine resources in huge quantities. The phenomenon repeats along the coast yearly. Along the west coast of India, bordered by eastern Arabian Sea there are several unpublished reports of such shoreward movements of benthic fishes and invertebrates. (<https://www.hindustantimes.com/mumbai-news/here-s-why-dead-fish-marine-animals-are-washing-up-maharashtra-shores/story-N9RxH40FpB9G4Dcycav5TK.html>). However, detailed and authentic studies regarding the causes are lacking. Oxygen minimum zones and expansion of hypoxia are the suspected causes of such shoreward movements of benthic fauna in masses. The oxygen minimum zone along the Arabian Sea is reported to be increasing with the alterations in monsoon cycles¹¹. This expansion can deleteriously affect the biogeochemistry of the region in near future. A jubilee phenomenon by crabs and flatfishes were reported from the central Kerala

coast of South Eastern Arabian Sea recently¹². The study reports a re-occurrence of such an event of mass shoreward movement of benthic fauna along the coast of South Eastern Arabian Sea during summer monsoon and the possibilities of such events in the coming years.

Materials and Methods

An unusual mass aggregation of molluscs was reported by local fisher folk and in newspaper from the coastal waters off Nainamvalappu, Calicut- South Eastern Arabian Sea (Lat. 11° 13.8 N, Long. 75° 46.65 E, Fig. 1) on 24th September 2017. Prior to the event, coastal waters off Calicut were sampled for various physico-chemical parameters as a part of regular monitoring programme to study the eco-physiology of coastal algal blooms. Water samples were collected from discrete depths by using Niskin water sampler for measuring various water quality parameters. Hydrographic parameters such as temperature, salinity and dissolved oxygen (DO) were measured immediately after the collection of water samples

during the field survey. Temperature was measured using an alcohol thermometer with an accuracy $\pm 0.01^\circ\text{C}$. Salinity was measured using a hand held refractometer (*ATAGO-Smill-E, Japan*). Dissolved oxygen was estimated by Winkler method¹³. Chlorophyll *a* was measured spectrophotometrically using UV-Visible spectrophotometer following acetone extraction method¹⁴. Phytoplankton samples were collected by filtering ~50 litres of surface water through 20 μm bolting silk, and the filtrates were preserved in 1–3 % neutralized formaldehyde-lugol's iodine solution. Qualitative and quantitative analysis of phytoplankton samples were carried out using a Sedgewick Rafter counting cell under a Nikon Eclipse microscope following standard identification keys¹⁵. Similar measurements of physico-chemical characteristics were carried out during the present phenomenon along the coast. The bivalve samples were collected, cleaned and immediately fixed in the field with 90-100 % ethanol and were taken to the laboratory. Species level identification was carried out under stereomicroscope by using standard identification keys¹⁶.

Results

An unusual mass aggregation of molluscs along coastal waters off Nainamvalappu Calicut was found to be as a result of large scale shoreward movement of bivalve mollusc *Donax scortum* (locally referred as “*eranthu*”) (Fig 2). The bivalves accumulated along the shore were handpicked by fishermen as well as local people for their consumption. The meat of *Donax* is locally referred to as *eranthu* along the Malabar coast and is usually considered as culinary delicacy. No toxic effects on humans were reported following the consumption of *Donax* that moved shoreward because of this phenomenon.

Donax scortum belongs to order Veneroida. It is a marine species, which usually burrows in the sand in the surf line along sandy beaches. It has a length of 23-79 mm, the colour dirty white and violet in the posterior region. The shells are triangularly oblong and gibbous. Umbos posterior, elevated and pointed. Shell ovate with fine concentric striae; keel between the umbo and posterior margin are absent. Breeding period in India extends from November-June, with two spawning peaks, in November- December and May- June. The species is considered abundant along the Malabar coast (North Kerala) of South Eastern Arabian Sea.

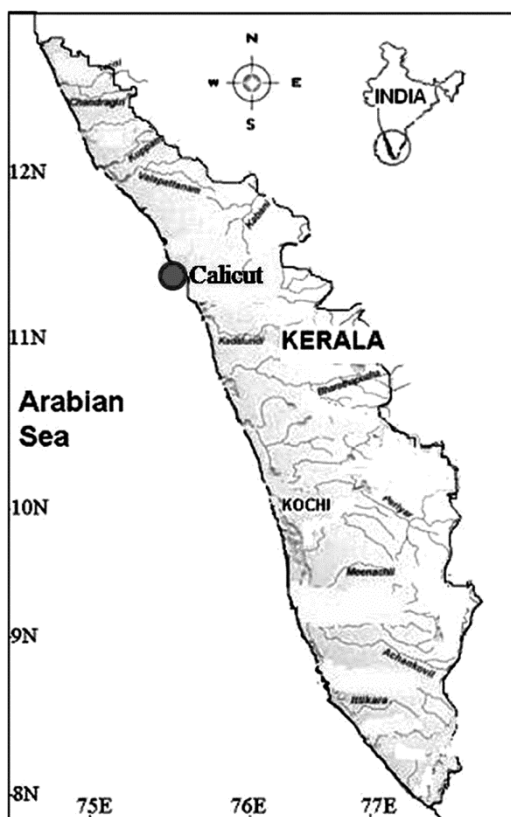


Fig. 1 — Study area. Black dot represents the area where the mass shoreward movement of *Donax scortum* was observed along the South Eastern Arabian Sea.

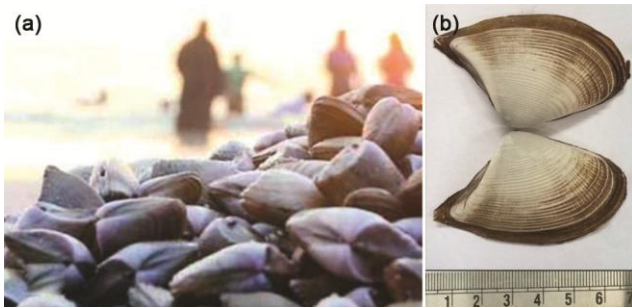


Fig. 2 — (a) Aggregation of *Donax scortum* along the shore (Photo courtesy: www.mathrubhumi.com) (b) *Donax scortum*

Hydrobiological observations of the region showed a low bottom water dissolved oxygen (0.25 ml L^{-1}) which falls in the range of hypoxic conditions (Fig. 3). The sea surface temperature (SST) in the region was 27.6° C with a bottom water temperature of 22.3° C . Surface salinity of the region was 32.48 psu. Prior to this shoreward movement event, an extensive bloom of *Noctiluca scintillans* was observed along the coastal waters of Calicut two weeks ago. The blooms were found to be nearly monospecific with cell density of $3 \times 10^5 \text{ cells L}^{-1}$ and occupied an area of 12 km along the coast. The bloom was by red coloured *N. scintillans*, which fed upon diatoms following heterotrophic mode of nutrition. The prasinophyte photosynthetic endosymbiont *Pedinomonas noctilucae* was absent inside the dinoflagellate cells unlike green *Noctiluca scintillans* (Fig. 4). Satellite imagery of the surface chlorophyll *a* distribution of the region also observed intense surface algal blooms (Fig. 5). The surface chlorophyll *a* was observed to be 20 mg m^{-3} . At the time of mass shoreward movement event the bloom of *Noctiluca scintillans* almost decayed with remnants of decaying cells in the water column. Oxygen consumption during the decay of this large dinoflagellate might have resulted in the hypoxia of the water column in the region.

Discussion

Coastal ecosystems are regions of higher biodiversity and is characterised by heterogeneous habitats. Environmental factors undergo frequent alterations in accordance with the natural and anthropogenic influences along the coastal waters than the open water ecosystems¹⁷. Depletion of oxygen due to eutrophication and high biomass production is one among the major factor influencing the coastal ecosystems function and sustainability¹.

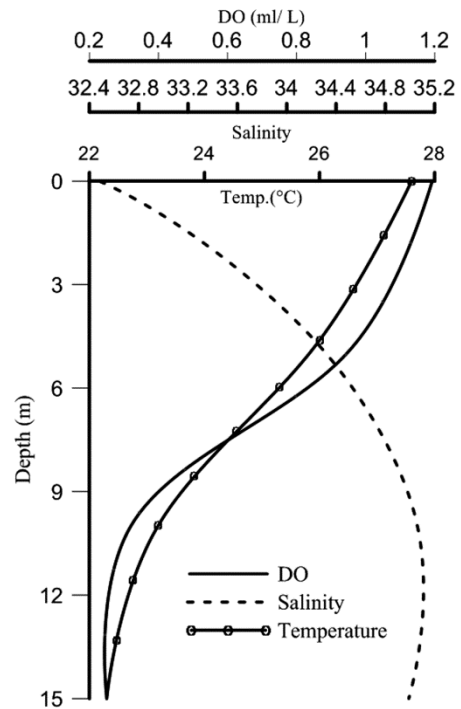


Fig. 3 — Vertical profile of Temperature, Salinity and Dissolved oxygen along the inshore waters during mass shore ward movement phenomenon of *D. scortum*.

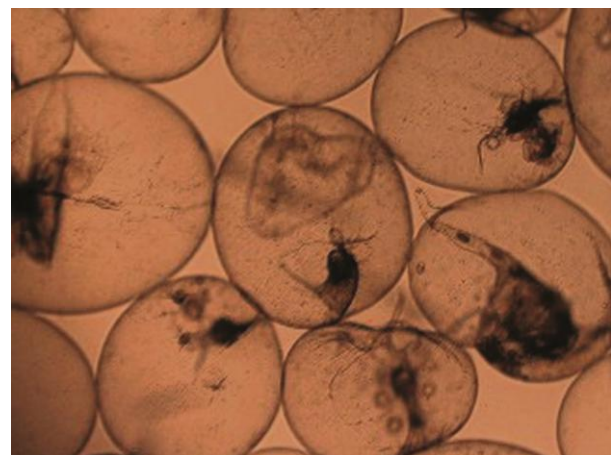


Fig. 4 — Microphotographs of Red *Noctiluca scintillans* without endosymbiont *Pedinomonas noctilucae* (x40)

Benthic fauna experiences habitat loss and food web disruption as a consequence of hypoxic conditions¹⁸. In responses to such alterations these organisms tends to move off from their habitat or express variabilities in their physiological responses. In extreme cases mortalities are also observed resulting in change in benthic community composition and diversities¹⁹. The mass shoreward movement of bivalve *Donax scortum* can be attributed mainly towards the hypoxic condition of the coastal bottom

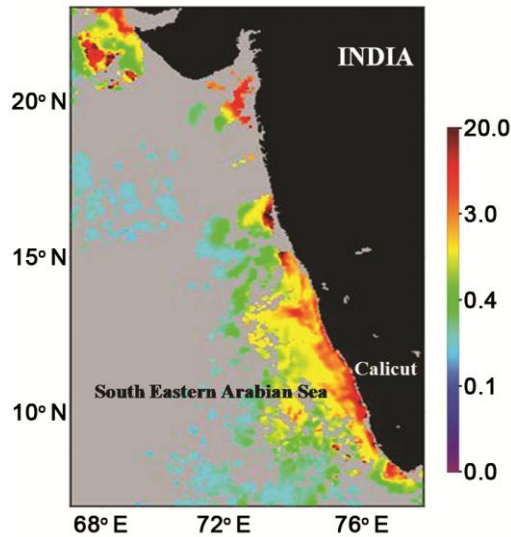


Fig. 5 — Satellite imagery of surface chlorophyll *a* distribution along the SEAS during the bloom event prior to mass shoreward movement of *D. scortum*.

waters. During summer monsoon season extensive short term blooms occur along SEAS among which the bloom of *Noctiluca scintillans* forms a major causative organism especially during the relaxation periods of summer monsoon upwelling²⁰. The intense bloom and crash of this large size dinoflagellate demands dissolved oxygen. Since the biomass that sinks is of a larger quantity, consumption of oxygen will be much higher. This might have resulted in the hypoxia of shallow coastal waters.

During the present event of bivalve shoreward movement in large numbers, hypoxic conditions caused by extensive bloom of *Noctiluca scintillans* might have played a crucial role. Generally, *Noctiluca scintillans* is unpalatable and are often avoided by predators, due to its large size, nature of bioluminescence and the external metabolites produced²¹. As a result, the accumulated large algal biomass consumes oxygen during their death and decay resulting in dissolved oxygen depletion (hypoxia). Such hypoxic conditions are discussed to alter the structure and function of benthic communities²². Coastal systems are highly vulnerable to environmental alterations and are a region where strong benthic-pelagic coupling occurs. Faunal variabilities in the benthic communities take place in accordance with the fluctuations in environmental parameters such as temperature, salinity, oxygen, nutrient supply and animal interactions^{23,24}. These variabilities can be either due to natural processes or due to anthropogenic influences. Algal blooms occur

partly due to natural nutrient enrichment and other due to eutrophication from anthropogenic sources. Upwelling induced nutrient input along with runoff from the anthropogenic sources supports the coastal production along SEAS during summer monsoon^{25,26}. Algal blooms often results from the alterations in the nutrient stoichiometry²⁷ that occurs during these productive period. On the instance of extensive blooms of large *N. scintillans* blooms, which are characterized by huge algal biomass, the tendency to develop hypoxia occurs²⁸.

Lowering of dissolved oxygen levels affects the benthic organisms³ when the dissolved oxygen (DO) concentrations comes to as low as $<1.45 \text{ ml L}^{-1}$. During the present phenomenon, DO of the bottom water reached to 0.25 ml L^{-1} . In such situations, benthic fauna tends to shift away from the stressed waters. The shoreward movement of *Scorpaenopsis scortum* can be attributed to the hypoxic conditions created by *N. scintillans* blooms. The usual response of benthic macro fauna towards oxygen depletion is either avoidance or mortalities⁴. This anomalous shoreward movement of fishes, crustaceans and shellfishes in great numbers is called as “Jubilee”¹⁰. This type of event was first reported from the Mobile Bay (Gulf of Mexico) during which irregular movement of bottom dwelling marine fauna moved towards the shore¹⁰. A similar event was observed from the coastal waters off Chavakkad along the South-West coast of India that resulted in the mass shoreward movement of crabs and flatfishes¹². The reoccurrence of these phenomenona might be due to the increased and frequent occurrence of *Noctiluca scintillans* blooms along the Arabian Sea during monsoon seasons. The food web disruptions and oxygen depletion caused by *N. scintillans* blooms thus influence both pelagic as well as benthic ecosystems which is a serious matter of concern.

The Arabian Sea is experiencing variabilities in the production patterns due to the bi-annually reversing monsoon winds as well as climate change. The basin also observes an increase in the intensity and expanse of oxygen minimum zones (OMZ)¹¹. Various processes have been suggested for this expanse and algal blooms are one among them. Indian EEZ reports an increase in algal bloom events in the recent decades²⁹. Among the bloom forming algae *Noctiluca scintillans* is found to be a major species. With the increase in the frequency of algal blooms that can lead to oxygen depleted condition, both pelagic and benthic fauna may observe stressed conditions and Jubilee like phenomenon can re-occur.

Conclusion

Algal blooms are considered as a frequent outcome of upwelling ecosystems mainly in the coastal and shallow near shore waters. Even then intense blooms of large sized algae such as *Noctiluca scintillans* seriously affects the stability of coastal systems. Hypoxia, one among the major consequence of these extensive blooms negatively influences both the pelagic and benthic ecosystems. The avoidance of *Donax scroto* from its habitat and shift to shore due to oxygen depletion indicates the stressful conditions prevailed in the coastal waters during summer *Noctiluca* blooms. The frequency and occurrence of *Noctiluca* blooms are reported to be on an increasing scale along the west coast of India. Along with this the increased occurrence of Jubilee like phenomenon points towards the possible ecological threats of *Noctiluca* blooms along the South Eastern Arabian Sea.

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