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Occurrence of fine scale to massive green tides in coastal waters of Palk Bay and Gulf of Mannar regions, southeast coast of Tamil Nadu, India

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Short communication

Abstract

Several kilometers of green tides (GT) formed by seaweed and seagrass were recently observed in intertidal, swash, and shallow subtidal zones of Palk Bay and Gulf of Mannar regions, southeast coast of Tamil Nadu, India. On a finer scale (few hundreds of Kgs), GT of *Ulva rigida* observed in the Palk Bay region during November 2018 was due to eutrophication and heavy currents and waves. While finer scale to massive (several tons) GT of seagrass mixed with seaweeds observed during May 2019 in Gulf of Mannar (GoM) region was recurrent due to heavy wind-driven rough waves and strong current drift but not due to eutrophication as seagrasses do not bloom like seaweeds. GTs of seaweeds and seagrasses appeared in both study regions were due to strong wind and current patterns observed in respective periods. GTs that occurred in both GoM, and Palk Bay regions were appearing to be seasonal but not annual. The present study infers that GTs of free-floating and stranding seagrass and seaweeds could alter the reproduction of benthic and coastal flora and fauna communities. Thus, further studies need to be conducted to understand the negative impact of GTs. Alternatively, these seaweed and seagrass sources can be exploited for commercial and biomedical research purposes.

***Keywords**: Green tides, Ulva rigida, seagrass, currents, Tamil Nadu*

Introduction

Marine algal blooms documented worldwide are primarily caused by three major microalgae groups, such as dinoflagellates, diatoms, and cyanobacteria. Different colors of tides such as red and black tides (Dierssen *et al.,* 2006) brown tide (Smetacek and Zingone, 2013) and green tide (Ye *et al.,* 2011) caused by different macroalgal species were reported worldwide (Fletcher, 1996). However, GTs were not highlighted much in the literature due to fewer incidents. Climate change is one of the major factors known to involve increasing algal blooms around the world. Although numerous species of macroalgae reported causing GTs (Fletcher, 1996), significantly in recent times, GTs of *Ulva* species have been increased in tropical and subtropical coastal regions, causing a severe negative impact on aquaculture and tourism operations (Ye *et al.,* 2011; Le Luherne *et al.,* 2017).

Considerably, macroalgal blooms directly or indirectly damage seagrass ecosystems and coral reefs through smothering, light inhibition, competition for space, and increasing hypoxia conditions via decomposition (Qiuying and Dongyan, 2014). Seaweeds play a crucial role in determining coastal habitat structure. Significantly, seaweed blooms caused by opportunistic and cosmopolitan *Ulva* species are known to display negative impacts on the marine food web by exhibiting allelopathic properties against other algae and invertebrates (Nelson *et al.,* 2003). Recently, GT of *Ulva rigida* reported from Ireland was known to occur regularly and causing severe problem in coastal and estuarine systems (Wan *et al.,* 2017). To maintain the healthy and clean coastal beach environment, these GT forming seaweed biomass were needed to be removed with a higher price (e.g., a total of €200 million was spent for removing one million tonnes of *Ulva* biomass in the Qingdao region, China during 2008) (Ye *et al.,* 2011). This indicating that GTs could show a severe negative impact on ecological and economic consequences (Charlier *et al.,* 2008; Leliaert *et al.,* 2009).

Marine plants such as seaweeds, seagrasses, and mangroves serve an important role in Carbon sequestration. The permanence of CO_2 and greenhouse gasses emission from the earth is mainly balanced by these ecosystems (Arias-Ortiz *et al.,* 2018). However, these important ecosystems are being declined due to rapid climate change and macroalgal invasion (Qiuying and Dongyan, 2014). On the other hand, green tides caused by seagrasses have not been reported so far. Therefore, understanding seaweeds and seagrasses' bloom dynamics is important to avoid ecological and economic damage of coastal regions worldwide. In the present study, two different GT forming plant components such as seaweeds and seagrass were identified on the southeast coast of Tamil Nadu, India.

Material and methods

Field surveys were carried out along Palk Bay and Gulf of Mannar regions on the southeast coast of Tamil Nadu, India (Fig. 1). GT of green seaweed observed in Palk Bay area was documented during November 2018. Seagrass tide along Mandapam and Keelakarai coasts of GoM region was observed during May 2019. The compositions of green tides observed along study sites were examined meticulously and identified the species responsible for these GTs. Photographic evidence were generated using Nikon Coolpix.

Results and discussion

Massive biomass of seagrass GT washed ashore on Vedalai, Hare Island, and Periyapattinam, Keelakarai coasts were observed during May 2019 (Fig. 2). GT of seagrass consists of a consortium of three major species such as *Cymodocea*, *Thalassia,* and *Syringodium*. GT was very thick on Vedalai coast, whereas in the Keelakarai region, it was very thin due to the impact of strong waves and currents. The washed ashore seagrass amount was also very less in Keelakarai region due to strong waves flashing them to shore and at the same time, pulling them back into seawater and transporting seagrass towards Vedalai coast via current pattern. The tidal amplitude and current pattern are strong at Keelakarai due to sudden slope and deeper depth, whereas the bottom topography of the Vedalai coast is very flat and shallow. Thus wave action was not intense similar to Keelakarai region. However, a large amount of seagrass was drifted from Keelakarai region via currents and deposited on Vedalai shore vastly. The washed ashore seagrass was deposited in massive layers and dried due to intense sunlight (Fig. 2c; Fig 3). Approximately, an average wet weight of 0.005 and 0.1 tons/m^2 was estimated for seaweed and seagrass tides correspondingly (Fig. 4).

Whereas in Palk Bay region *U. rigida* formed fine-scale green tide, which represents few hundreds of Kgs of biomass onshore. The biomass washed ashore was not stagnant, as observed in the case of seagrass on Vedalai coast. This is due to flat beach topography allowing rough wave action washing *U. rigida* biomass back into the floating state in

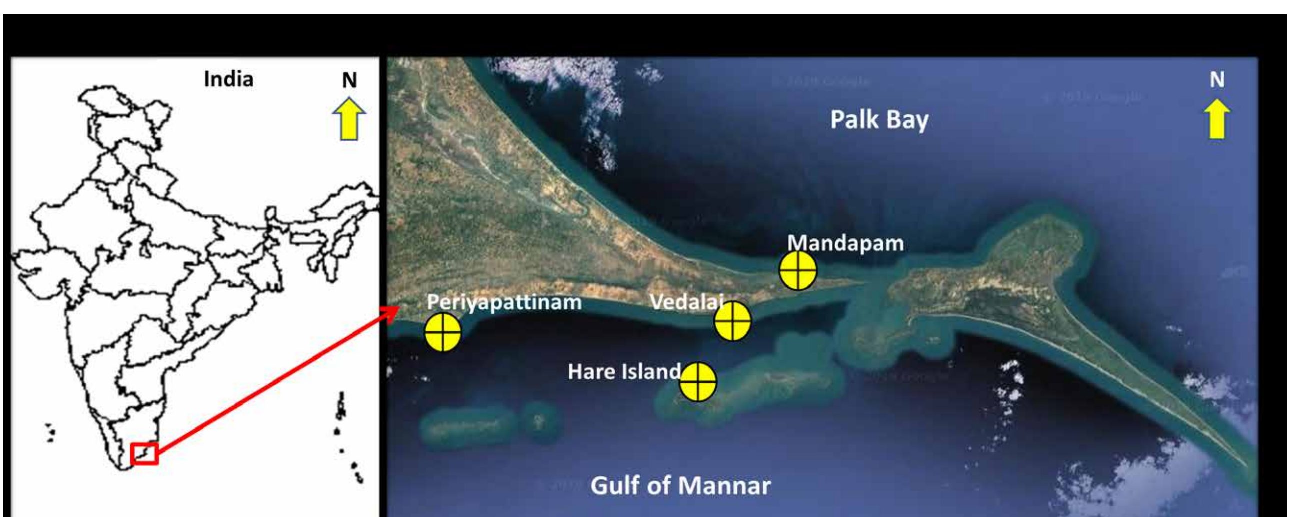

Fig. 1. Map showing green tide observed study locations in the Gulf of Mannar and Palk Bay regions.

Fig. 2. Green tides of seagrass and seaweed in the GoM and Palk Bay region. Massive GT of seagrass on Vedalai shore (a-c); finer scale GT of seagrass in Hare Island (d) and Periyapattinam in Keelakarai region (e). Finer scale GT of *U. rigida* on Mandapam coast in the Palk Bay region, the picture was taken after one week of the GT event (f).

Fig. 3. Massive accumulation of seagrass on the Vedalai coast (a-d). The accumulated depth of seagrass onshore (c-d).

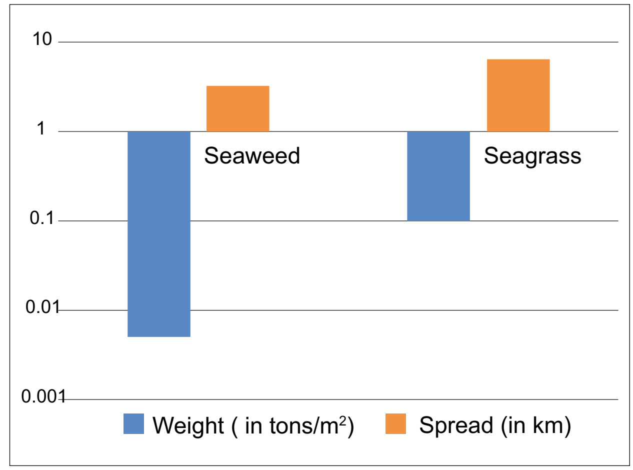

Fig. 4. Approximate quantity and spread of seaweed and seagrass washed ashore in Mandapam region.

coastal waters. Significantly, during aerial studies on island topography using satellite mapping and remote sensing, this washed ashore seagrass mimics plants and thus creating a false understanding about the land extension. Due to rich organic matter in seagrasses, the washed ashore seagrass biomass has decomposed over time through microbial degradation and resulted in intense sulfide odor on the Vedalai coast.

Previous studies suggested that damage to the vast area of seagrass meadows in Shark Bay, Western Australia was due to heatwave in 2010/2011 (Arias-Ortiz *et al.,* 2018). Although elevated temperatures were observed during this study, we are uncertain to confirm that this GT was due to heatwaves. Visual observations and diving experiences in the survey sites indicated that strong currents and heavy wind-driven rough waves might be responsible for these GTs. Seagrass pastures in the Keelakarai region are believed to be eroded by strong currents. The drastic loss of seagrass meadows by the erosion process is dependent on the size of seagrass and the magnitude of recurrent disturbance (Cabaco *et al.,* 2008). In the Keelakarai region, the regular disturbances on seagrass meadows caused by strong currents and waves have resulted in the uprooting of seagrasses resulting fine-scale to massive green tides. Erosion of beaches was also observed at several locations at Keelakarai coast, indicating that strong currents might be involved in causing dense seagrass tides in this region. Local fisher-folk from Vedalai and Keelakarai coasts witnessed that a massive quantity of seagrass deposition onshore was due to strong currents. Thus further studies are needed to conduct on current patterns in GoM and Palk Bay regions.

GT of *U. rigida* in Palk Bay is also thought to be due to three reasons: 1. eutrophication, 2. heavy wind and currents and 3. lack of strong fast hold. Previous studies indicated that GTs of *Ulva* sp. are recurrent due to eutrophication (Gladyshev and Gubelit, 2019). Perhaps, this could be one of the reasons in this study that Ulva GT occurred in the Palk Bay region. Although during the green tide period, *U. rigida* was abundantly available throughout a week in coastal waters of Palk Bay, herbivore fish have not preferred to feed on *U. rigida,* indicating the deterrent activity of *U. rigida* against herbivore fish. A previous study observed such similar incidence of deterrent activity exhibited by *Ulva* species (Nelson *et al.,* 2003). Blooms of seaweeds can alter the chemistry of coastal water by releasing allelochemicals which in turn disturb the food web (Alstyne *et al.,* 2015). Thus more attention is needed to be given to incidences like GTs to maintain ecological balance.

We infer that studying the current patterns in GoM and Palk Bay regions would help in implementing effective management practices to protect seagrass ecosystems and macroalgae, as well as to take safety measures to protect the coastal area from erosion. On the other hand, the allelopathic properties of seaweed and seagrass tides are not well studied so far, and thus further studies are required to understand the level of the negative impact of GTs on the ecological food web. Since, seagrass ecosystems are known to trap the atmospheric CO_2 into seagrass beds and are also known to be the unique food source for endangered mammal *Dugong dugon*, conservation of seagrass ecosystem need to be implemented in GoM and Palk Bay regions. Seaweeds can be utilized for biomedical applications. Further quantitative assessment on the seagrass ecosystem in the study areas is essential to understand the actual loss of seagrass from seagrass meadows. Remote sensing studies would help us to understand the spatial and temporal changes that occurred in the seagrass ecosystems in the last two decades.

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