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Seagrass meadows as proxy for assessment of ecosystem health

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ABSTRACT

Seagrass meadows of the Palk Bay region are biological sentinels that are widespread with 14 identified species. Health of major seagrass meadows along Palk Bay on the southeast coast of India was examined by assessing their ecological functions through ecosystem health indices. Water Quality Index (WQI), Sea Life Index (SLI) and Coral Health Index (CHI) were used to relate the key ecological and biogeochemical processes in addition to the assessment of human impacts on the meadows. Seagrass meadows are very efficient in trapping suspended particles and absorbing dissolved nutrients. However, nutrient enrichment and competitive interactions of epiphytes lead to a regime shift in seagrass communities in shallow waters (up to 0.5 m depth) of Palk Bay. Results highlight that the proliferation of epiphytes has significant negative impacts on the health of seagrass ecosystems. The study demonstrated that the status of seagrass can serve as an ecological proxy in assessing the health of adjoining coral reef ecosystems.

1. Introduction

Seagrass meadows are highly productive ecosystems that offer several ecosystem goods and services such as food, recreation, natural shelter, conservation, among others (Tuya et al., 2014). There are several direct and indirect ecological interactions between seagrass and coral reefs, such as maintenance of herbivore diversity in associated reef ecosystems (Unsworth et al., 2008); organic material transport between these systems (Gillis et al., 2014); protective role of seagrass in the health of marine systems (Lamb et al., 2017) etc. In addition, seagrass ecosystems act as traps for suspended sediments, supporting coral recruitment by maintaining the water clarity/light availability (Björk et al., 2008). Both these ecosystems are a complex assemblage of organisms, but the response of seagrass and coral assemblage, is an essential factor that determines the survival or loss of the entire community under stressed conditions due to changes in temperature, pH, salinity, turbidity etc. (Burkepile and Hay, 2010).

Generally, biomass and diversity studies can be used to investigate the status of seagrass and corals; however, this alone may not reflect the health status of a sentinel species and ecosystem. In recent decades, the potential usefulness of a multi- parameter approach for monitoring both environmental quality and ecosystem health has received significant attention (Goussen et al., 2016; Muniz et al., 2011). Developing an effective and inclusive ecosystem health assessment is necessary considering the complexity involved in merging environmental quality criteria with management options (Waycott et al., 2009).

Palk Bay, in the southeast coast of India, is one of the most diverse ecosystems, comprising seagrass and coral patches. A total of fourteen seagrass species has been identified from this region, of which *Cymodocea* sp. and *Syringodium* sp. are the most dominant (Govindasamy and Arulpriya, 2011; Geevarghese et al., 2016; Ganguly et al., 2017). Patches of live coral (66 species of corals belonging to 23 genera) have also been reported adjacent to these meadows (Manikandan et al., 2014). Together, they form a natural bio-shield, protecting the coast from wave action. In recent years, increased anthropogenic pressure has placed substantial stress on these ecosystems (Vikas and Dwarakish, 2015). However, comprehensive studies on growth, productivity and function of an ecosystem that features both seagrass and corals are limited from this region (Kannan and Thangaradjou, 2006; Sulochanan et al., 2011).

In this study, several biotic and abiotic factors were used to assess the health of seagrass meadows and its potential impact on the adjacent coral environment. Environmental and ecological indices have also been used to develop management strategies for the conservation of seagrass and coral ecosystems.

2. Materials and methods

2.1. Study area

Palk Bay is a 137 km wide strait between the Indian state of Tamil Nadu and Sri Lanka. It stretches from Point Calimere in the north to Pamban in the south (Fig. 1). The bay has predominantly sandy or silty substratum (Manikandan et al., 2011), and harbors dense seagrass in

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the shallow coastal waters (up to 2–3 km offshore) at the southern and northern ends. The bay has the largest seagrass extent (330 km^2) in India due to its ideal topography and sediment texture (Geevarghese et al., 2016). Seagrass meadows in Palk Bay also co-exist with patchy corals in several places, primarily in the southern end and at relatively deeper coastal waters (> 4 m). The Palk Bay reef ecosystem extends from Rameswaram Island in the east to Munaikaud (Mandapam) in the west (Fig. 1). The reef ecosystem includes a 25–30 km stretch of coral reef flat which is less than 200 m wide and the maximum depth is ~3 m (Kumaraguru et al., 2008). Due to the abundant fishery resources, Palk Bay has been a support system for a population of 256,906 people living in 251 fishing villages (CMFRI, 2010), for their livelihood. Based on the ecological features and human pressures, the coastal stretch has been divided into four sectors to determine the environmental and ecological health of the seagrass meadows (Table 1 and Fig. 1).

2.2. Distribution of seagrass

Species composition and biomass of seagrass were studied in all the four sectors of Palk Bay (Fig. 1) both during dry (April 2016) and wet (October 2016) seasons. Depending on the spatial extent and distribution of species, seagrass species were randomly sampled (12–15 samples per sector) by hand-picking (for qualitative estimation) and preserved in 10% formalin. Identification of seagrass was made up to the species-level using standard taxonomic keys (Kannan and Thangaradjou, 2006; McKenzie et al., 2003). For quantitative analysis of seagrass density, quadrats consisting of one square meter area were randomly sampled (in duplicate) from the same locations. The percentage cover of seagrass was estimated through visual spatial coverage method (very sparse; 0–20%, sparse; 20–40%, medium; 40–60%, dense; 60–80% and very dense; 80–100%) following McKenzie et al. (2003). For the estimation of biomass, seagrass samples were washed thoroughly with ambient seawater to remove any sediment and external debris. Moisture was removed from the samples using adsorbent paper and biomass value was expressed in gram fresh weight per square meter (g fr. wt. m^{-2}). Epiphytic cover on the above-ground part of seagrass was collected from each sampling station following Green et al. (2015).

2.3. Sampling and analysis

In order to analyze the existing environmental conditions that influence seagrass and coral health, water samples (in duplicate) were collected from 31 evenly distributed sampling stations (~5 km intervals) during dry (April 2016) and wet (October 2016) seasons. At each station, water samples were collected ~0.5 m above the canopy, as seagrass productivity strongly influences the surrounding water quality (Hendriks et al., 2014). The water depth varied between stations from 1 m to 4 m and the seagrass meadows extended to approximately 3 km from the coast.

Water samples were collected in acid-washed polythene bottles rinsed with seawater prior to sampling and were filtered *in situ* using 0.45 μm Millipore® membrane filters through a Millipore® hand filtration unit and preserved at 4 °C until further analysis. Hondex® ps-7 digital sounder was used to measure the water depth at the sampling stations. Temperature, pH, salinity and dissolved oxygen (DO) were measured *in situ* using the pre-calibrated multiparameter Hydrolab® sonde equipped with an optical probe. This optode was used due to its most efficient performance under well-mixed conditions with internal temperature corrections. Under ambient conditions, the precision of DO measurements was < 0.1 μmol kg^{-1} and the accuracy with respect to the DO obtained from Winkler titration was ± 3.0 μmol kg^{-1}.

Concentration of dissolved nutrients [inorganic phosphate (PO_4^{3-}-P), nitrite (NO_2^--N), nitrate (NO_3^--N), ammonium (NH_4^+-N), silicate (SiO_4-Si)], in the bay waters was estimated using Skalar SAN++ automated nutrient analyzer with appropriate standards. For analysis of Chlorophyll-a (Chl-a), 1 l of water sample was filtered through GF/F filter with a gentle vacuum (of ≤80 mm Hg) and fixed with $MgCO_3$. The filters were frozen until further analysis using standard spectrophotometric methods (Strickland and Parsons, 1972). Total suspended matter (TSM) was measured by filtering a known volume of water through 0.45 μm cellulose acetate membrane filters (Millipore), rinsed with Milli-Q water and the difference of initial and final weights of filter were calculated.

Further, the rate of sedimentation was estimated at three stations along sector 1, using a set of three cylindrical acrylic sediment traps following English et al. (1997). Two sets of sedimentation traps were placed at sector 1 b (Olaikuda; 9°19.342′N & 79°19.872′E and near Pamban; 9°17.665′N & 79°15.900′E) and one was placed at sector 1a (Near Mandapam 9° 17.413′N & 79° 8.203′E) during April 2016. The sedimentation rate was calculated using the following formula and expressed in mg cm^{-2} d^{-1}:

$$\text{Rate of sedimentation} = \frac{\text{Weight of sediment}}{(\text{Cylinder surface area} \times \text{No. of days})}$$

where, surface area of the cylinder = πr^2 and r is the radius of the cylinder (3.75 cm).

In order to understand the role of seagrass meadows in the assessment of ecosystem health, Water Quality Index (WQI), Coral Health Index (CHI) and Sea Life Index (SLI) were calculated. Water quality index (WQI) was calculated for all the 4 sectors of Palk Bay, whereas Coral Health Index (CHI) and Sea Life Index (SLI) were calculated for the sector 1 (Agniteertham to Mandapam) due to the coexistence of luxuriant seagrass meadows and coral patches in this sector (Fig. 2). Other sectors in the shallow seagrass meadows are devoid of corals.

2.4. Water quality index (WQI)

Coastal water quality was assessed by determining the Water Quality Index (WQI) from all the 4 sectors of Palk Bay. Factors such as sea surface temperature, dissolved oxygen, turbidity, nutrients and chlorophyll-a were used to determine WQI.

The WQI combines the threshold scores of the above parameters into a single overarching index (Tirkey et al., 2015) and is an indication of water quality, with respect to any particular parameter. The WQI value can be used to highlight spatial and temporal variations in water quality and is calculated using the formula given below (Horton, 1965; Gupta et al., 2003):

$$\text{WQI} = \sum_{i=1}^{n} Wi\ Qi$$

where 'n' refers to the number of parameters, Q_i value represents the indication of water quality relative to 100 of one parameter, W_i is the weighting factor that sets the relative importance of the attributes of overall water quality. Assigning weightage to each parameter depends on its relative importance and a temporary weightage is assigned to each parameter. The final weightage was determined by dividing the individual temporary weight of each parameter by the total temporary weight. Threshold values for the variables were considered based on available guidelines [Central Pollution Control Board (CPCB), 2011], current scientific knowledge, and historical data and trends (i.e. through frequency distribution analysis). Based on the grades, color codes were provided, following the method of Integration and Application Network, University of Maryland Center for Environmental Science (Williams et al., 2009) as given in Fig. 3 below:

2.5. Coral health index (CHI) and sea life index (SLI)

Coral Health Index and Sea Life Index were assessed in the dry season (April 2016) following the method of Murdoch (2014), to understand the overall environmental condition and possible interaction with the adjacent seagrass meadows of Palk Bay. Forty four sites,