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A comprehensive geospatial assessment of seagrass distribution in India

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ABSTRACT

The study deals with the first comprehensive spatial distribution and area estimate of seagrass patches of India with a standardized methodology. Seagrass patches are mainly located in Palk Bay – Gulf of Mannar (Tamil Nadu), Gulf of Kachchh (Gujarat), Chilika Lake (Odisha) and Islands of Andaman & Nicobar and Lakshadweep. Medium resolution satellite images of Landsat 8 OLI were subjected to radiometric, atmospheric and water column correction prior to digital classification and contextual editing. Total estimated seagrass area amounts to 516.59 km^2 of which Palk Bay and Gulf of Mannar of Tamil Nadu together contribute to 398.81 km^2. Overall classification accuracy for the six sites studied, ranged between 64% (Lakshadweep Islands) and 83.5% (Palk Bay). This suggests that for surveillance studies of homogeneous seagrass meadows with low interspersion of other benthic units such as corals, seaweeds etc., digital mapping using medium resolution data sets with mandatory attenuation correction procedures is suitable. The results of this study and the related area statistics were accepted as a baseline at national level for the delineation of Ecologically Sensitive Areas (ESA) and in the formulation of its conservation strategies. For a cursory appraisal of the status of major seagrass regions, a matrix representation of its locational occurrence and habitat characteristics is provided.

1. Introduction

Seagrass are submerged flowering plants found in shallow marine waters such as bays, estuaries, lagoons and along the continental shelf and play an important role in maintaining the biodiversity and overall health of coastal ecosystems. It is observed that there is no comprehensive global inventory of the seagrass area and the documented seagrass area is approximately 177,000 km^2 (Green and Short, 2003). In India, dense seagrass patches are primarily located in the Palk Bay - Gulf of Mannar (Tamil Nadu), Gulf of Kachchh (Gujarat), Chilika Lagoon (Odisha), and in stretches surrounding the Islands of Andaman & Nicobar and Lakshadweep. A comprehensive areal estimate and spatial distribution at country level is lacking, although estimates at selected locations are available. Furthermore, a standardized methodology involving attenuation correction; algorithms that nullify the effect of atmospheric aberrations, sunglint, variable water column, suspended sediments, turbidity, phytoplankton communities etc., were not followed for mapping. Considering the spatial distribution and temporal behaviour of seagrass, mapping and monitoring of seagrass meadows also need to be on a tangible scale.

In the visible region, seagrass meadows tend to have distinctly different spectral signature from their adjacent substrata. Wavelengths between the range 350–950 nm can be effectively used for discriminating benthic features such as seaweeds, seagrass, corals, sand and rock. Seaweeds and seagrass have differences in reflectance within 700–950 nm (near-infrared band) wavelengths. Although near-infrared band gets absorbed in the uppermost part of the water column, floating mats of algae cause increased reflectance, which helps in differentiating it from bottom dwelling seagrass (Fyfe, 2003; Sagawa et al., 2012). Presence of algal epibionts on seagrass is discriminable at 560–670 nm due to increased reflectance peaks (Fyfe and Dekker, 2001).

In recent times satellite-based optical remote sensing and digital image processing have been successfully used as a valuable tool in mapping and in the assessment of benthic habitats (Andréfouët et al., 2001; Eugenio et al., 2015; Fornes et al., 2006; Manessa et al., 2016; Mishra et al., 2006; Mumby and Edwards, 2002; Nayak and Bahuguna, 2001; Phinn et al., 2005, 2012; Purkis and Riegl, 2005; Schweizer et al., 2005; Wicaksono, 2016). Landsat sensors have been widely used in benthic habitat assessment with reasonable success (Blakey et al., 2015; Guebas et al., 1999; Mervyn et al., 1997; Shapiro and Rohmann, 2006; Wabnitz et al., 2008; Yang and Yang, 2009). There are around forty studies dealing with seagrass mapping in India for selected locations of Andaman and Lakshadweep Islands, Palk Bay, Gulf of Mannar and Chilika with disparate methods. Some of the studies are based on *in situ*

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SCUBA - GPS assisted transect surveys. Until recently, the general lack of awareness in India regarding water column correction has been reflected in many of the previous studies, which had been a concern among reef scientists in late '90s (Mumby et al., 1998). These studies utilised IRS Series of LISS III /LISS IV scenes/aerial photographs (Jagtap and Inamdar, 1991, 2009; Nobi and Dinesh, 2014; Sridhar et al., 2010; Thangaradjou et al., 2008; Umamaheswari et al., 2009), which lacked blue band and had not implemented attenuation correction algorithms.

The present work comprehensively maps the seagrass extent of India using Landsat 8 OLI data incorporating radiometric, atmospheric and water column attenuation correction algorithms. In many areas, seagrass meadows exhibit temporal variations in terms of spatial extent and density due to various seasonal, environmental and anthropogenic causes. This study provides a one-time assessment of the current spatial distribution of seagrass and its comprehensive area statistics. However, repetitive monitoring at appropriate time periods is necessary to develop a holistic perspective of changes caused by physico-chemical and biotic influences.

The spatial distribution of seagrass varies from continuous meadows to highly dispersed heterogeneous patches (Frederiksen et al., 2004; Robbins and Bell, 1994; Turner et al., 1999). Seagrass landscape can be considered as a heterogeneous mix of seagrass patches embedded in a substrate background of soft sediments, sand, clay or coral debris often coexisting with diverse marine fauna. Analysis of the heterogeneity of these habitat mosaics ranging from small discrete patches to landscape meadows using the spatial outputs have helped in configuring these ecosystems into a hierarchy of spatial scales, which also could serve as an indicator of ecosystem conditions. The present study also explores the spatial heterogeneity of the seagrass benthos of the five major regions based on the average nearest neighbour and patch size analysis of the seagrass distribution obtained from map outputs.

2. Materials and methods

2.1. Study area

Six sites (i) Palk Bay (ii) Gulf of Mannar (Tamil Nadu) (iii) Gulf of Kachchh (Gujarat) (iv) Chilika Lake (Odisha) (v) Islands of Andaman & Nicobar and (vi) lagoons of Lakshadweep Islands are the major seagrass sustaining regions in India.

Palk Bay forms the south western portion of the Palk Straight, an inlet of Bay of Bengal between south eastern India and northern Sri Lanka. It is situated within the latitude 9°18′N - 10°18′N and longitude 78°54′E − 79°54′E. Palk Bay is approximately 60–85 km wide and has significantly shallow warm water than the adjacent Bay of Bengal and Indian Ocean. Maximum depth of the sea bed in this region is about 13 m. The water is turbulent during the north east monsoon season and remains calm in other seasons. The spring tidal range is between 0.06 m and 0.7 m and neap tidal range is 0.32–0.48 m. The region is enriched with rich marine flora and fauna and especially significant and diverse submarine habitats. Palk Bay sustains the most extensive cover of seagrass in the Indian subcontinent.

Gulf of Mannar Marine National Park with 21 small islets established in the year 1986 has an area of about 560 km^2. It is separated from Palk Bay by a chain of small islands and reefs known as Ramsethu, also known as Adam's Bridge, which includes the Mannar Island. The region stretches from 08°47′N - 09°15′N; 78°12′E − 79°14′E and is rich in biodiversity with endangered sea cow (*Dugong dugon*), corals, seagrass, salt marshes, algal communities and mangroves. Tidal amplitude of the area is about 0.5 m.

Seagrass in Gujarat are restricted to the Gulf of Kachchh, which extends over an area of about 7350 km^2 and was declared as a Marine National Park in 1982 under the provisions of the Wildlife (Protection) Act, 1972 of India. The Gulf of Kachchh divides Kachchh and the Kathiawar peninsula regions of Gujarat between 22°24′N −23°05′N and 69°00′E − 70°50′E. Because of the geo-physical effects caused by shallow inner regions and narrowing cross section, the tidal amplitude increases significantly towards east in Gulf of Kachchh. The highest high water reaches to about 7 m and tidal influx covers the adjacent areas of creeks and alluvial marshy lands increasing the inter tidal expanse. India's first marine reserve, the Gulf of Kachchh Marine National Park, and the Marine Sanctuary, Jamnagar comprising of about 620 km^2 is located along the Southern part of the Gulf. Gulf of Kachchh sustains a variety of species including corals, sea mammals, mangroves, salt marshes and marine algae.

The Chilika is the largest brackish water lagoon in Asia situated along the eastern coast of India in the State of Odisha. It stretches within the latitude of 19°28′N - 19°54′N and the longitude of 85°05′E − 85°38′E. Based on biogeochemical parameters, the lagoon is broadly divided into four sectors namely northern sector, central sector, southern sector and outer channel. During the monsoon season, it covers an area of 1144 km^2 whereas in the dry winter season it reduces to 780 km^2 (National Wetland Atlas, Orissa, 2010). The average depth of the lagoon is between 1.5 and 2 m. Lagoon experiences a semidiurnal tidal pattern with annual spring and neap tidal range of 1.60 m and 0.50 m respectively. Because of the estuarine intertidal setting in the eastern part and the riverine influences on the north-western part, it experiences a highly dynamic environment with seasonal variations in bio-resources. Chilika is a highly productive ecosystem sustaining rich fishery resources as well as seaweeds, micro algae, seagrass and crabs providing livelihood for people living around the lake. The rare endangered Irrawaddy dolphins is the flagship species occurring in the lagoon.

The Andaman and Nicobar Islands contain a significant share of the seagrass patches. Separating the Bay of Bengal and Andaman Sea, they are a group of 836 islands, of which 36 are inhabited. The Andaman Islands are geographically located at 6°N - 14°N and 92°E − 94°E with total areal extent of 8249 km^2. Shores are rocky with fringing coral reefs intermittent with seagrass and few sandy beaches. Muddy grounds are limited and are found only in protected bays and creeks. The tides are semidiurnal with amplitude of 3 m. Coastal belts of both the archipelago supports littoral forests and various other marine communities. Mahatma Gandhi National park (1983) at Wandoor, Rani Jhansi National Park (1996) sustains rich patches of seagrass in immaculate state.

The Lakshadweep Island group is located in the Arabian Sea towards the south-western side of the Indian peninsula. Located between 10° 00′ N - 12° 00′ N and 73° 00′ E − 92° 40′ E, the islands are the northern portion of the vast undersea mountain range: the Chagos-Laccadive Ridge. Lakshadweep Islands are the only atoll reefs in India. There are 32 small islands of which only 10 are inhabited. The tide over the near shore waters of Lakshadweep islands is of semi-diurnal type with a maximum tidal range of 1.4 m. Islands are surrounded by coral reefs with sandy beaches, seagrass patches in the lagoons, and coralline algal ridges on the seaward boundary.

2.2. Data sets

Selection of satellite data set was a crucial aspect in this study. Decisive factors that steered the selection of the data set were (a) the need to produce the maps and area statistics within a reasonable time span of two years to arrive at a comprehensive national level statistics while taking into consideration seasonal fluctuations and options for temporal analysis wherever necessary (b) extensive, yet disconnected coverage area of interest (c) compatibility of seagrass spectral characteristics and patch size (minimum mappable unit) with the spatial resolution and band characteristics of data (d) open access of suitable medium resolution data in terms of temporal, radiometric and spectral resolutions and (e) data gap and incongruence in the array of scenes of high resolution images with respect to seasonal variations and benthic cover characteristics due to scene multiplicity resulting out of low swath width.