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Article

Loss of Dugong Grass [*Halophila Ovalis* (R. Brown)] Population Structure Due to Habitat Disturbance in an Island Ecosystem

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Abstract: Seagrass ecosystems are lost due to habitat disturbance, coastal development and human pressure. We assessed the impact of boat anchors from traditional fishing and recreational activities on the seagrass *Halophila ovalis* from the Andaman and Nicobar Isalnds of India. The plant density, biomass, morphometrics, canopy height and percentage cover were estimated from two sites of Govind Nagar beach of Andaman and Nicobar Islands. The shoot density of *H. ovalis* was reduced by physical damage caused by boat anchors. The morphometrics of *H. ovalis*, such as number of leaves per ramet, leaf length, width and horizontal rhizome length were significantly reduced when impacted by boat anchors. Seagrass canopy height and percentage cover were reduced by 41% and 47% respectively. Though the impact of boat anchors reported here is on small-scale, it may impact feeding grounds of locally endangered dugongs. Therefore, proper management and preventive measures should be implemented to prevent the loss of dugong grass habitats from tourism, recreational and fishing activities.

Keywords: seagrass; anthropogenic disturbance; boat anchoring; meadow traits; habitat loss; island ecosystem

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Introduction

Seagrass ecosystems represent one of the richest and widely distributed coastal habitats in the ocean, that provide 24 different types of ecosystem services and support a range of keystone and ecologically important marine species from all trophic levels[1,2]. Seagrass ecosystems form important habitat and nurseries to1/5th of 25 commercially important fish populations and provide feeding grounds for endangered sea cows and seahorses[3]. This provisioning of seagrass supports the livelihood of millions of coastal communities[2,3]. Though seagrass ecosystems provide valuable ecosystem services and play significant role in maintaining coastal trophic structure, they are declining globally (~35% lost) under the influence of anthropogenic pressure[4]. Recent reports have indicated that,11 species of seagrass worldwide are under extinction risk, whereas three species are endangered[1].

One of the major contributors to seagrass decline worldwide is coastal development and modification caused by human settlement, that reduces coastal water quality through nutrient enrichment leading to eutrophication[5,6] increased sedimentation from land run-off and increased tourism and fishing activities[1]. Tourism and fishing activities utilize various boats, that deploy boat anchors. Boat anchors are of serious concern[7] as they cause long-term small-scale physical disturbance and permanent damage to shallow water seagrass root and rhizome structure resulting in loss of seagrass meadows[8]. The loss of seagrass meadows due to boat anchors has been documented in India for various seagrass species of Palk bay and Gulf of Mannar region[9]. Outside India, it has been reported for species like *Zostera marina* (Linnaeus) of San Francisco Bay, USA[10] and Studland Bay, UK[11,12] *Posidonia oceanica* [(Linnaeus) Delile] in the Mediterranean Sea[13,14] and mixed seagrass species of Rottnest Island, Australia[15]. Loss of seagrass meadows eventually resulted in the loss of valuable ecosystem services, such as release of stored carbon of 4.2 kg C_{org} m^{-2} (ref.15) and loss of fish habitats and feeding grounds for sea cows[12]

India has an estimated cover of 517 km^2 of seagrass beds consisting of 7 genera and 16 species distributed along its coastline including Andaman and Nicobar Islands (ANI)[16,17]. The seagrass *Halophila ovalis* (R. Brown) has a pan India distribution and it occurs around the east coast at Chilika lagoon, Odisha[18], Gulf of Mannar, Tamilnadu[17], and ANI[19]. 13 out of 16 seagrass species are found at ANI, covering an area of 29.42 km^2 distributed around mudflats and sandy regions from intertidal zone to 10-15m depth[19]. *H. ovalis* has a frequent occurrence around ANI mostly in intertidal regions, as individual patches or mixed with other seagrass species such as *Halodule uninervis* [(Forsskål) Asch.] and *Thalassia hemprichii* [(Ehrenberg) Asch.][20,21]. *H. ovalis* is the fastest growing seagrass species in this region[19] *and* is a preferred food source for the endangered *Dugong dugon*[22]. Swaraj Dweep (hereafter referred as Havelock island) is home to the endangered *Dugong dugon*, which depends on the *H. ovalis* beds for it feeding[23].

Tourism is a major source of income in Havelock island of ANI because of its natural beaches and under water marine life, such as coral reefs and associated biodiversity. Being a tourist hotspot, these islands have had a rapid increase in the number of boats operating at this island for SCUBA diving, fishing (traditional and recreational) and various other recreational activities. However, the impacts of increased boat anchoring on seagrass species of ANI is not well documented. Thus, this study evaluated the density, biomass, morphometrics and canopy structure of *H. ovalis* meadows of Havelock island under the influence of boat anchoring to understand the impact on seagrass population structure.

Materials and Methods:

Havelock island is located in the south east region of Andaman and Nicobar Islands of India (Fig.1). The island has a tidal amplitude of 2.45m, 26.28 to31.67°C temperature range and salinity between 32 to 35. Two sites within Govind nagar beach, Havelock island were selected for this study (Fig. 1). The number of fishing and recreational boats anchored here are about ~120 at site1 and ~15 at the site 2. This site 1 had only anchors deployed and there was no sign of moorings deployment. The sites were 500m apart and were separated by dead coral patches. Site1 has a high number of anchored boats and the anchor trails and holes were visible (Fig. 2c) whereas the site 2 was sheltered by a mixed patch of live and dead corals. We selected those patches at both sites where considerable amount of seagrass biomass was available for collection.

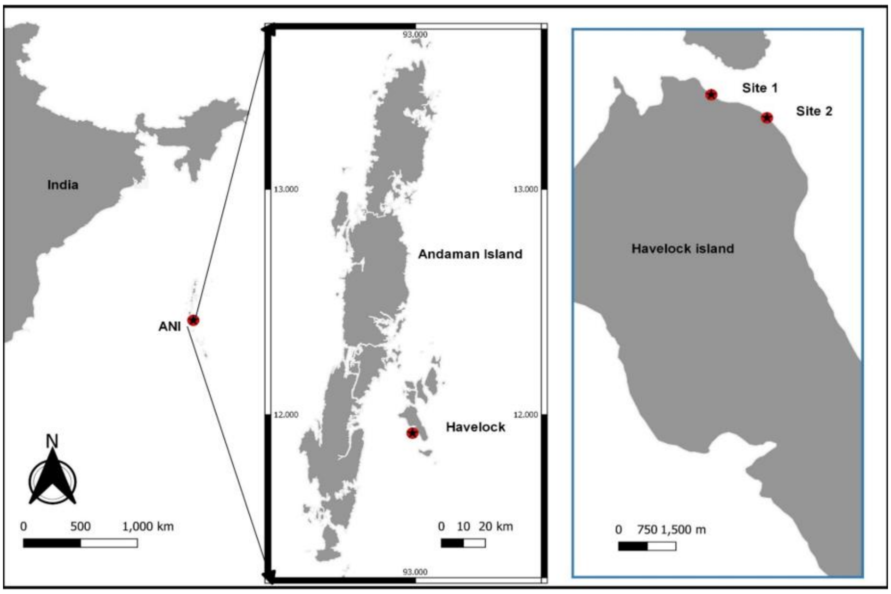

Figure 1. Study area showing site 1 and 2 of Havelock island of ANI, India.

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(a).

(b).

(c).

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Figure 2. *H. ovalis* patches at highly anchored site1 (a), sheltered site2 (b) and type of anchors used (c). Image credits: Amrit Kumar Mishra.

Sediment cores (n=12) were collected from each quadrat where seagrass was sampled using a 5cm diameter and 10 cm long plastic core. Sediments were collected in plastic bags and brought to the laboratory. In the laboratory, sediment samples and were oven dried at 60°C for 72 hours before being sieved for grain size fractions (500µm, 150 µm, 75 µm and 63 µm). We used a quadrat of 20 cm x 20 cm and a hand shovel to dig out seagrass samples up to 10 cm depth in February-March 2019. Twelve quadrats of *H. ovalis* were collected during low tide within a depth of 0.5m from a transect of 10 m x 15 m perpendicular to the beach from each site. Sampling was carried out randomly within the transect covering the whole transect area at both sites. The *H. ovalis* beds were monospecific at both sites (Fig.2a & b).

From each quadrat seagrass leaves, rhizomes and roots were collected in plastic bags and brought to the laboratory for further analysis. In the laboratory, the plant samples were washed again with double distilled water and the leaf epiphytes were scrapped of by a plastic razor. Density (no.m^{-2}) was calculated by counting the total number of shoots per quadrat. Horizontal rhizome length (n=15/quadrat) were measured for the rhizomes with apex shoot attached. Leaf length (cm), width (mm) and height (cm) from shoot (n=20/quadrat) was measured using a Vernier Calliper(accuracy-0.02mm). The canopy height (cm) of *H. ovalis*, i.e., the leaf length of the longest leaf from the sediment to the leaf tip was measured using a ruler[24]. After initial measurements, the plant parts were separated and oven dried at 60°C for 48 hours to get the dry weight biomass (g DW m^{-2}). The above-ground (leaf biomass) and below-ground (rhizome + root) biomass was used to estimate the biomass ratios. The percentage cover of the seagrass was estimated (visually) from the area covered by seagrass from the total quadrat (nine small quadrats) area.

One -way ANOVA was used to test the significant differences between *H. ovalis* density, biomass and morphometric features between the two sites. All data were pre-checked for normality and homogeneity of variance. Data were log transformed when normality and homogeneity of variance was not achieved for raw data. Data are presented as mean and standard error (S.E.). SIGMAPLOT ver. 11 was used for the statistical analysis.

Results and Discussion:

The negative impact of habitat disturbance by boat anchors on *H. ovalis* was evident compared to that of sheltered areas. Sand constituted 85 to 94% of the sediment grain size fractions (coarse, fine and very fine), whereas silt content was low. The silt content at site 1 was 2.47-fold lower than site 2 (Table 1) which may reflect the continued disturbance of the upper layer of the sediment by boat anchors resulting in mobilization and dispersion of the impacted sediments by daily wave actions and crab holes[12] leading to loss of the fine fraction of sediment at site 1. Sediment grain size (fine fractions) helps the seagrass retain nutrients and essential trace elements for primary production[7]. However, change in resident sediment fractions can alter the seagrass population structure and thus have negative impacts on seagrass growth as *H. ovalis* needs higher silt content for better growth and production[22]. Lower silt and higher sand content can result in the loss of shoot density as this proportion of sediment increases the penetration of anchors and cause subsequent damage to the seagrass rhizome structure[13]. The combination of sediment erosion by boat anchors and wave dynamics may lead to a release of the buried sediment organic carbon stocks and can convert affected seagrass meadows to a source of carbon rather than carbon sinks as reported for seagrass meadows of Rottnest Island, Australia which were affected by boat anchoring and mooring[15].

Table 1. Results of grain size analysis of sediments and various *H. ovalis* traits from the anchor impacted (site 1) and sheltered (site 2) area of Havelock island of ANI, India. Mean ± Standard error (SE) values are presented. Small letters indicate significant differences between the two sites. One-way ANOVA p values are presented. Above ground (AB), below ground (BG). No values (nv).

Variables		Site 1	Site 2	p-value
Grain size (%)	Sand	94.05 ±5.55[a]	95.25±4.15[a]	<0.001
	Silt	5.95 ±2.39[a]	4.75±2.09[b]	<0.001
Biomass (g DW m^{-2})	AB	0.71±0.24[a]	1.68±0.23[b]	0.019
	BG	2.72±0.14[a]	4.14±0.79[b]	<0.001
	AB:BG	0.32±0.04	0.57±0.22	nv
No. of leaves $shoot^{-1}$		5.87 ±0.45[a]	6.51±0.87[a]	0.675
Canopy height (cm)		1.15 ±0.04[a]	2.20 ±0.01[b]	<0.001
Leaf length (cm)		1.02±0.09[a]	2.05 ±0.09[b]	0.004
Leaf width (cm)		0.94 ±0.01[a]	1.23±0.08[b]	<0.001
Horizontal rhizome length (cm)		9.05 ±0.08[a]	15.26 ±0.38[b]	0.008
Percentage cover (%)		20.30±0.12	34.50±0.89	nv

The shoot density of *H. ovalis* was significantly different between the two sites, whereas the apex density was similar (Fig.3). The total density (shoot+ apex) observed at site 1(391.7±11.7 shoots m^{-2}) was lower and site 2 (454.7±47.0 shoots m^{-2}) density was similar (427.2±24.8) to the reported values of *H. ovalis* from the coast of Palk Bay, India[25]. However, the density values were higher than density of *H. ovalis* from east coast of Malaysia[26]. Lower shoot density at site 1, indicates physical damage caused by boat anchors to the shoot structures of *H. ovalis*, similar to boat anchors impact on *P. oceanica* of the Turkish coast in the Mediterranean Sea[7]. However, the damage to shoot structure of *H. ovalis* is highly significant as plant structure is very fragile and easily breakable compared to the rigid shoot structure of *P. oceanica*. Secondly, *H. ovalis* is generally found in the upper intertidal regions subjected to high wave action that can damage its physical integrity[20]

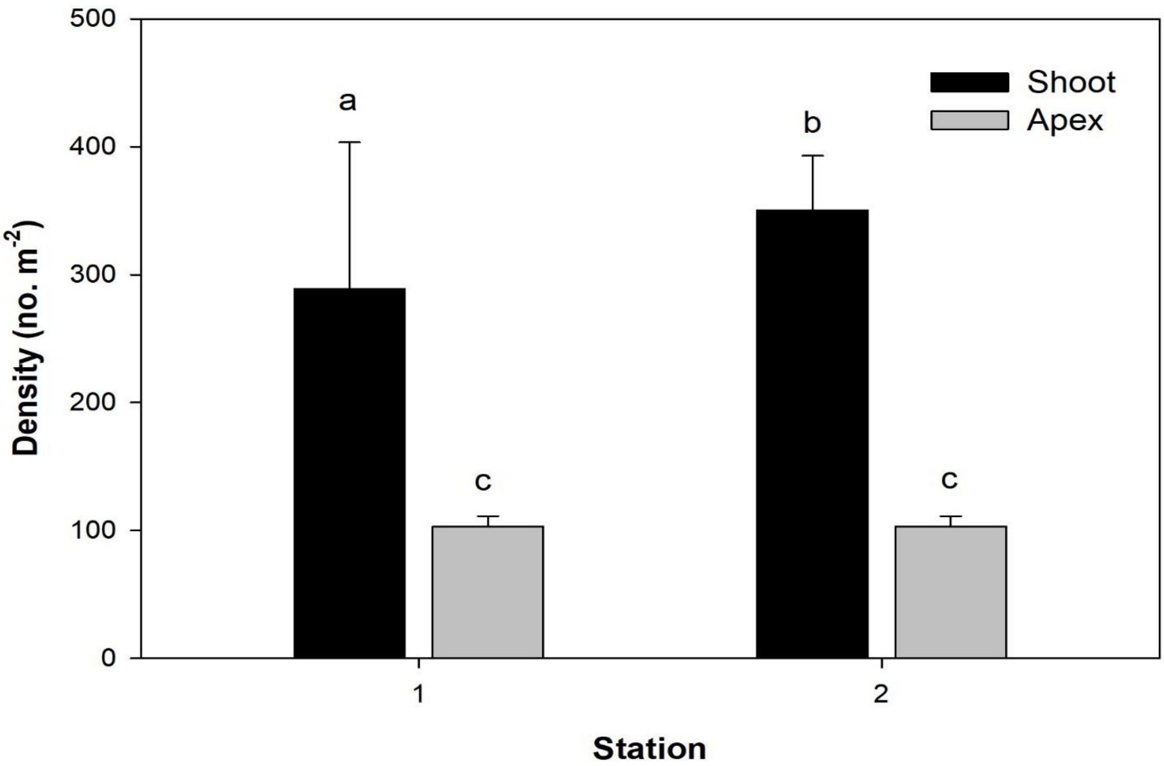

Figure 3. Shoot and apex density (no. m^{-2}) of *H. ovalis* at site 1 and site 2 of Havelock island, ANI. Small letters indicate significant difference between sites.

Above-ground (AG) and below-ground (BG) biomass of *H. ovalis* were significantly different between the two sites. The AG and BG biomass of site 1 were 2.3-fold and 1.5-fold lower respectively, whereas the AG: BG ratio of biomass was 1.7-fold lower than site 2 (Table 1). Lower AG biomass in other seagrass species such as *Halophila beccarii* (Aschers.) has also been observed around the Andaman Sea under the influence of similar intertidal conditions[27]. The BG biomass of site 1 (71%)

and site 2 (79%) coincide within the range of BG biomass of 63-77% observed for *H. ovalis* meadows around the Andaman Sea[26]. Though the BG biomass at site 1 was lower than site 2, its contribution in the plant total biomass was higher than site 2 (Table 1). This suggests that *H. ovalis* having smaller plant structure (roots and rhizomes), needs extensive rhizome networks buried in the sediment to withstand the sand wave breaking at this site. Secondly to survive the anchoring damage it needs to migrate spatially to more favourable conditions. Consequently, in response to habitat disturbance *H. ovalis* increases its BG biomass and bed patchiness, which has been observed *H. ovalis* and other seagrasses like *T. hemprichii* and *Halodule uninervis* [(Forsskål) Asch.] of the coast of Indonesia subjected to cyclone disturbance and intense grazing[28]. These extensive rhizome network also helps withstand anchoring damage and facilitates spatial migration of the plant to a suitable habitat, which has been observed for *T. hemprichii* from the Havelock island of ANI[20].

The morphometrics of *H. ovalis* were significantly different between the two sites, (Table 1). Between the two sites, the number of leaves per ramet was higher (10.22±0.88) at site 2. Both the leaf length (1.02±0.09 cm) and width (0.94 ± 0.01 cm) of *H. ovalis* at site 1 were 2-fold and 1.3-fold lower respectively than site 2. The number of leaves per ramet, length and width of *H. ovalis* at site 1 were lower than site 2 (Table 1) as a result of the bending of the leaf stem by the rope and anchors and subsequent breakage and burial of leaf structure in the upper layer of the sediment (Fig.2a). This leaf breakage, inhibits the plant growth, productivity and AG biomass. Physical damage by boat anchors and reduction in leaf length and width has been observed for *T. hemprichii* from Havelock island of ANI[20] for seagrass species like *P. oceanica* in the Mediterranean Sea[14].

The canopy height of seagrass at site 1 was 1.9-fold lower and the horizontal rhizome length was 1.6-fold lower than site 2 (Table 1), indicating about the physical injury/breakage of the leaf structure during the drop down of boat anchors leads to formation of leaf scars and broken-down leaf-stems at site1. While anchored, continuous swinging of the attached rope with the semi-diurnal tidal movement, the size of the anchor and the settlement of the boat during the low tide on seagrass canopy also plays an important role in determining the extent of damage. Once broken from the stem seagrass leaves are covered with sediments and microbenthic algae, which alternatively reduces the seagrass photosynthetic capacity and its resilience to meadow development. Anchor deployment and reduction of canopy height was also observed for *Zostera marina* in the UK[12], *P. oceanica* of Turkish coast in the Mediterranean Sea[7] and *Posidonia australis* (J.D. Hooker) from the coast of Australia[29]. The horizontal rhizome length being shorter at site 1 than site 2 clearly indicates the negative impact of physical damage on the rhizome structure of H. *ovalis*, resulting in meadow fragmentation and reduced migration, even though *H. ovalis* has a higher growth rate. Loss of rhizome structure and negative effects on meadow migration has been observed for *T. hemprichii* around the Havelock island of ANI[20] and P. *oceanica* in the Mediterranean Sea[30].

Reduction in morphometrics and density resulted in low percentage cover (20.3± 0.12%) of *H. ovalis* at site 1, which was 2-fold lower than site 2 (Table 1). The observed canopy height of *H. ovalis* at the site1 were similar to canopy height of *H. beccarii* (0.7-1.5 cm) observed at the Kalegauk island, Myanmar[27] and *H. ovalis* (1.98 cm) on the east coast of Malaysia[26] in the Andaman Sea, where disturbances due to boat anchors have been reported. Negative impact of boat anchors on the morphometrics, resulting in low percentage cover has also been observed for other seagrass species like *Z. marina* in the UK[12] and USA[10], *P. oceanica* in the Mediterranean Sea [7,13,14] and *P. australis* in Australia[15].

The loss of seagrass patches under the influence of boat anchors at the Havelock island of ANI, India is small (within an area of 1 km^2) but significant at local scale (loss of suitable habitat) as these disturbances lead to removal of *H. ovalis* biomass (AG and BG) by shoot uprooting and breakage of leaves. These losses will directly impact the local biota that depend on *H. ovalis* meadows for food and habitat, such as *Dugong dugon* (which have been reported to visit this site for feeding), an endangered mammal found in the waters of ANI[23]. Loss of their preferred feeding grounds can impact its conservation and recovery aspects. Saying that, physical damages due to boat anchors may also result in fragmentation of the seagrass meadows and combined with other physical disturbance like sand wave breaking and trampling and tourism footfall can result in loss of plant physical structures[5,6]. Loss of seagrass meadows will also reduce the extensive ecosystem services seagrasses provide, such as habitat for commercially important fish population and invertebrate biodiversity and carbon sequestration[3,8,15].

We report for the first time about the effects of boat anchors and increased tourism on seagrass ecosystems of ANI of India and found a clear evidence that a combination of physical stressors combined with sand wave breaking and touristic footfall can cause loss of fragile *H. ovalis* patches. The loss of *H. ovalis* was mostly restricted to the area that had an increased anchor deployment compared to the sheltered site with a clear indication in reduction of density, biomass, morphometrics, canopy height and percentage cover. This damage to seagrass meadows is local on scale within the beach, which can lead to loss of feeding habitat for fish and dugong population. Therefore, an extensive survey is required around the island to get a more detailed picture of loss of seagrass meadows due to tourism and fishing. This study suggests that proper management and planning should be placed for conservation of coastal shallow water seagrass ecosystems of ANI, that can be lost due to damage caused by boat anchors, direct fall of boats on seagrass meadows during low tides and damage by recreational and tourism activities.

Conclusion:

We report here for the first time about the impacts of boats anchors from tourism, recreational and fishing activities on the population structure of shallow water Dugong grass (*Halophila ovalis*) for the Andaman and Nicobar Island ecosystem of India. The negative impacts of boat anchors deployment were observed on the *H. ovalis* density, above ground biomass, leaf morphometrics, canopy height and percentage cover. Loss of *H. ovalis* population structure can result in loss of feeding grounds for endangered mammals like *Dugong dugon* that inhabit these islands. Our results will serve as a baseline for further research on loss of shallow water seagrass ecosystems due to the impacts of tourism and fishing.

Acknowledgments: We are grateful to the PCCF, wildlife to provide the required official help during the sampling programme. This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors. We are thankful to the reviewers for their suggestions to improve the manuscript.

Conflicts of Interest: The authors declare there is no conflict of interest between any organization or funding agencies.

Authors Contribution: AKM: Conceptualization, Methodology, Formal analysis, Investigation, Writing, Visualization; SN: Conceptualization, Resources, Writing-Review and Editing; DA: Conceptualization, Resources, Writing-Review, Editing, Supervision.

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