"STRATEGIC OR OPPORTUNISTIC?" – Subtidal Seagrass Use by Dugongs in the Sibu-Tinggi Archipelago, Johor, Malaysia

Wei-Khang HENG[1]*, Jillian Lean-Sim OOI[1,2] and Louisa S. PONNAMPALAM[3]

[1] Institute of Ocean and Earth Sciences, University of Malaya, Malaysia
[2] Department of Geography, Faculty of Arts and Social Sciences, University of Malaya, Malaysia
[3] The MareCet Research Organization, Malaysia

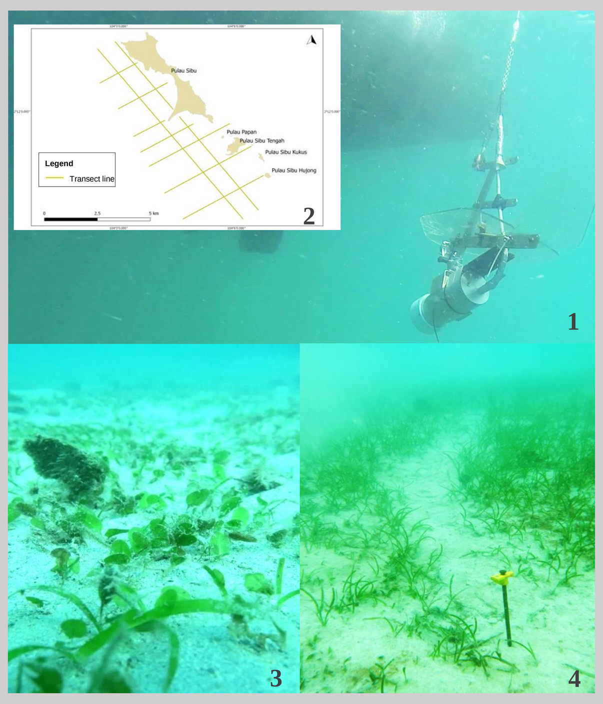
Abstract

In Peninsular Malaysia, endangered dugongs (*Dugong dugon*) are localized around the Sibu-Tinggi Archipelago (South China Sea) owing to the presence of extensive seagrass meadows. Field surveys were conducted in 2016 and 2017 to study the distribution of seagrass meadows and the dugongs' interactions with their seagrass habitat in the subtidal tropical environment of the archipelago. We examined the spatial distribution patterns of the dugong feeding trails across different seasons using towed underwater video and ascertained whether dugong feeding patterns in subtidal meadows were related to seagrass diversity, biomass, nutrient composition, water depth and/or substrate. Sixteen feeding trails were sampled by SCUBA diving for seagrass and sediment. Feeding trails were on average 2.9 ± 1.0 cm deep, and were dominated by small and fast-growing species, *Halophila ovalis* (mean shoot density 1236.27 ± 410.31 m^{-2}) and *Halodule uninervis* (mean shoot density 499.18 ± 297.61 m^{-2}) while *Cymodocea serrulata* (mean shoot density 36.71 ± 74.51 m^{-2}) and *Syringodium isoetifolium* (mean shoot density 17.54 ± 44.30 m^{-2}) were less abundant. Most of these feeding trails occurred in the mid to southern part of the meadow. The distribution of intensive feeding areas across the seasons suggested a practice of regular dugong grazing of sectional swards, called "feeding hotspots". Such regular, non-random feeding patterns imply the dugongs utilize the meadows in a strategic way, driven by the vegetative and physical habitat factors measured in this study. By identifying the most influential drivers, this study provides a seagrass-explicit rationale for designing better protected areas for dugongs.

Introduction

The dugong (*Dugong dugon*) is a herbivorous marine mammal listed as 'Vulnerable' on the IUCN Red List of Threatened Species. Its distribution and survival is highly dependent on the availability of healthy acreages of seagrass meadows in shallow coastal waters. Sibu-Tinggi Archipelago, Johor, appears to be the only location where a small but significant population of dugongs is found owing to the presence of extensive seagrass meadows which are often overlooked at the local and national scales (Ooi *et al*., 2010). The population size is most likely not more than 100 individuals (Ponnampalam *et al*., 2015). The objectives of this project were to determine the spatial distribution of seagrass habitats, to elucidate spatial and temporal distribution of dugong feeding trails in the subtidal seagrass meadow, and to ascertain the vegetative qualities (i.e. diversity, biomass and nutrient composition) of seagrass consumed to elucidate dugong feeding preferences.

Materials and Methods



Field surveys were conducted in Pulau Sibu and Pulau Tinggi (pulau=island) in June and October 2016, and May, September and November 2017. Both coastal islands are predominated by tropical subtidal and forereef seagrass meadows, with fringing coral reefs and small littoral mangrove forest patches.

Seagrass and Feeding Trail Mapping: Towed video survey (Fig. 1) was conducted in Sibu Archipelago along transects (Fig. 2). Seagrass extent and feeding trail occurrence (Figs. 3 & 4) were assessed during the video review by systematic point sampling protocol and data was then integrated into spatial database in QGIS software. Feeding Hotspot Areas (FHA) was analysed statistically with non-parametric Kernel-Density Estimation model by using QGIS software.

Photogrammetry and Sample Collection: Photo-quadrats were taken to measure the dimension and area of selected feeding trails, based on freshness indicators adapted from D'Souza *et al*., 2015 (Fig. 5). Seagrass samples were collected from both islands by coring and then sorted according to species, above- and below-ground components for biomass determination and nutrient analysis, i.e. total carbon, nitrogen, phosphorus, starch and fibre (Fig. 6).

Ongoing Results & Discussions

Locations of dugong feeding trails and Feeding Hotspot Areas (FHA) on subtidal seagrass meadow in Sibu Archipelago

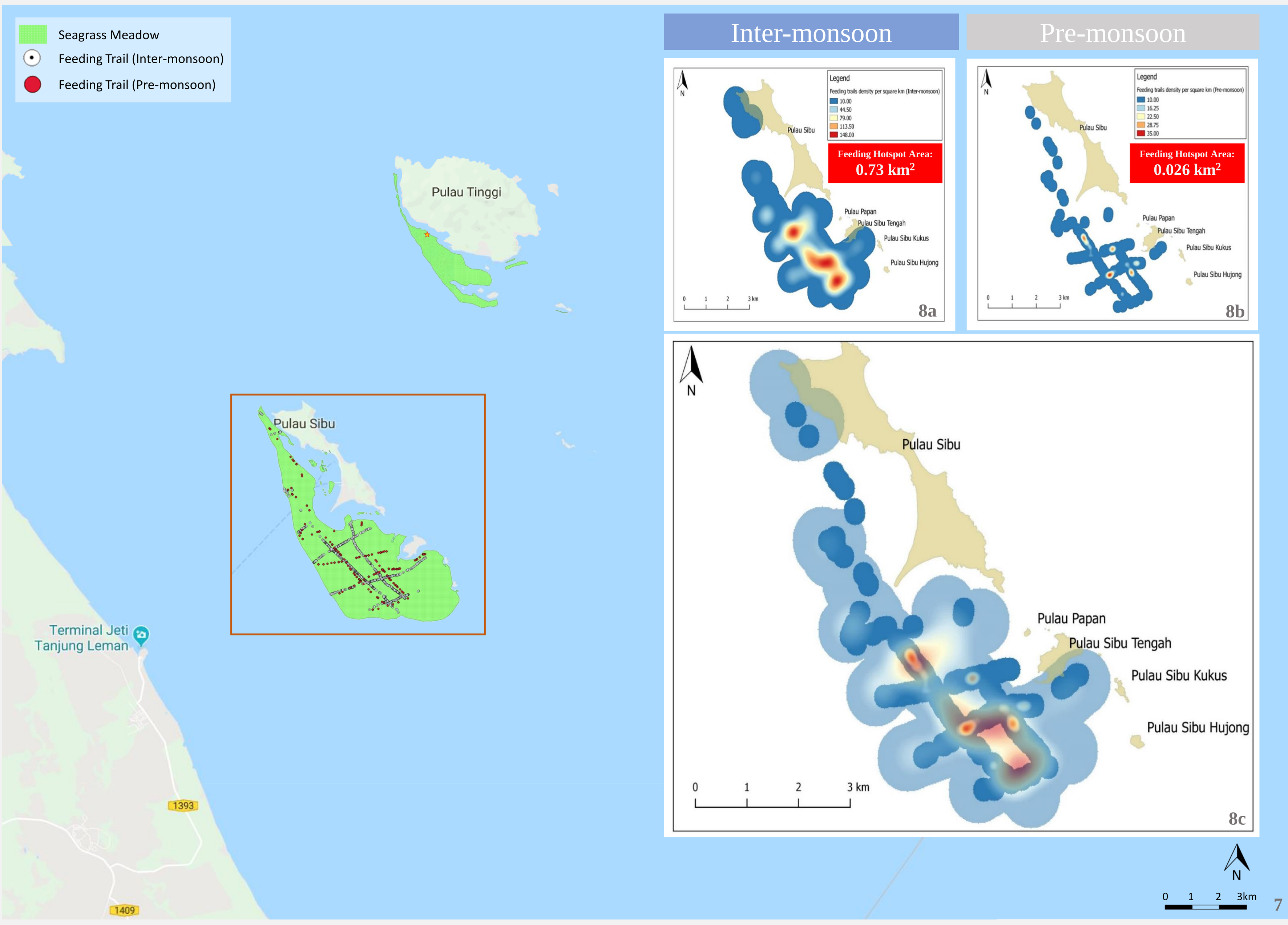


Fig. 7 Feeding trail locations observed and marked via underwater towed video sampling on the Pulau Sibu seagrass meadows during the June 2016 inter-monsoon (white) and October 2016 pre-monsoon (red). Seagrass meadow in the Sibu archipelago covering an area approximately 16.5 km^2 as depicted by the green polygon. Most of the dugong feeding trails occurred at the mid-southern part of the meadow throughout the two seasons, suggesting that dugong feeding grounds are centralized around Pulau Sibu Tengah and Pulau Sibu Hujong. In Pulau Tinggi, SCUBA diving surveys for seagrass sampling revealed that dugong feeding trails were mainly concentrated in a small area (red star) at the leeward edge of the meadow.

Heatmap in Figs. 8a and 8b showed that the FHA, as indicated by red zones, has shrunk by 95% between the inter-monsoon (0.73 km^2) and pre-monsoon (0.026 km^2) in 2016. However the overlap of red zones from the two seasons (Fig. 8c), suggests that there is site-fidelity for the dugongs' feeding grounds in the Sibu Archipelago. Repeated samplings and analyses are needed to improve the understanding of the FHA occurrence in the areas.

Note: A total of approximately 45 hours of video footages were recorded via towed video survey of Sibu Archipelago meadow and 31 feeding trails were sampled from Pulau Sibu and Pulau Tinggi. In this poster, we reported only seagrass and feeding trail presence in map form from both inter-monsoon* and pre-monsoon* seasons in 2016, and feeding trails information from 22 samples (n=22) which collected in 2016 and 2017.

**Northeast monsoon winds and rainfalls occur during November to March in the study site.*

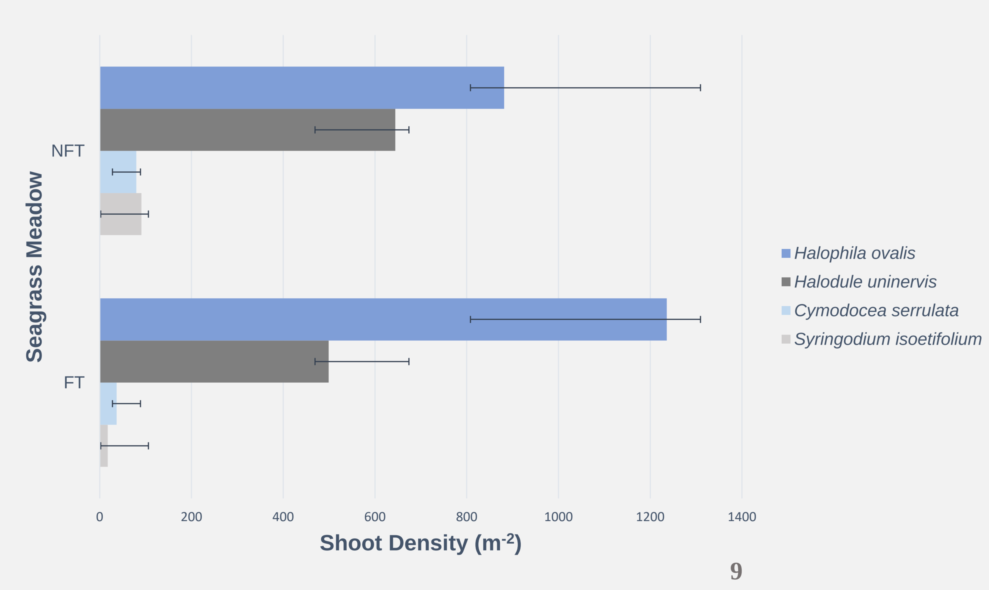
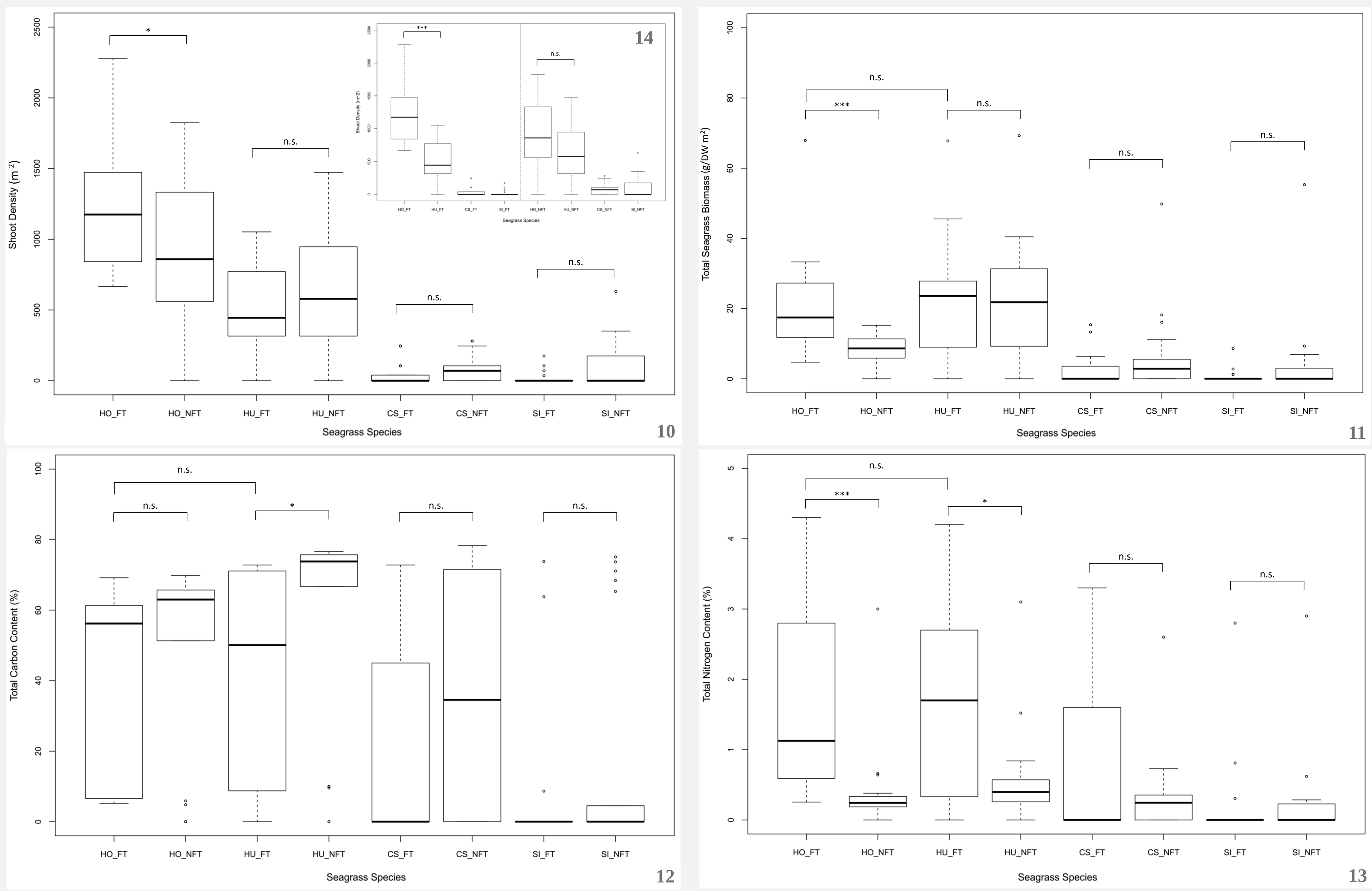


Fig. 9 The analysis on shoot density showed that dugongs primarily chose *Halophila ovalis* (12356.27 shoots/m^2, 69%) and *Halodule uninervis* (499.18 shoots/m^2, 43%) as their food within their feeding ground (FT) in Sibu-Tinggi Archipelago.

H. ovalis (*HO*) and *H. uninervis* (*HU*) were the most abundant seagrass species at all sampling sites. The results matched other tropical studies which reported dugongs to be grazing on these two species of seagrass (Yamamuro & Chirapat, 2005).

Factors Driving Dugong Feeding Preferences



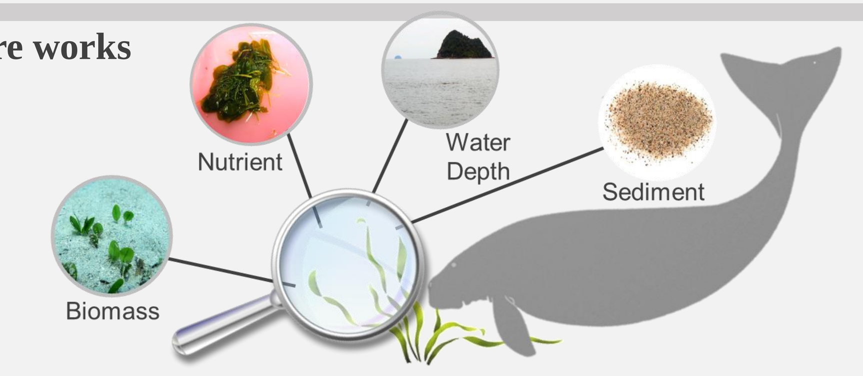
Figs. 10-13 Whole plant shoot density (m^{-2}), biomass (g/DW m^2) and total nitrogen (%) of *HO* were significantly different across feeding trail areas (FT) and non-feeding trail areas (NFT) (Wilcoxon rank sum: $Z = 2.16$, $n = 22$, $p = 0.03$ [Shoot Density], $Z = 4.13$, $n = 22$, $p = <0.001$ [Biomass], $Z = 4.53$, $n = 22$, $p = <0.001$ [Nitrogen]). Shoot density of *HO* and *HU* were significantly different between species in FT areas (Fig. 14) (Wilcoxon signed rank: $Z = 4.93$, $n = 22$, $p = <0.001$), but not significantly different in NFT areas. Total carbon (C) and nitrogen (N) in *HU* varied significantly across FT and NFT areas (Wilcoxon rank sum: $Z = -2.56$, $n = 22$, $p = 0.010$ [Carbon], $Z = 2.30$, $n = 22$, $p = 0.021$ [Nitrogen]).

Dugong feeding is potentially influenced by *HO* properties such as shoot density, biomass and plant N content because these properties were significantly higher in feeding trail areas. The N content of *HU* was also significantly higher in feeding trails areas, which suggests the potential role of this species in determining popular feeding areas for dugongs. However, N and C did not differ between *HO* and *HU*, which suggests that feeding preference may be influenced more by plant abundance than by N and C content. Both species are common and often occur in mixed meadows, making selective feeding difficult. Thus, site preference in feeding may presumably be influenced by the density, biomass and N content of the seagrass community as a whole, instead of individual species.

Closing Remarks

- Dugongs fed primarily at the mid-southern part of the Sibu Archipelago seagrass meadow and maintained their FHA throughout the two seasons in 2016. Despite the FHA shrinking by 95% between the two seasons, our results showed evidence of strategic feeding behaviour of dugongs, as they fed in a non-random pattern in terms of geographical area.
- Two mostly grazed seagrass – *H. ovalis* and *H. uninervis* were the most abundant species present in our study site. We found that feeding trails were most associated with *H. ovalis* with higher density, biomass and nitrogen content compared to the meadow with no feeding trail.
- A better understanding of meadow characteristics is important to identify important dugong feeding areas and feeding behaviour, for protection of dugong habitats in tropical meadows.

Future works



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Acknowledgments

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Contact Information
hengweikhang@gmail.com