Project Seagrass Brief Technical Report

Project: IKI Seagrass Ecosystem Services Project: "Conservation of biodiversity, seagrass ecosystems and their services – safeguarding food security and resilience in vulnerable coastal communities in a changing climate"

Authors: The MareCet Research Organization

Summary

Seagrass meadows are present throughout the majority of Malaysia's coastlines (Bujang et al., 2018), yet research on its many ecosystem services is limited. Research work is mainly conducted in certain areas of Johor and Sabah due to the extensive acreage of the meadows, or the presence of larger herbivores (i.e., dugongs, sea turtles) that rely on the meadows as a source of food. This project set out to determine the baseline of fish species at the sites as well as the importance of seagrass meadows on the east coast of Johor as a nursery site for juvenile species of fish, especially species that are commercially important, so as to better understand a meadow's value to fishery stocks. This research was conducted using baited remote underwater video systems (BRUVS). Our findings show that commercially important fish such as Nemipteridae (Threadfin breams) and Terapontidae (Grunts), and Lethrinidae (Emperor) are present in high abundance at our sites. These initial findings can help direct future research efforts and will be of great aid in furthering our understanding of the importance of seagrass meadows in relation to human economy. The research findings can also aid in more robust conservation and management planning for coastal seagrass habitats.

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Introduction

Seagrass meadows are known to be a host of biodiversity and offer a wide range of ecosystem services, with one such ecosystem service being that meadows can act as a nursery habitat for juvenile fish species (Cullen-Unsworth et al., 2014). This project aims to assess the local importance of seagrass habitats as a nursery site for juvenile fish species, especially to juveniles of commercially important fisheries species. The initial project objective was to explore how to best safeguard food security by way of seagrass conservation, and to assess the value of meadows in selected field sites in Peninsular Malaysia. However, due to challenges posed by the COVID-19 pandemic, our efforts were reduced to conducting the baseline survey to assess fish biodiversity in the meadows of our field sites, the results of which form the basis of this report.

This assessment was done by monitoring underwater biodiversity in seagrass meadows, with a focus on fish species. The baited remote underwater video system (BRUVS) was used in this study. BRUVS have been used in many studies to assess fish abundance and richness and offer several advantages. These include higher efficiency and a more cost-effective method for surveying an area (Harvey et al., 2013). While some limitations and biases are afforded with the use of the BRUVS, this method was deemed most suitable for the purposes of the project. In Malaysia, BRUVS studies appear to be limited or unpublished, with one such known study conducted in a reef ecosystem (Farhana-Azmi et al., 2022). Underwater monitoring has also been done to understand fish behaviour and aggregation (Yoshida et al., 2010), and one other similar study conducted in seagrass meadows used un-baited RUVS (Ho et al., 2018).

This study was conducted in seagrass meadows of different environmental conditions, awarded protection status, and level of knowledge of the meadow.

Objectives and activities completed

Two overarching goals were identified at the beginning of the project:

a. Establishment of a baseline of the biodiversity associated with seagrass meadows in an area with limited research, no protection, and plans for a development
b. Assessment of fish species that use seagrass meadows located in an MPA, where studies are occasionally conducted

1. Determine species composition and seagrass habitat usage of fish assemblages

a. Seagrass fish survey using Baited Remote Underwater Video (BRUV) systems across three sites
b. Database compiled for sites in need of baseline data
c. Summary statistics available for both fishery and non-fishery species

2. **Establish contribution of seagrass fisheries to the local people and food security**
    a. Qualitative field observations conducted alongside BRUV surveys

Methods

Study site description

Pulau Setindan (pulau = island), consists of an intertidal seagrass meadow, of which information about its ecology is limited apart from its distribution throughout the area and the species found at the site. Seagrass species observed in this meadow include *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule uninervis*, *Halophila pinifolia*, *Halophila ovalis*, *Thalassia hemprichii*, and *Syringodium isoetifolium* (Ismail & Khoo, 2018; MareCet, pers. obs.). This location is not currently protected by law. With a large tidal window, the meadows become completely exposed during low tides and is directly accessible from the main road. The island itself is accessible by foot and is located approximately 1.5 km from the mainland coast. The depth of water in the area ranges between 1-3 m. The meadow here is spread across a relatively large area but is patchy and has a mixed species composition. Observed invertebrate diversity is low and sediment type is soft mud and silt. Currently, this site is slotted for some future development plans, under the *Rancangan Tempatan Daerah* Mersing 2030 (Mersing District Local Plan 2030), which will see a bridge built from the mainland over to Pulau Setindan. This bridge is planned to be directly built over the current existing meadow. Should the development take place, it is likely that the seagrass will decline (Duarte, 2002).

The next two sites consist of subtidal seagrass meadows: Pulau Sibu Tengah and Pulau Tinggi. These islands are located off the east coast of Johor in Peninsular Malaysia. A few seagrass studies have been conducted in and around these islands. Seagrass species in these sites include *Halophila ovalis*, *Halodule uninervis*, *Cymodocea serrulata*, *Syringodium isoetifolium* at Pulau Sibu (Heng et al., 2022), and *Halophila decipiens, Halophila ovalis, Halophila spinulosa, Halophila minor, Cymodocea rotundata, Cymodocea serrulata, Halodule pinifolia, Halodule uninervis,* and *Syringodium isoetifolium* (Ooi et al., 2011) at Pulau Tinggi. Both islands are located within a marine park that is designated as a no-take zone spanning 2 n.m away from the islands' lowest water marks. The depth of water in the meadows range between 2-10 m. The Sibu islands are known to have the most extensive subtidal seagrass hectare coverage in Peninsular Malaysia (Heng et al. 2022) and are also home to an endangered population of dugongs (Ponnampalam et al. 2014, 2015; Ponnampalam 2017). Since 2019, the area is designated as an Important Marine Mammal Area (IMMA) by the IUCN (MMPA, 2022).

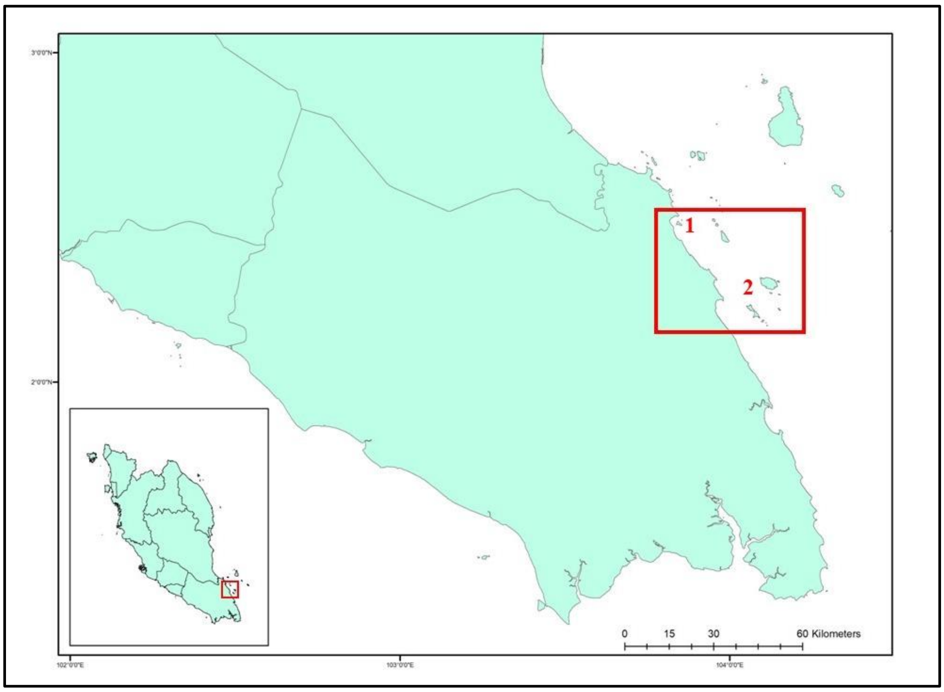


Figure 1: map showing the location of the BRUV deployments, on the east coast of Peninsular Malaysia. (1) indicates the location of the intertidal site, Pulau Setindan. (2) indicates the location of the subtidal sites, Pulau Sibu Tengah and Pulau Tinggi

Quadrat sampling

Quadrats measuring 1m x 1m were randomly placed in the intertidal meadows of Pulau Setindan, close to the deployment sites. Habitat data were then recorded for each quadrat. Data recorded included seagrass species composition within the quadrats, percentage coverage, epiphyte cover, canopy height, sediment type, and fauna present. A total of 15 quadrat samples were taken. No quadrats were collected for the subtidal sites due to an ongoing SCUBA diving ban at the time of sampling.

BRUV system

The BRUV systems were deployed multiple times at each site to record fish abundance and richness. The BRUVS were deployed for approximately an hour with recorded data starting after 2-10 minutes of the deployment (additional recording time taken to be used as a buffer to allow for sediment to settle and for fish to acclimatize to setup). The BRUVS were deployed three times a day (9am; 12pm; 3pm), using GoPros (of varying models mainly 5, 8 and 10). Camera orientation used was horizontal to the seafloor. The BRUVS setup was built using PVC pipes, as seen in Appendix 1. Distance between the systems were kept to at least 50 m to avoid bait plumes or counting repetitions. Bait used was tinned sardines and placed in the bait box slightly crushed. Tinned sardines were used as they were readily available and easy to find near the field sites and can also be kept for longer periods of time. Sardines are also an oily fish frequently used as bait for BRUVS as oily fish are efficient with attracting more fish (Wraith et al., 2013). Bait was attached at maximum length of 1 m away from the camera, but this changed depending on the visibility of the site as most sites had low visibility and the bait box could not be seen from 1m away. Under such conditions, the bait box was moved to approximately 50 cm away from the camera.

While the use of bait is a known bias when conducting BRUVS sampling (Wraith et al., 2013), baited systems were used in this study to better lure individuals closer to the camera for identification as our sites are quite turbid.

BRUVS were randomly deployed throughout the meadows (Figures 1 – 3). The total hours of footage that were collected and then analysed were 21 h for Pulau Setindan, 30 h for Pulau Tinggi, and 12 h for Pulau Sibu Tengah. Variations in the total hours collected were due to tide and weather. In the intertidal sites, some rapid habitat and ecological assessments were done alongside the BRUVS. This was unfortunately not possible in the subtidal sites due to an ongoing SCUBA diving ban at the time.

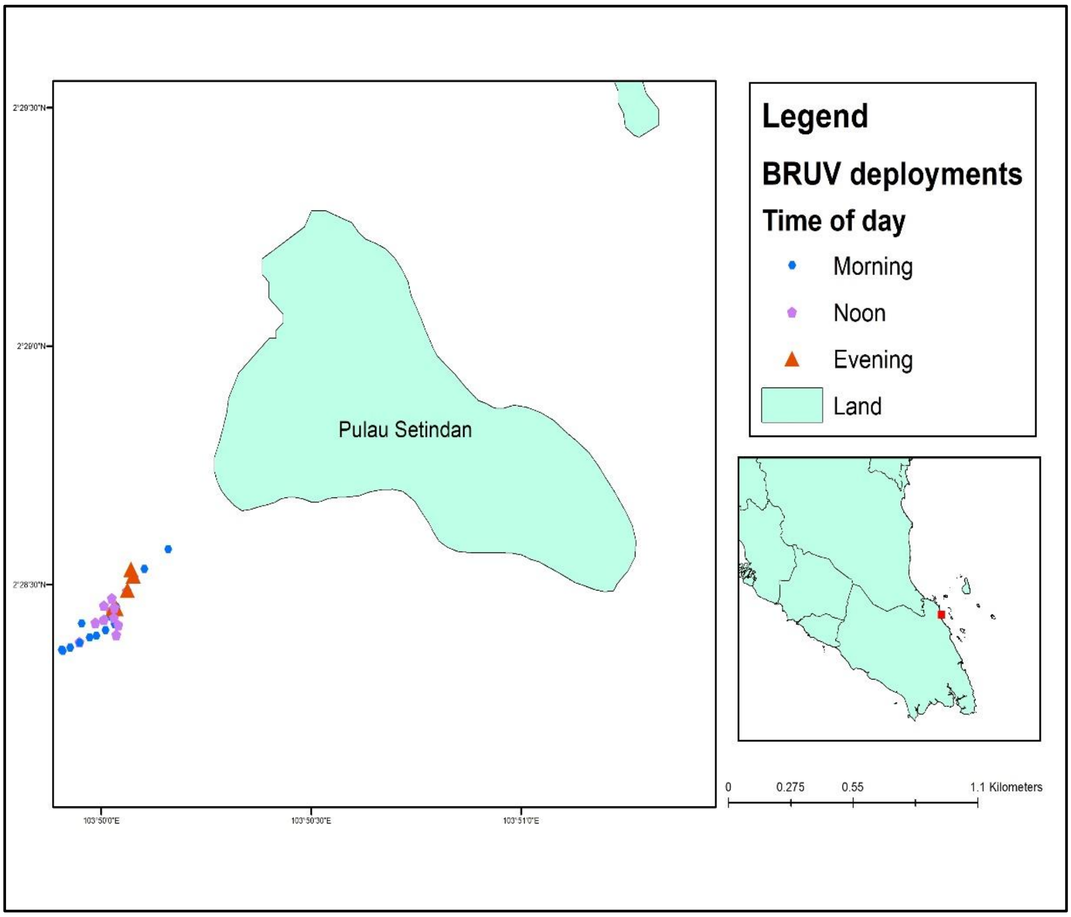


Figure 2: Map showing the deployment locations of the BRUVS setups near Pulau Setindan at three different times of the day

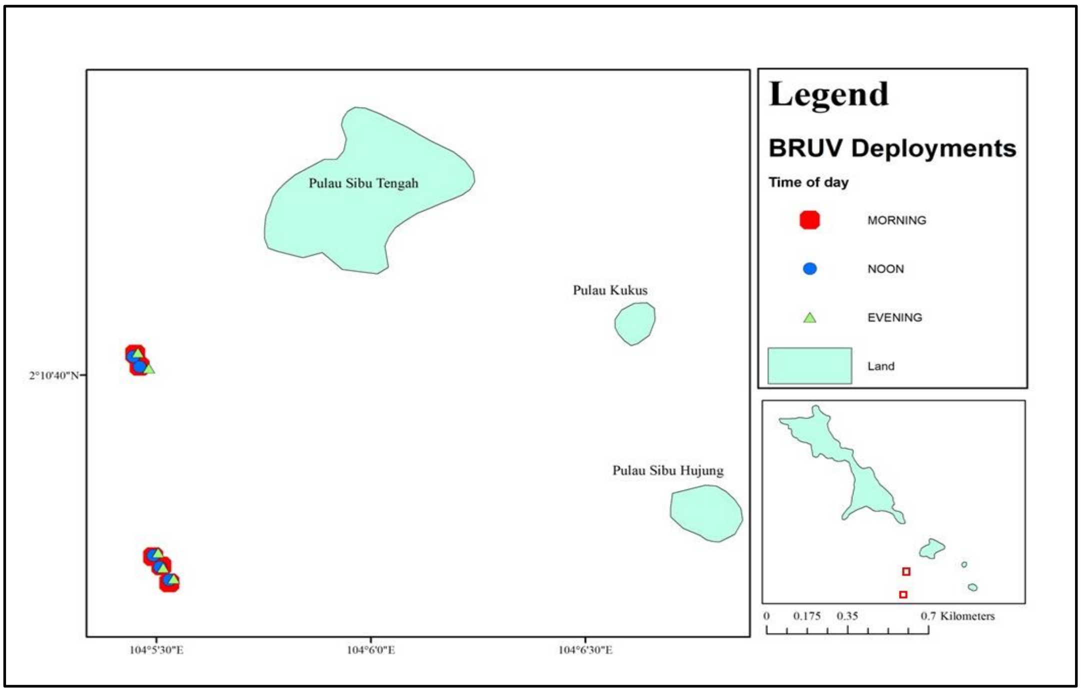


Figure 3: Map showing the deployment locations of the BRUVS setups near Pulau Sibu Tengah at three different times of the day

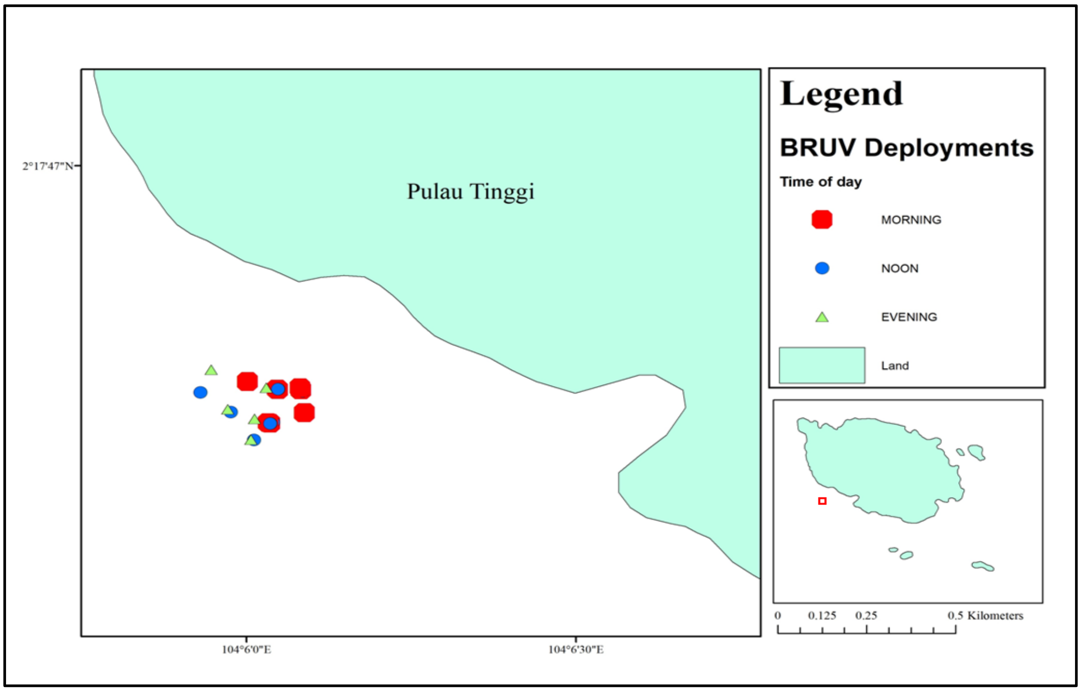


Figure 4: Map showing the deployment locations of the BRUVS setups near Pulau Tinggi at three different times of the day

Video analysis

The recorded videos were then analysed. Video metric used was the maximum number of individuals (MaxN) for each species at any given time in the video frame. Videos were watched on VideoLAN Client (VLC) media player. During video analysis, BRUVS that landed either on the side or were facing upwards were eliminated from the analysis pool. Of the 32 h collected for Pulau Setindan, 34% of deployment footage was eliminated. As for the subtidal sites, 20% of 15 h at Pulau Sibu Tengah, and 30 h of footage at Pulau Tinggi, and was eliminated. The MaxN for each species was recorded for each deployment.

Fish market surveys

Fish market surveys were conducted in 2021 in Mersing town, to better understand the fish species available for purchase from markets. When visiting these markets (which included roadside stalls and larger markets), we recorded the species available as well as anecdotal data from the fish mongers about where the fish were caught. Pictures were taken to facilitate the identification of these fish.

Anecdotal data and qualitative observations

Social data were mainly collected by means of qualitative observations while the research work was being conducted. Conducting household surveys at our project sites was also deemed not suitable due to multiple factors. The first factor was due to the coincidence of the project being initiated during the COVID-19 pandemic whereby a multitude of restrictions were placed on face-to-face and in-person interactions. Household visits were also not suitable at the intertidal location as it is set in a town where residents were spread out over several areas. Out at Pulau Setindan's intertidal meadow, gleaners were only observed occasionally during our field deployments, mainly looking for marine worms to be used as bait or for other bivalves. Gleaning was conducted mainly for subsistence and not to be sold for income. Fishers were only observed once, walking out into the meadow at high tide to collect catch from a deployed net. At the subtidal location, no fishing activity was observed during our field deployments, and this would be due to the fact that the subtidal meadows are located in a marine park which is a no-take zone. As such, household surveys were not conducted on the island.

Results & Discussion

Summary of habitat data

Habitat data for the meadows in Pulau Setindan were collected alongside the BRUV deployments (see Figure 1). A total of 15 quadrats were done, collecting information on the seagrass biodiversity present, seagrass cover, canopy height, epiphyte cover, and fauna present, all within the quadrats. A total of eight species were observed in the intertidal meadows at Pulau Setindan. These include *Cymodocea rotundata*, *Cymodocea serrulata*, *Halophila ovalis, Halodule uninervis, Halodule pinifolia, Enhalus acoroides, Syringodium isoetifolium,* and *Thalassia hemprichii*.

Pulau Setindan habitat data summary figure:

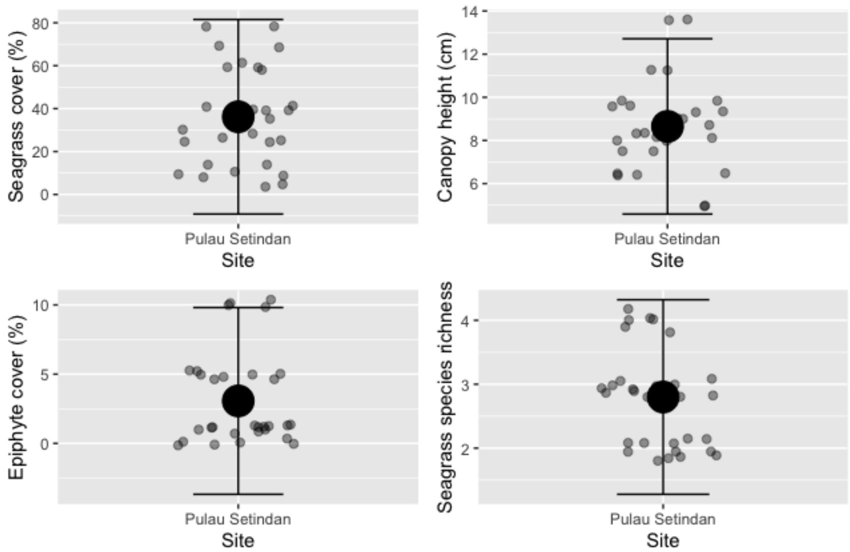


Figure 5. Average seagrass cover (%), canopy height (cm), epiphyte cover (%), and seagrass species richness across 15 quadrat replicates conducted at the Pulau Setindan intertidal meadows. Black points represent the Mean + SE and grey point represent raw quadrat values.

As shown in Figure 5, the meadows of Pulau Setindan are mainly a mixed species meadow, with canopy height averaging between 7 – 10 cm. The meadow is generally patchy, with an average 30% cover per quadrat.

These results are preliminary as the sample size is small, and a larger number of quadrats need to be conducted to get a more complete representation of the meadow.

Pulau Sibu Tengah and Pulau Tinggi habitat data summary:

No quadrat habitat data were collected for both the subtidal sites at Pulau Sibu Tengah and Pulau Tinggi. However, previous studies conducted in these areas can give us some insight into the meadows' habitat characteristics. The meadows of Pulau Sibu Tengah have four species of seagrass present. These include *Halophila ovalis, Halodule uninervis, Cymodocea serrulata,* and *Syringodium isoetifolium* (Heng et al., 2022). The meadows sit in and around the Sibu Archipelago and is located at depths of 2 – 10 m. Sediment in the area is sandy with fine silt and can be quite turbid as the area experiences strong currents. A previous study showed that the seagrass meadows at Pulau Sibu have variable coverage depending on the monsoon season (Heng et al., 2022). The seagrass meadow at Pulau Sibu Tengah is also the primary feeding ground for the population of endangered dugongs that occur in the area (Ponnampalam et al. 2014, 2015; Ponnampalam 2017; Heng et al. 2022), whereby the archipelago itself is situated within the Mersing Archipelago Important Marine Mammal Area (IMMA).

Conversely, Pulau Tinggi, has higher seagrass biodiversity whereby 9 species were reported between the depths of 5 – 13 m by Ooi et al. (2011). These species include *Halophila decipiens, Halophila ovalis, Halophila spinulosa, Halophila minor, Cymodocea rotundata, Cymodocea serrulata, Halodule pinifolia, Halodule uninervis,* and *Syringodium isoetifolium* (Ooi et al., 2011). A more recent study is not currently available and highlights the need for an updated mapping effort of the seagrass meadows in this region. The seagrass meadows in Pulau Tinggi are also an important site for dugongs (Ponnampalam, 2017). Pulau Tinggi also sits within the Mersing Archipelago Important Marine Mammal Area (IMMA).

Summary of seagrass associated biodiversity

In Pulau Setindan, the average number of fish species per 200 m^2 of seagrass across the deployments was 3.76 ± 1.61. On average, each deployment recorded an abundance of 11.14 ± 8.06 individuals.

In Pulau Sibu Tengah, the average number of fish species per 200 m^2 of seagrass across the deployments was 8.25 ± 1.76. On average, each deployment recorded an abundance of 29.75 ± 7.97 individuals.

In Pulau Tinggi, the average number of fish species per 200 m^2 of seagrass across the deployments was 8.33 ± 2.18. On average, each deployment recorded an abundance of 45.67 ± 22.67 individuals.

In comparing the subtidal sites, Pulau Tinggi had higher abundance and species richness of fish species than Pulau Sibu Tengah.

According to Malaysia's 2022 Annual Fisheries Statistics (Volume 1), the top five species for catch landings in terms of quantity and commercial value included Nemipteridae (Threadfin breams and Terapontidae (Grunts), both of which were observed during the BRUVS, particularly at the subtidal sites. Other commercially important fish that were amongst the most abundant species observed at these subtidal sites include *Lethrinus genivittatus*, or the Longspine emperor, and *Lutjanus vitta*, Brownstripe snapper. At the intertidal site, two species of *Terapon* were among the five most sighted species (Table 1). These were *Terapon puta*, or Small scaled terapon, and *Terapon jarbua*, or the Tiger perch.

Table 1: Top five most abundant species of fish across all three BRUVS sites

Rank	**Pulau Setindan**	**Pulau Sibu Tengah**	**Pulau Tinggi**
1	*Terapon puta*	*Lethrinidae genivittatus*	*Lethrinidae genivittatus*
2	*Hexanematichthys sagor*	*Pentapodus setosus*	*Pentapodus setosus*
3	*Sillago sihama*	*Upeneus oligospilus*	*Gnathonodon speciosus*
4	*Terapon jarbua*	*Novaculoides macrolepidotus*	*Siganus fuscescens*
5	*Acentrogobius caninus*	*Lutjanus vitta*	*Upeneus oligospilus*

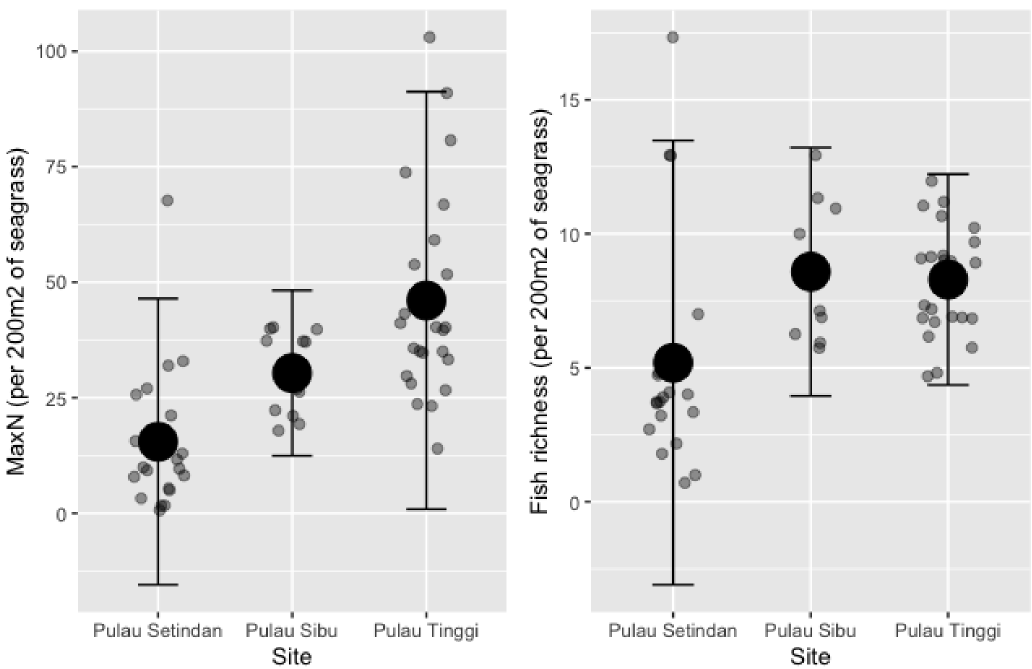


Figure 6. Boxplots representing MaxN and fish species richness across sites. Grey points beyond the bars represent outliers

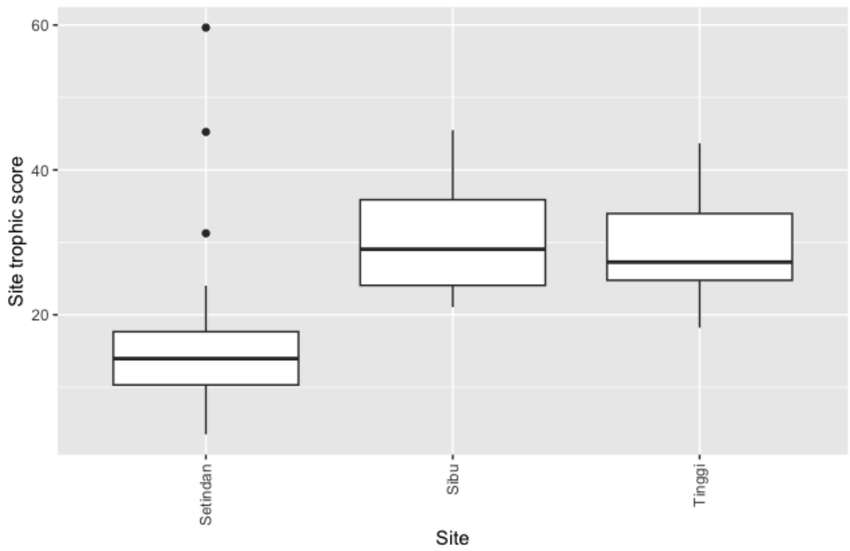


Figure 7. Boxplots showing the average site trophic score of fish species present across all three sites

Trophic scores for each identified species were taken from FishBase, to then identify the average trophic scores across the three sites, as shown in Figure 7. Trophic scores can give us an idea of a sites value in terms of a habitat being of importance for key fisheries species. Fisheries species are usually those with higher trophic scores, given they are likely to be placed higher in the food chain. Trophic scores are calculated based on the species' diet.

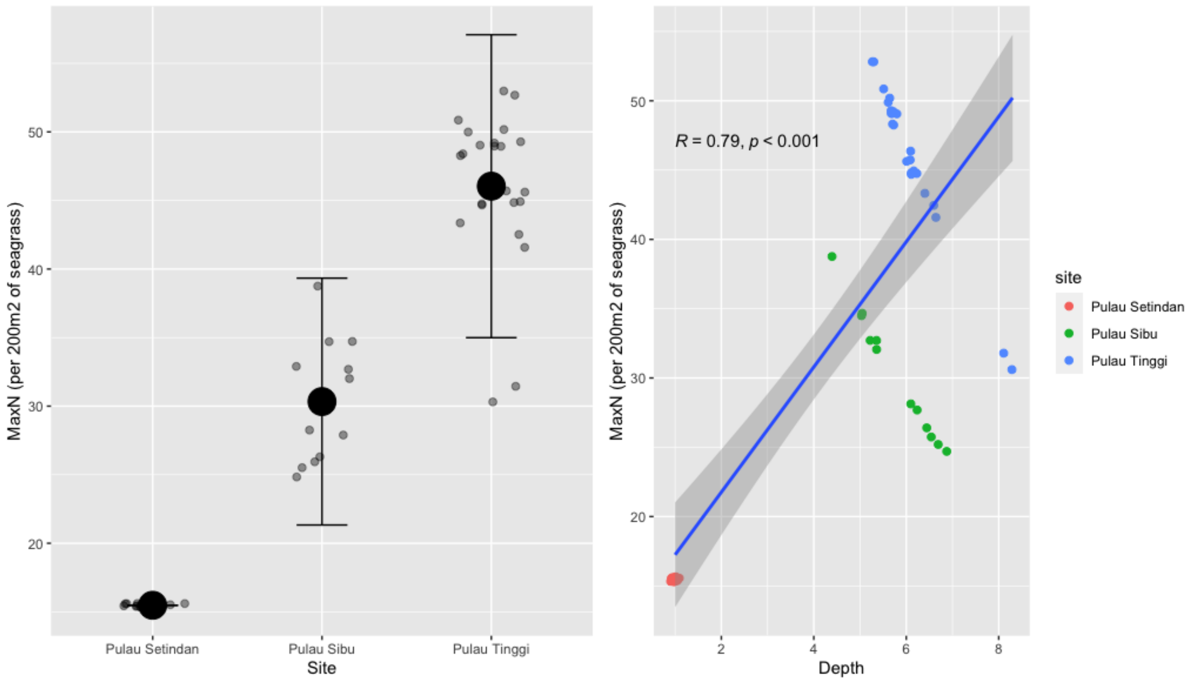


Figure 8:
(Left): shows the plotted MaxN value for all three sites. Grey points beyond the bars represent outliers
(Right): shows the MaxN values plotted against the depth in which those values were recorded, across all three sites

MaxN and modelled MaxN based on depth

The average MaxN as plotted in Figure 8 (left), shows the values for each of the three sites. The average MaxN recorded for Pulau Setindan is about 11. Whereas for Pulau Sibu and Pulau Tinggi, it was 30 and 46 respectively. Of the two comparable subtidal sites, Pulau Tinggi recorded a higher relative abundance of fish as well as a higher species richness value of 28. Pulau Sibu has a species richness of 21 and Pulau Setindan 14.

Given no other habitat data were collected during the sampling period in the subtidal sites, it is difficult to draw a conclusion on the links between the local seagrass habitat attributes and the abundance values across sites and species.

MaxN data were then also plotted against depth of the area where the deployments were conducted, as shown in Figure 8 (right). In comparing the two sites, Pulau Tinggi had deployments in deeper depths. The graph shows an increase of abundance with depth, suggesting that species may prefer meadows in a deeper range of depths. Previous studies have also shown similar findings (Jones et al., 2021; Alonso Aller et al., 2014).

Several factors can contribute to the difference in abundance across sites. Meadow structure, with traits such as canopy height and shoot density, have been shown to effect richness and abundance of fish species in seagrass meadows (Jones et al., 2021). However, species diversity does not have an effect on fish assemblage (Jones et al., 2021), and hence the higher seagrass species count at Pulau Tinggi does not explain the higher abundance seen there. Often, it is the additive effects of multiple environmental traits that may explain the abundance or richness in an area.

In comparing a similar study done at Pulau Tinggi that used RUVS, Ho et al. (2018) found that the contributing factor to fish density and species richness was seagrass percent cover. The study also found similar species and that commercially important species used these subtidal meadows, namely Lethrinidae (Emperor), Nemipteridae (threadfin breams), and Mullidae (Goatfish). One other finding from the Ho et al. (2018) study showed that fish density and richness were positively correlated with proximity to the closest adjacent reef habitat. This was not a factor that was looked at under our study but shows that these coastal habitats are often linked and their connectivity important for juvenile fish species.

Summary of market survey data & social data

The fish market surveys conducted showed about 46 species of fish being sold. These include Lutjanidae (Snappers), Carangidae (Scad), Scombridae (Mackerel), and even some sharks and rays. When speaking to the fishmongers, it was revealed that most stalls had fish that were caught in other sites (e.g., Endau, to the north of Mersing) that were either in a different state, or from islands further offshore from the location of the project sites. Only one stall indicated fishing in the waters of Mersing. When conducting reconnaissance work prior to our fieldwork, many fish traps were observed to be placed on the seaward facing side of Pulau Setindan (there is no seagrass in this area), hence it is possible that some of the fish sold as these markets come from the waters close to Pulau Setindan. While there was no fishmonger who mentioned fishing near the waters of the east coast islands near our deployment sites, it is important to note that the two subtidal meadows are situated within a marine park, hence if any fishing activity was to be conducted there, it is likely not to be disclosed.

In terms of social data, no data could be collected from the subtidal meadow site, due to complications and restrictions during the COVID-19 pandemic. However, qualitative observations were made while we were at the intertidal site. At Pulau Setindan, not many gleaners were observed during low tide. The communities living in and around the island site are located in a small town (Mersing), and not many rely directly on fishing or gleaning as a source of income. Most locals either work inland or in tourism. Over the period of our fieldwork, we only occasionally saw gleaners or fishers, and were only able to speak to five. Out of the five, two were fishers, who were observed to be coming back from collecting a deployed net. When spoken to, both mentioned occasionally coming out to fish for subsistence when the tide is high. Gleaners were observed to be collecting marine worms to be used as bait when fishing, and some bivalves. All gleaners were gleaning for subsistence, and none used their catch or collection for selling purposes.

Conclusions

This project has worked as a good initiative to get a baseline understanding of the importance of the seagrass meadows around Mersing and their importance from a fisheries and livelihood perspective. The study also provided a basic understanding of the species composition of subtidal seagrass meadows in a marine park. While seagrass meadows provide many services, these may differ in extent depending on local conditions and context.

As seen with the BRUVS, all three sites are important hubs of biodiversity of fish species, with the subtidal sites serving as an important site to an abundant juvenile population of many fish species, including commercially important ones like Nemipteridae (Threadfin breams), Lethrinidae (Emperor), and Terapontidae (Grunts). These results were shown to be in line with another study, Ho et al. (2018), and further proves the importance of these sites as an important habitat for juvenile fish species. The subtidal meadows are not gleaned or fished, and hence there is no immediate social link between the meadows and the communities that live near them.

Current collected evidence suggests that the intertidal meadows of Pulau Setindan serve as an alternative site for gleaning for bait rather than a primary location where one goes to in order to glean for seafood resources. While the meadows of Pulau Setindan boast an impressive and sizeable meadow, biodiversity recorded here was lower than expected. A number of factors could explain this outcome. For one, the large tidal window often leaves the meadows exposed for long periods of time. The Pulau Setindan meadows also experience sedimental deposition with the incoming tides, which often bury much of the seagrass in the meadows (MareCet, pers. obvs.), as such reducing available canopy cover. However, the lack of biodiversity in the area is not such that the meadow is not of importance. As mentioned previously, seagrass meadows are a host to an array ecosystem services, and from a blue carbon project that was done coinciding with this project (under the IKI Project), we know that these meadows are sites for carbon storage (Lavery et al., 2023). The meadows of Pulau Setindan and Pulau Sibu Tengah host stocks ranging 9-36 Mg Corg ha^{-1} (Lavery et al., 2023). No blue carbon work was done on the meadows at Pulau Tinggi.

More deployments and supplementary habitat data like those collected during the quadrat sampling, are needed to form robust conclusions about the ways in which the seagrass meadows support local marine biodiversity, given how dynamic these meadows are. A deeper understanding of the habitat ecology in our study sites can facilitate better protection measures for the sites and add value to any protection already available to these sites.

References:

Alonso Aller, E., Gullström, M., Eveleens Maarse, F. K., Gren, M., Nordlund, L. M., Jiddawi, N., & Eklöf, J. S. (2014). Single and joint effects of regional-and local-scale variables on tropical seagrass fish assemblages. *Marine Biology*, *161*, 2395-2405.

Cullen-Unsworth, L. C., Nordlund, L. M., Paddock, J., Baker, S., McKenzie, L. J., & Unsworth, R. K. (2014). Seagrass meadows globally as a coupled social–ecological system: Implications for human wellbeing. *Marine pollution bulletin*, *83*(2), 387-397.

Duarte, C. M. (2002). The future of seagrass meadows. *Environmental conservation*, *29*(2), 192-206.

Farhana-Azmi, N., Manjaji-Matsumoto, B. M., Maidin, N., John, J. B., Bavoh, E. M., & Saleh, E. (2022). Checklist of coral reef fishes of Darvel Bay, Sabah, Malaysian Coral Triangle, with a note on the biodiversity and community structure. *Biodiversity Data Journal*, *10*, e79201.
Available online at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9848608/

Harvey, E., McLean, D., Frusher, S., Haywood, M., Newman, S. J., & Williams, A. (2013). The use of BRUVs as a tool for assessing marine fisheries and ecosystems: a review of the hurdles and potential. *University of Western Australia*, *20*.
Available online at:
https://www.researchgate.net/publication/260122217_The_use_of_BRUVs_as_a_tool_for_assessing_marine_fisheries_and_ecosystems_a_review_of_the_hurdles_and_potential

Heng, H. W. K., Ooi, J. L. S., Affendi, Y. A., Kee Alfian, A. A. & Ponnampalam, L. S. (2022). Dugong feeding grounds and spatial feeding patterns in subtidal seagrass: A case study at Sibu Archipelago, Malaysia. *Estuarine, Coastal and Shelf Science*, *264*, 107670.

Ho, N. A. J., Ooi, J. L. S., Affendi, Y. A., & Chong, V. C. (2018). Influence of habitat complexity on fish density and species richness in structurally simple forereef seagrass meadows. *Botanica Marina*, *61*(6), 547-557.

Ismail, M. S. & Khoo, M. L. (2019). Occurrence and Distribution of Seagrass in Waters of Pulau Setindan Johor. Malaysian Fisheries Journal 17: 12 – 18.

Jones, B. L., Nordlund, L. M., Unsworth, R. K., Jiddawi, N. S., & Eklöf, J. S. (2021). Seagrass structural traits drive fish assemblages in small-scale fisheries. *Frontiers in Marine Science*, *8*, 640528.

Lavery, P., Lafratta, A., Nair, D., Ponnampalam, L., Ng, J. E., Hisne, F. I. J., & Serrano, O. (2023). Blue Carbon Opportunities: seagrass carbon storage and accumulation rates at Johor and Penang, Malaysia.

Available online at: https://ro.ecu.edu.au/ecuworks2022-2026/3187/

Ooi, J. L. S., Kendrick, G. A., Van Niel, K. P., & Affendi, Y. A. (2011). Knowledge gaps in tropical Southeast Asian seagrass systems. *Estuarine, Coastal and Shelf Science*, *92*(1), 118-131.

Wraith, J., Lynch, T., Minchinton, T. E., Broad, A., & Davis, A. R. (2013). Bait type affects fish assemblages and feeding guilds observed at baited remote underwater video stations. *Marine Ecology Progress Series*, *477*, 189-199.

Ponnampalam, L. S., Fairul Izmal, J. H., Ichikawa, K., Akamatsu, T., Kee Alfian, A. A., Wetzel D. and Reynolds III, J. 2014. A multi-pronged approach for overcoming knowledge barriers on the ecology and status of dugongs (*Dugong dugon*) in Johor, Malaysia: Towards critical habitat protection. Pages 101 – 112 *in* Wan Musthapa, W. F. Z., Nik Rosely, N. F. and Othman, A. S. (Eds). Johor Nature Heritage. School of Biological Sciences, Universiti Sains Malaysia, Penang, Malaysia.

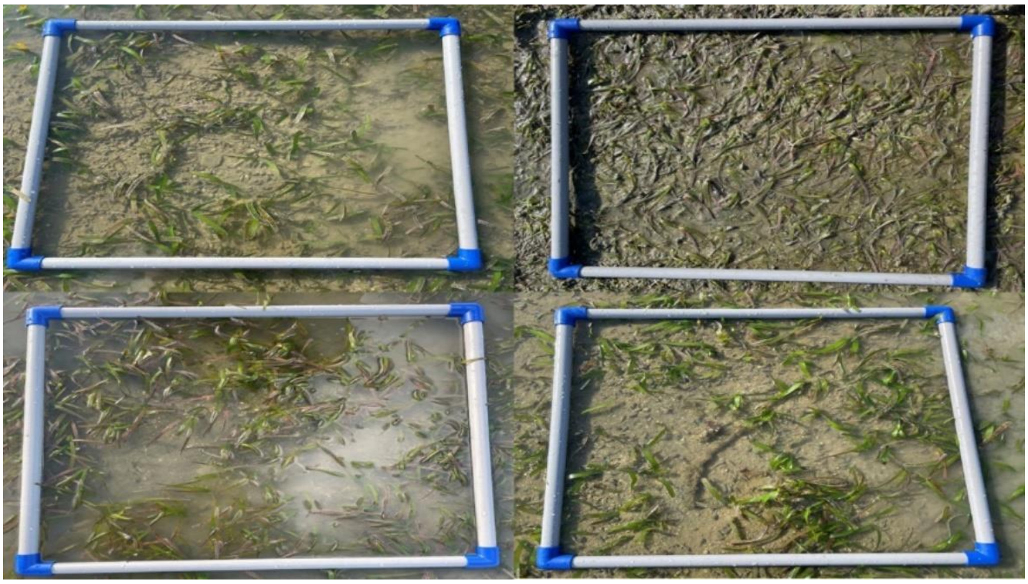
Ponnampalam, L.S., Fairul Izmal, J.H., Adulyanukosol, K., Ooi, J.L.S. and Reynolds III, J.E. 2015. Aligning conservation and research priorities for proactive species and habitat management: the case of dugongs *Dugong dugon* in Johor, Malaysia. Oryx 49(4): 743-749. DOI:10.1017/S0030605313001580

Ponnampalam, L.S., 2017. A Three-Pronged Approach for Overcoming Knowledge Barriers on the Ecology and Status of Dugongs in Johor, Malaysia – towards Critical Habitat Protection. Narrative Report #3: Year 3 (Final) Progress Report of PEW Fellowship in Marine Conservation (2014 – 2017). Report submitted to The PEW Charitable Trusts.

Yoshida, T., Akagi, K., Toda, T., Kushairi, M. M. R., Kee, A. A. A., & Othman, B. H. R. (2010). Evaluation of fish behaviour and aggregation by underwater videography in an artificial reef in tioman island, malaysia. *Sains Malaysiana*, *39*(3), 395-403.

Appendix 1:

Habitat data collection with quadrats:



Quadrats were used to collect supplementary habitat data at the intertidal meadows of Pulau Setindan, using the SeagrassWatch method

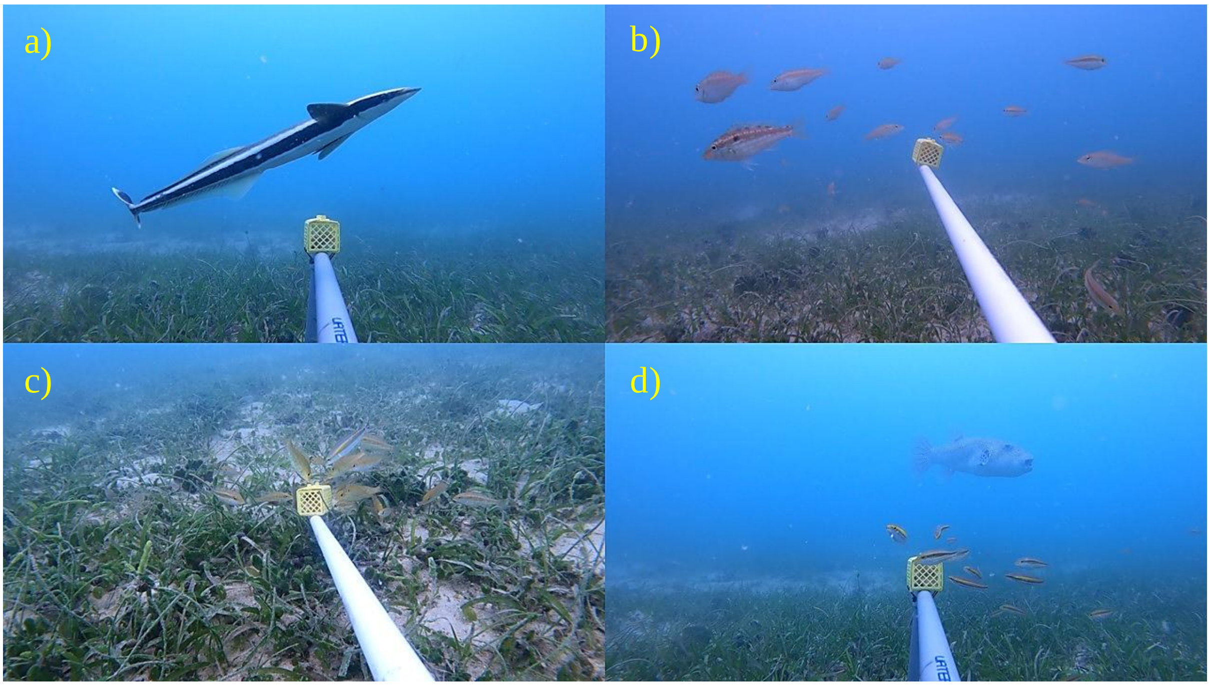
BRUVS fieldwork:

BRUVS deployment conducted at the intertidal meadows of Pulau Setindan. An angle bar and rod were used to secure the camera and bait box

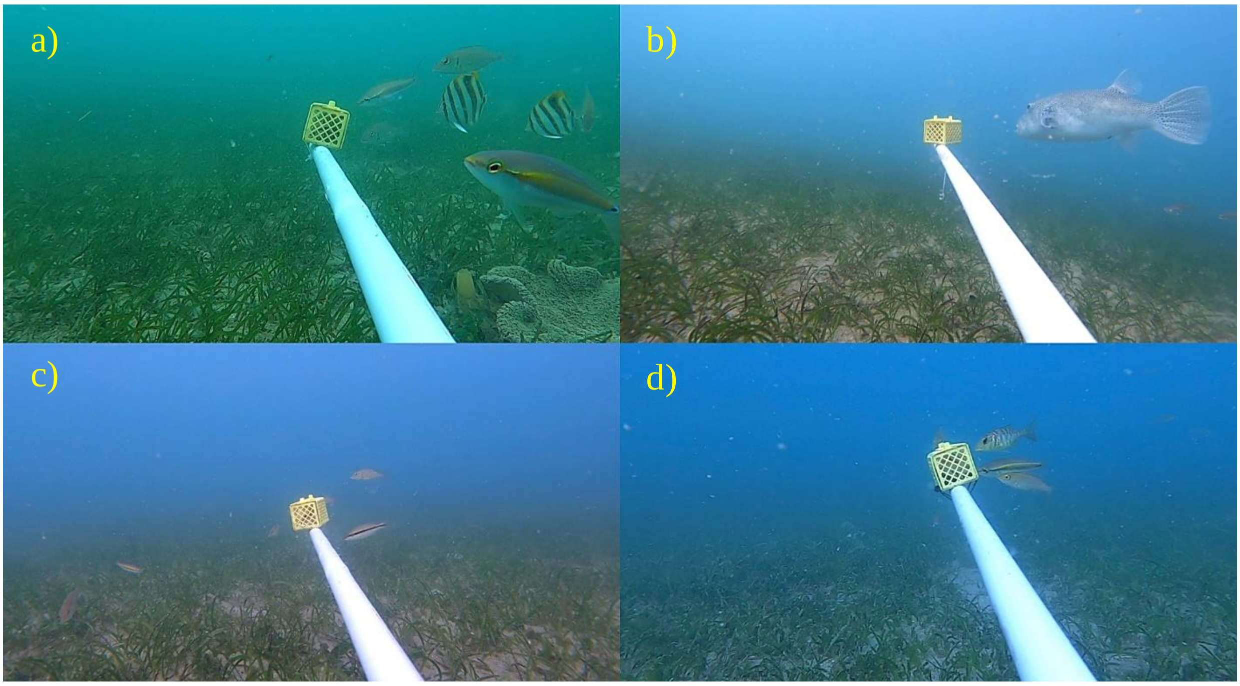
(Left) In the subtidal sites, a PVC setup was built as shown by [MarAlliance](). (Right) These were then deployed off the boat using ropes

BRUVS video stills:

Video stills from Pulau Setindan showing various species including a) Four lined terapon (*Pelates quadrilineatus*), b) Silver sillago (*Sillago sihama*), c) Tropical sand goby (*Acetrogobius caninus*), and d) Sagor catfish (*Hexanematichthys sagor*)



Video stills from Pulau Tinggi showing various species including a) the Slender suckerfish (*Echeneis naucrates*), b) Slender emperor (*Lethrinus variegatus*), c) Butterfly whiptail (*Pentapodus setosus*), and d) Starry pufferfish (*Arothron stellatus*)



Video stills from Pulau Tinggi showing various species including the a) Slender emperor (*Lethrinus variegatus*), b) Butterfly whiptail (*Pentapodus setosus*), c) Sixspine butterflyfish (*Parachaetodon ocellatus*), and d) Starry pufferfish (*Arothron stellatus*)

Gleaners at Pulau Setindan

A gleaner at Pulau Setindan digging for marine worms to be used as bait when fishing

A gleaner at Pulau Setindan collecting cockles for consumption during the low tide