SEAGRASS-WATCH
GLOBAL SEAGRASS OBSERVING NETWORK

SEAGRASS
ECOSYSTEM SERVICES
PROJECT

IKI SES PROJECT 2023

Report to Edith Cowen University of activities conducted by Seagrass-Watch for the “Conservation of biodiversity, seagrass ecosystems and their services – safeguarding food security and resilience in vulnerable coastal communities in a changing climate”.

Len McKenzie, Rudi Yoshida, & Lucas Langlois

December 2023

SEAGRASS-WATCH

IMAGES

Front cover

Top left (Clockwise):

- *ZSL monitoring Ulugan Bay (© ZSL)*
- *Blue Ventures Timor-Leste, deploying drop camera at Hera (© Blue Ventures)*
- *SAN team with grab on site at Trang sites (© SAN)*
- *SAN team in-situ at Trang sites (© SAN)*

Copyright page

Top left (Clockwise):

- *Yapeka at Northern Minahasa sites (© Yapeka)*
- *Thalassodendron ciliatum Hera (© BV)*
- *ZSL Van veen grab deployment Ulugan Bay (© ZSL)*
- *SAN team in-situ at Trang sites (© SAN)*
- *Tablet with Field ID sheets (© SAN)*
- *BV mapping seagrass at Hera (© Alex Bartlett)*

The IKI Project is a partnership between the CMS Dugong MoU, Edith Cowan University, Project Seagrass, Seagrass-Watch Ltd, Murdoch University, Marine Research Foundation, Blue Ventures, Save Andaman Network, Community Centred Conservation Philippines, Zoological Society of London CMRP Philippines, MareCet and Yapeka. This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

The collaboration enhances understanding of seagrass ecosystem services and the capacity to develop and deliver science-based policy solutions in seagrass conservation. It brings together scientists, policy experts, business development experts and conservation NGOs to provide expert and independent advice on seagrass ecosystems services and how these might be relevant to policy and financial solutions to marine conservation issues. This report deals specifically with the mapping and assessment of intertidal and shallow subtidal seagrass meadows, including development of methodological tools and capacity building.

Data: Raw field survey data remains the property of the National Partners (data collectors). The complete data set for the IKI SES Project, seagrass mapping component is available through Creative Commons Attribution 4.0 International (CC BY 4.0) (https://creativecommons.org/licenses/by/4.0/) from Pangaea.de (https://doi.org/TBA) or by request from Seagrass-Watch (admin@seagrasswatch.org).

For bibliographic purposes, this document may be cited as

McKenzie, L.J., Yoshida, R.L. & Langlois, L. (2023). IKI SES Project. Report to Edith Cowen University of activities conducted by Seagrass-Watch for the "Conservation of biodiversity, seagrass ecosystems and their services – safeguarding food security and resilience in vulnerable coastal communities in a changing climate". (Seagrass-Watch HQ, Clifton Beach). 60pp

Enquiries should be directed to:
Seagrass-Watch HQ
PO BOX 4, Clifton Beach, QLD, 4879 Australia.
admin@seagrasswatch.org

SEAGRASS-WATCH

Table of Contents

LIST OF FIGURES

List of Tables

Acronyms & Abbreviations Used In This Report

App .... Application software
GPS .... Global Positioning System
ha .... hectares
HQ .... Head Quarters
km .... kilometre
m .... metre
SE .... Standard Error
SES .... Seagrass Ecosystem Services
WiFi .... Wireless Fidelity

ACKNOWLEDGEMENTS

The Seagrass-Watch team would like to express our deepest appreciation and thanks to all National Partners, who worked and collaborated with us on this project, including Blue Ventures Timor-Leste, YAPEKA (Indonesia), Save the Andaman Network (Thailand), MareCet (Malaysia), Zoological Society of London (Philippines), and Community Centred Conservation (Philippines). We also thank our Technical Partners in the project, including: Project Seagrass, Edith Cowan University (ECU), Blue Ventures, Marine Research Foundation, Murdoch University and James Cook University.

We thank the individuals, National Partners, local groups and NGOs who assisted with field data collections, including: Cecilia Mimi Lay, Ryan Lewis, Patricio Ximenes (Konservasaun Flora no Fauna) Rujinun Palahan, Kanyanat Pengkasit, Onanong Sanitmat, Pathiwat Mueangklang, Chisanupong Juthamat, Thananporn Jitpakdee, Korawan Buadoktoom, Ramita Choongan, Chanyanuch Kongtee, Pontep Wirachwong, Mary Rose C. Lopez , Abdurahjid A. Ibrahim, Ulugan Bay Ecotour Association (Dax Dequito, Mayeth Peralta, Carlo John Bocobo), Akbar A Digdo, Abie Ariyo Dandoro, Citra Septiani, Bonnke Sagai, Joandi Arendege, and Alex Bartlett (Project Seagrass). We thank the Ministry of Marine Affairs and Fisheries Republic of Indonesia for their support.

We thank Donna Kwan, Nicola Piludu and Philippa Loates from the Dugong MOU for their overall project management and guidance prior to 2022.

Finally, we would like to thank Paul Lavery and ECU for their support of the project, contract management and reporting.

The IKI SES Project was managed by the Secretariat of the Memorandum of Understanding on the Conservation and Management of Dugongs and their Habitats throughout their Range of the Convention on the Conservation of Migratory Species of Wild Animals (CMS Dugong MoU).

This project is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

EXECUTIVE SUMMARY

Background:

Coastal communities throughout south east Asia have expressed interest in assessing seagrass areas, to provide an evidence-base for conservation measures of seagrass resources, particularly in relation to critical habitat for dugong and ecosystem services. Information on seagrass distribution and condition is a necessary prerequisite to managing this critically important ecosystem. To make informed decisions, coastal managers need information on the characteristics of seagrass ecosystems, such as where species of seagrasses occur and in what proportions and quantities, and whether damaged meadows can be repaired or rehabilitated.

The IKI SES Project was tasked with putting seagrass on the global conservation agenda, by using participatory approaches to provide site-specific seagrass assessment, policy and management recommendations, business models, and communication strategies, to promote local engagement and investment in conserving seagrass meadows.

Project goals and approach:

The overall project goal was to improve conservation of seagrass meadows and the biodiversity they support in Indonesia, Malaysia, the Philippines, Thailand, and Timor-Leste. In support of this goal, the project outcome was focused on integrating seagrass ecosystem services into policy frameworks and business models in selected sites within these five target countries.

The project took a tailored, integrated, site based, ecosystems approach to conservation. National Partners and Technical Partners worked together to developed an integrated research programme that addressed the goals of the project, that were implemented in each of the project sites. The programme used community-participatory methodological tools to collect quantitative data on extent and condition of seagrass meadows at all five project sites. Using globally standardised protocols ensured all data collected will be publicly available and shared with national and global open-access databanks.

Results & key findings:

A suite of community-participatory methodological tools for seagrass assessment were modified and/or developed using new and emerging technologies. The methodological tools included booklets and field guides which detailed the collection of quantitative data seagrass on seagrass condition using subtidal and Intertidal spot checks. To encourage participation by a wider constituency of participants, to supplement the quantitative mapping, Project Seagrass updated and tailored the online app Seagrass Spotter to the project sites.

Due to COVID-19 travel restrictions from 2020 to 2022, a compendium of training materials was developed in lieu of onsite in-country training workshops. The series of instructional training videos for mapping seagrass provided easy to follow step by step instructions on how quantitative data can be collected at field validation points in a variety of habitats (intertidal and subtidal). On-site visits by Project Seagrass provided opportunities to demonstrate the tools and answer and questions. Training videos were also developed for intertidal seagrass monitoring, as the planned training workshops scheduled in 2023 could not be undertaken within the timeframe of the project due to administrative issues with the IKI SES Project management team (CMS Dugong MOU).

The capacity of National Partners and local groups (e.g., NGOs, fishers) to contribute to the collection of globally standardised seagrass assessment data was built at all project sites. Four project sites completed the collection of field validation (survey) data, necessary for the creation of maps within their specific areas of interest, within the project period.

The mapping approach agreed and implemented with the National Partners was Earth Observing from Space, coupled with on-site Near Earth and direct *in situ* Observing. In the field, observers walked or used drop-cameras to collect photoquadrats at mapping points, which were positioned using a restricted random sampling design. Spatially explicit seagrass maps were created from

PlanetScope Dove (3.7 m × 3.7 m pixel) imagery, using the field validation point data and a machine-learning model (random forest).

Within Hera bay (Timor-Leste), 247.7 ha of seagrass was mapped between the 30 November 2022 and 08 March 2023. Seagrass abundance was 36.9 ±2.1 % cover on average, and the area of seagrass was a mosaic of 9 seagrass community types located on fringing reef habitats. Ten seagrass species were identified and the meadows were primarily enduring in nature and dominated by *Enhalus acoroides* and *Thalassia hemprichii*.

Around Northern Minahasa, North Sulawesi (Indonesia), 242.3 ha of seagrass was mapped between 18 January and 26 June 2023. Seagrass abundance was 30.3 ±1.2 % cover on average, and the area of seagrass was a mosaic of 7 seagrass community types located on fringing reef habitats. Nine seagrass species were identified and the meadows were primarily enduring in nature and dominated by *Enhalus acoroides* and *Thalassia hemprichii*.

Within the Trang (Thailand) area of interest, 1,166.2 ha of seagrass was mapped around Koh Libong and Modtanoi between 03 April and 12 May 2023. Seagrass abundance was 15 ±1.2 % cover on average, and the area of seagrass was a mosaic of 7 seagrass community types located on coastal and fringing reef habitats. Nine seagrass species were identified and the meadows were a mix of transitory and enduring in nature. The largest extent was the transitory meadow dominated by the colonising species Halophila ovalis, which were located in the deeper subtidal areas of the turbid waters. The other meadows were primarily enduring and dominated by *Enhalus acoroides* and *Cymodocea rotundata*. Around Koh Mook, 71.7 ha of seagrass was mapped which were mostly *Thalassia hemprichii/Enhalus acoroides* with *Cymodocea rotundata* and *Halophila ovalis* meadows.

Within Ulugan Bay, Palawan (Philippines), 333.2 ha of seagrass was mapped between 13 October 2022 and 19 April 2023. Seagrass abundance was 23.0 ±2.3 % cover on average, and the area of seagrass was a mosaic of 7 seagrass community types located predominately on fringing reef habitats. Ten seagrass species were identified and the meadows were primarily enduring in nature and dominated by *Enhalus acoroides* and *Thalassia hemprichii*.

For each of the four project sites, a map package was created including: a survey spot-checks map/layer of field validation points; an extent map layer of seagrass presence (satellite remote sensing, min and max); a raster/polygon layer of interpolated seagrass abundance (% cover); and a polygon layer of seagrass communities. The maps were made available on open-access Map Viewer and the data are being published on open-access with Pangaea.

The mapping outputs demonstrate how the IKI SES Project successfully implemented a new, collaborative approach bringing together a variety of stakeholders, local NGOs and technical partners to map the extent and health of seagrass meadows using a combination of remote sensing, field validation and machine learning.

The maps and project-derived seagrass ecosystem services knowledge developed in this project has been widely shared with local stakeholders and in scientific and academic communities.

To strengthen the conservation of seagrass ecosystems and the goods and benefits to people's quality of life in the region, a number of broad policies were also recommended.

OBJECTIVES:

1. To modify or develop new methodological tools for seagrass data collection across the project sites
2. To build the capacity of National Partners to collect data using community-participatory methodological tools on status of and threats to seagrass meadows
3. Create maps and databases of seagrass extent and condition suitable for key seagrass ecosystem services assessment and valuation
4 Contribute to developing policy recommendations
5. Contribute as requested to business readiness trainings for community members
6. Assist to promote widely seagrass ecosystems, key seagrass ecosystem services, and dependent biodiversity among decision-makers, businesses, local communities and academia.

INTRODUCTION & BACKGROUND

Seagrass ecosystems

Seagrass has critical importance for peoples in the Indo-Pacific region, who rely on seagrass ecosystems to nurture the marine life on which coastal residents depend for livelihoods and food security (commercial and subsistence fishing). Seagrass ecosystems provide goods and benefits (aka services) critical for environmental protection/carbon sequestration, human food security, biodiversity protection, and fisheries production. Seagrass also protects marine and coastal health by filtering sediments, nutrients, and pollutants and providing a buffer against extreme weather events. Indo-Pacific seagrass areas are global hotspots for biodiversity, harbouring multiple species of ecological and cultural value, including globally important populations of dugongs and sea turtles. Seagrass also serves a key role in climate change mitigation, sequestering twice as much carbon per hectare as terrestrial forests [1].

Although seagrass are recognised as one of the most productive of the Earth's ecosystems, widespread and accelerating losses currently place seagrass ecosystems among the most threatened[2]. Seagrass are most abundant in coastal regions where available nutrients, light and suitable habitable substrate meet growth requirements. It is also these coastal areas where seagrass globally are exposed to the impacts from the billion or more people who live within 50 km of them[3]. These impacts have all led to a rapid loss of seagrass ecosystems, at a rate of around 1.5% of seagrass area per year globally[2]. These losses are likely a consequence of seagrass ecosystems often being marginalised throughout the policy and management landscape.

Information on seagrass distribution and condition is a necessary prerequisite to managing this critically important ecosystem. To make informed decisions, coastal managers need information on the characteristics of seagrass ecosystems, such as where species of seagrasses occur and in what proportions and quantities, and whether damaged meadows can be repaired or rehabilitated. Additionally, coastal managers may also need to know where seagrasses might have occurred for the purposes of recovery, restoration and to allow for natural spatial dynamics. Knowledge of the extent of natural changes in seagrass meadows is also important so that human impacts can be separated from normal background variation[4]. With seagrasses largely unmonitored and unmanaged, major seagrass losses in the region are driven primarily by coastal and port development, agricultural and industrial runoff, and destructive fishing practices such as trawling and blasting (Grech et al. 2012). Estimated seagrass loss is 30-40% in Indonesia (Fortes and McManus 1994), 30-50% in the Philippines (Short and Wyllie-Echeverria 1996), and 20-30% in Thailand (Shepherd et al. 1989). No estimates are available for Malaysia or Timor-Leste.

Also, the value of seagrass ecosystem services is not reflected in Indo-Pacific management practices or in local decision-making concerning coastal and upstream activities. Economic valuations of seagrass have typically focused on isolated aspects of seagrass ecosystem services, and have ranged from USD 394 per hectare for carbon sequestration to as high as USD 140,752 ha^{-1} for nutrient cycling and USD 684,000 ha^{-1} for food production (Dewsbury et al. 2016). In contrast to specific national targets for forest coverage and prioritisation given to REDD+ policies in the region, no country has set a measurable goal for seagrass protection. Indeed, there is no national data by which to benchmark such targets for seagrasses.

The IKI SES Project

Through the support of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMU), International Climate Initiative (IKI), the project "*Conservation of biodiversity, seagrass ecosystems and their services – safeguarding food security and resilience in vulnerable coastal communities in a changing climate*" (IKI SES Project) was tasked with putting seagrass on the global conservation agenda, while at the same time, trying to reduce reliance of local community groups/NGOs on donors/funding proposals to fund conservation, by developing business models that will provide an ongoing and sustainable funding source for seagrass conservation.

The overall project goal is to improve conservation of seagrass meadows and the biodiversity they support in Indonesia, Malaysia, the Philippines, Thailand, and Timor-Leste. In support of this goal, the project outcome is focused on integrating seagrass ecosystem services into policy frameworks and business models in selected sites within these five target countries. While specific policy recommendations and business model adaptations will be tailored to the selected sites, the project goals and expected results are consistent across all five countries: by using participatory approaches to provide site-specific seagrass assessment, policy and management recommendations, business models, and communication strategies, the project will promote local engagement and investment in conserving seagrass meadows.

The project is grounded in a) innovative models of conservation that sustain seagrass health while reducing the vulnerability of coastal communities, b) the development of economic arguments and engagement strategies that resonate with policy- and decision-makers, and c) acknowledging the central role that local communities must have in seagrass conservation and monitoring, as they are disproportionately reliant on and unique beneficiaries of these habitats and ecosystem services.

In the target countries of this project, poverty is the primary barrier to achieving environmental protection goals. Regardless of policies set at the national level, at the implementation level (within localities) income-producing activities (e.g. destructive fishing practices) and cost-cutting strategies (e.g. dumping untreated waste) take precedence over long-term conservation. Closely associated with poverty is the lack of institutional capacity and resources to enforce environmental protection.

Environmental management cannot succeed in these contexts without local buy-in. This project departs from the conventional focus on top-down policy development to instead centre on the needs of communities by (a) addressing local requirements for seagrass data through locally adapted and appropriate tools to assess and communicate seagrass status, threats, and seagrass ecosystem services; (b) closing capacity gaps in seagrass data collection and analysis; and (c) developing locally specific business models that meet income requirements while promoting seagrass health.

The project is broken down into seven Work Packages (Table 1). The project takes a tailored, integrated, site based, ecosystems approach to conservation. National Partners and Technical Partners will work together to developed an integrated research programme that addresses the goals of the project, that will be implemented in each of the project sites. The research programme will essentially be the same for each site, i.e. everyone is doing the same, standardised research/monitoring activities. All data collected will be publicly available on request and will be shared with national and global open-access databanks.

Table 1. *IKI SES Project work packages*

Work Package	Summary
WP1: Methodological Tool Development and Deployment	Community-participatory tools for seagrass and dugong data collection and monitoring developed and deployed at each of the project sites.
WP2: Key seagrass ecosystem services assessment and valuation	Key seagrass ecosystem services are identified, assessed and valued at each of the project sites.
WP3: Stakeholder/policy needs assessment	Stakeholder and policy needs assessment conducted at each project site, targets for key seagrass ecosystem services identified, policy priorities identified.
WP4: Integration	Capacity building for stakeholders to use seagrass ecosystem service assessment and valuation. Policy recommendations for integration of seagrass into management developed and presented to oversight bodies (governments etc.).
WP5: Business modelling	Business models (e.g., ecotourism, aquaculture, aquaponics) that integrate seagrass ecosystem services developed and adapted to the conditions at each project site. Community capacity built to implement business models. Mechanisms for reinvestment of funds into seagrass conservation put in place with community partners.
WP6: Communication	Seagrasses, their ecosystem services, and dugongs widely promoted among target audiences; including through participatory media (using photos or videos to tell a story), social media etc. A project website established, scientific articles produced, and the project promoted at relevant meetings and conferences.
WP7: Project Coordination	The project will be coordinated by a team of three people based in Abu Dhabi. A pre-planning workshop to be conducted prior to the Inception Workshop. Annual Coordination Meetings will follow in 2020, 2021 and 2022. National Planning Meetings will take place at each site after the Inception Meeting.

Integrated with the research components of the project, is the development of business models that safeguard seagrass ecosystem services and are relevant to each project site. Communities will be invited to participate in the business models, including receiving training, provided that they agree that a proportion of the money made by the businesses is reinvested into seagrass conservation – this should fund the ongoing conservation, management, monitoring and assessment activities at each site.

Seagrass-Watch, as a key Technical Partner in the IKI SES project, was subcontracted by ECU (project Implementing Partner) to undertake the following major tasks/activities in consultation with the National Partners:

- Modify or develop new methodological tools for seagrass data collection and monitoring for use across the project (activities WP1-1, WP1-2)
- Collect data using community-participatory methodological tools on status of and threats to seagrass meadows at all five project sites (activity WP1-4)
- Provide maps and databases of seagrass extent and condition suitable for key seagrass ecosystem services assessment and valuation in all five project sites (activity WP2-1)
- Assist with Stakeholder/Policy Needs Assessment at each of the five project sites to underpin and inform the integration of key seagrass ecosystem services guidelines and recommendations into sectoral policies (WP3)
- Assist with policy recommendations for relevant policymakers for all five sites (activity WP4)
- Assist with conceptualisation of seagrass ecosystem services business models for each site (WP5)
- Promote widely seagrass ecosystems, key seagrass ecosystem services, and dependent biodiversity widely among decision-makers, businesses, local communities and academia (activity WP6-2).

METHODOLOGY

Methodological Tool deployment / training

Traditional seagrass field mapping protocols were modified and supplemented with new protocols to enable collection of high resolution field data/imagery (coupled with higher positional accuracy). The geospatial imagery/data was, to enable the training of machine-learning models to create spatially explicit seagrass maps from PlanetScope Dove (3.7 m × 3.7 m pixel) imagery. The protocols included several field validation data collection options, based around photoquadrats, *in situ* observations and/or grab sampling.

Georeferenced/geotagged photoquadrats are digital nadir photographs of a standardised area of the benthos. Photographs are classified as Nadir when the camera axis points directly downwards and the point on the benthos is vertically beneath the perspective centre of the camera lens. The standardised area of benthos can be contained within a quadrat (e.g. 0.25m^2) or from a height above the substrate which results in a fixed field of view (e.g. 0.25m^2 or 1m^2). Photoquadrats can be collected on foot (benthos exposed or in clear water <1m depth), by snorkelling (to a water depth of 3m) or by using a drop camera (1m-25m) (Figure 1Figure 1).

Geotagged photoquadrats are captured using photographic equipment with geopositioning capabilities, where the geospatial position on the earth surface/seabed is recorded within the image metadata. Alternatively, a photoquadrat is georeferenced by recording the geospatial position using a portable Geographic Positioning System (GPS) unit. When collecting photoquadrats subtidally by snorkelling, the position is recorded by a GPS floating on the water surface directly above. In deeper waters, the position is recorded by a GPS on-board the vessel from which the camera was deployed; where the vessel is positioned on the surface as close as possible to be directly above the camera.

The modified and newly developed protocols enabled individuals with limited experience in seagrass field data collection, with limited capacity (including funds), to collected quality field validation data for mapping and/or condition assessments. These protocols enabled the collection of the Global Ocean Observing System's (GOOS) Essential Ocean Variables (EOV) for seagrass cover and composition, and are globally standardised [5].

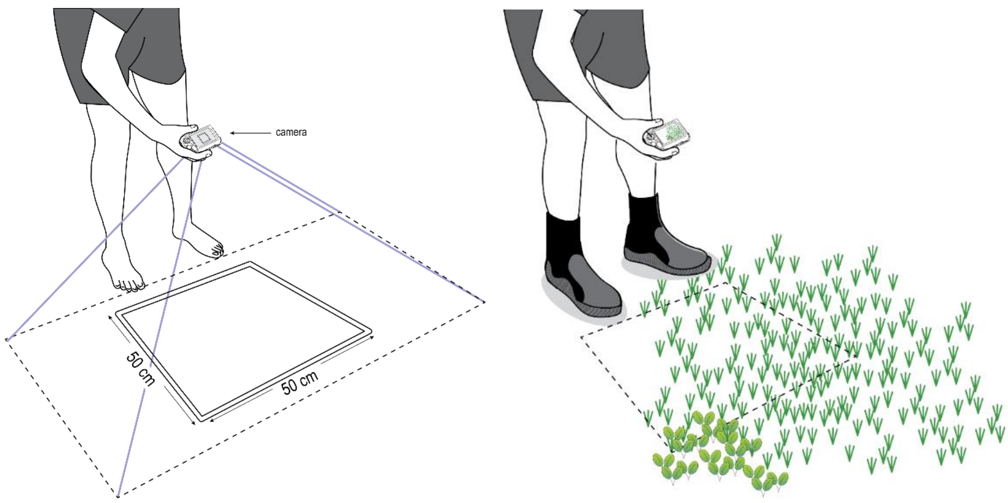


Figure 1. *Illustration showing how to collect photoquadrat in the field using approximated height when 0.25m^2 quadrat absent.*

Photoquadrats and *in situ* observations and/or grab samples can be collected at predetermined points within the Area of Interest (AOI), after consultation with the field teams. Collection was either using spot-checks or photo-transects.

Spot-checks are where the field validation is conducted at a specific point in the AOI and observations of benthic variables are measured *in situ* or *post hoc*. The point can be predetermined in the planning phase of the survey strategy or *ad hoc* (when necessary or needed). The size (radius) of the point where the spot-check is conducted is generally the positional accuracy of the geolocation device (e.g. 1-3m). Field measures can be collected using photoquadrats, quadrat observations or sampler observations. Spot-checks can be conducted: in person by foot, diving (free or SCUBA), or helicopter/hovercraft; remotely using drop camera, ROV; or via a sampler, such as a grab, rake, sled.

Photo-transects are where field observations are collected using photoquadrats by foot when the area to be surveyed is exposed during low spring tides, or the water is very shallow (<0.5m depth), sea state smooth and water clear. In clear waters greater than 0.5m depth, photo-transects can be conducted on snorkel (0.5-3m water depth) or SCUBA (>3-5m water depth), when conditions are safe for in-water activities. The technique for conducting photo-transects on snorkel and SCUBA are widely used for the purpose of calibrating or validating coral reef maps derived from satellite data as part of the Allen Coral Atlas (ACA). Each photoquadrat captures a $0.25m^2$ area of the benthos, every 2-3 meters along 100+m long transects positioned in transitional zones to capture the full range of benthic types (e.g. bare substrate to sparse seagrass to dense seagrass to algae to reef). Photo-transect locations are chosen based on expert interpretation of high or spaceborne imagery to determine best placement to ensure coverage of the variety of benthic cover types to provide the most benefit for the mapping calibration / validation. The direction and length of the transects ensure that the photos capture the variance in the benthic composition. Transects are often perpendicular to the perceived meadow boundary. The transect locations are generally pre-planned on available imagery as waypoints of either end of the transect that can be uploaded to a handheld GPS unit for the field.

Seagrass mapping

Areas of Interest

For each of the participating countries, National Partners first identified the Area of Interest (AOI) in which to conduct mapping activities; based on the question being addressed, the groups capacity and access to suitable vessels. In most instances, the AOI was also restricted to waters shallower than 15m water depth. Once the extent of the AOI was identified (as this determined the scale of the mapping exercise) (Table 2), a sampling design for field data collection was prepared. In preparation for the sampling design, all available seagrass spatial data was first collated for each of the AOI via extensive literature and database searches.

Table 2. *Project sites and Area of Interest (AOI) size to be mapped.*

Country	**National Partner**	**Location/Site AOI**	**Size of AOI** (ha)
Timor-Leste	Blue Ventures	Hera bay	600
Indonesia	Yapeka	Northern Minahasa	1,500
Thailand	Save the Andaman Network (SAN)	Koh Libong + Koh Mook, Trang	5,500
Malaysia	MareCet	Mersing Bay + Pulau Setindan	500
Philippines	Zoological Society of London CMRP Philippines, Inc.	Ulugan Bay, Palawan	4,000
Philippines	Community Centred Conservation (C3) Philippines	Green Island Bay + Roxas, Palawan	3,500

Hera bay, Timor-Leste

Located 15 km east of the capital Dili on the north-eastern coast of Timor-Leste, Hera bay (aka Bucht von Hera) is a sheltered embayment with large fringing reef habitats and a coast fringed by sandy beaches and 37 ha of mangroves. In the central part of the bay is a seaport facility with significant infrastructure and associated development (e.g. Naval Base, Hera Generating Station and Oil Terminal), vital to allow Timor-Leste to import critical goods and equipment to bolster its economy. Proposed development in the region includes an industrial estate at the port and expansion of the Eastern Tourist Zone, which is expected to extend from Tutuala along the coastal road to Hera, providing coastal eco-tourist accommodation options that will also act as staging points for local scuba diving trips, fishing and whale watching.

No large rivers discharge into the bay of Hera, however, a number of small creeks and associated watersheds (catchments) drain urban and agricultural areas which support a population of at least 8,853 people [6]. The north coast is generally rocky and steep, and arid woodlands tend to be the dominant vegetation type. Coastal fringing and large elongate patch reefs dominate the northern coast, which are characterized by karst geology and uplifted ancient coral reefs [7, 8], which results in reefs with a narrow reef flat (<1000 m) and a steep drop-off (40-60 m depth). The waters on the north are generally deep and calm, with good clarity except during the wet season when pulses of sediment laden floodwater bathe the nearshore areas.

The climate is tropical with two distinct dry and wet seasons annually, driven by the annual movement of the inter-tropical convergence zone - the South-east and North-west monsoons. The northwest monsoon during the wet season typically extends from October-November to February-March and the southeast monsoon during the dry season from May to October, with a transition period of 1–2 months between seasons characterized by variable and lower winds. Timor-Leste is only occasionally affected by major tropical storms. The northern coast is generally dry, receiving only about 1,000 mm annually; a consequence of the distinct mountainous spine which runs along the country from west to east, causing most rain to fall on the southern coasts. Water temperatures around Timor-Leste range from 26.1°C in the cooler months (July/August) to 31.9°C in the summer (December – February), with temperatures one to several degrees cooler along the north coast [9]. Timor-Leste has mixed tides with prevailing semidiurnal tides and a maximum tidal range of 2.47m on the north coast.

Mapping of seagrass meadows within Timor Leste comes only from broad-scale, predominately remote assessments, conducted over the last fifteen or so years. The first broad-scale mapping of Timor Leste nearshore habitats was undertaken in 2007 along the northern coast, using Landsat TM/ETM+ imagery (captured between 2003 and 2006) and field assessments at a limited number of locations (19-30 November 2007) [10]. In 2012, broad-scale assessments using Landsat satellite imagery completed the 2007 survey for areas originally [11], providing an estimate of the overall area of seagrass habitat in Timor Leste to be approximately 4,266 ha. Over the next five to six years, seagrass assessments on the north coast were generally incidental to coral reef assessments, only collecting point data and excluded the bay of Hera [12, 13]. Recent (2017 - 2020) broad-scale mapping of coral reefs for the *Allen Coral Atlas* project estimated 13.95 km^2 of seagrass area for Timor-Leste and 156.7 ha within the bay of Hera AOI [14].

The AOI for the mapping exercise included all fringing reef habitats from shore to approx 10m depth, from Ponta Séri Tútun in the east to Ponta Hatomanulaho in the west. The field validation assessments would be conducted primarily from a vessel using a drop-camera assembly, as throughout the bay are strong currents and the presence of crocodiles.

Ulugan Bay (Palawan), Philippines

Due to logistical and financial constraints, the National Partner decided to only focus on Ulugan Bay. Ulugan Bay is a tropical marine embayment coving approximately 71 km^2, located on the western coast of Palawan, slightly north of the island's geographical centre. The southern tip of Ulugan Bay marks the narrowest point of Palawan island. The area around the bay is flat, consisting of alluvial material, sandstone and shale. The coastal plain does not extend more than a few kilometres inland before rising steeply to form a rugged hinterland. In the lowland areas, the forest cover has been largely cleared for agriculture and settlement; however, the mid to upper slopes still retain extensive areas of secondary and primary forest. The bay has a siltation gradient due to the 11 relatively small rivers draining from its catchment area [15]. In the deeper sections of the bay (Umalagan and Oyster Bay) which are not regularly exposed to strong wave action substrates are muddier and siltier. In contrast, Tarunayan, Buenavista and Manaburi are located in exposed areas. Five rural communities (barangays) border Ulugan Bay. Fishing is the main livelihood of the approximately 6,000 inhabitants of the bay; agriculture comes a close second. In the mangrove areas, fisher folk harvest the abundant shrimps, crabs, oysters and other shellfish, while the coral reefs and deeper waters are home to a wide range of commercially valuable fish species.

Extensive areas of seagrass are reported within Ulugan Bay and through a combination of remotely sensed imagery and ground truth surveys, it has been estimated as 11 km^2 [16]. During 1997–1998, seagrass meadows along with coral reefs, mangroves, fish, seaweeds and water quality were assessed at 13 sites across the bay [15]. Eight seagrass species were reported: *Cymodocea rotundata, Cymodocea serrulata, Enhalus acoroides, Halophila ovalis, Halodule pinifolia, Halodule uninervis, Syringodium isoetifolium* and *Thalassia hemprichii*. The highest overall density was recorded for *Halodule pinifolia* at Buenavista, with 876 shoots m^2. The most dominant species was *Enhalus acoroides* followed by *Halodule uninervis*, and *Cymodocea serrulata*.

In the late 1990s, the University of the Philippines conducted a number of studies at six seagrass sites within Ulugan Bay [16, 17]. Seven seagrass species were found in the Bay throughout the study period. *Enhalus acoroides* markedly dominated the sites, and there were no significant changes in the composition of the seagrass from February 1999 to March 2000 [17]. Abundance and flowering was generally higher during February/March, with lower abundances reported in October/November. Six of the seven species showed distribution patterns that appeared to be dictated both by site conditions and periods of the year. Hence, *Cymodocea rotundata* appeared to favour the summer months at the more exposed, coralline sites of Rita-Manaburi and Tarunayan. However, it showed no temporal variability in Buenavista, occurring throughout the entire period of the study, and with remarkably consistently high abundances. The distribution of the seagrass species throughout the Bay follows a pattern wherein more protected sites had fewer species, but greater abundances. On the other hand, those from more exposed sites had more species, but their abundances were much lower. The seagrass communities in Ulugan Bay have therefore been categorized as either *Enhalus acoroides* dominated characterized by a silty, muddy substrate or highly diverse seagrass in the wave-exposed areas [16].

In April/May 2005, an extensive survey of Puerto Princesa examined 4 coastal stations in Ulugan Bay to select areas of interest for the Palawan Biosphere Reserve Environmentally Critical Areas Network (ECAN) [18]. Eight species were reported within the bay, with the greatest diversity at Buenavista. Average cover of seagrass at stations in the bay varied between 6 - 34% [18]. The survey noted seagrass areas that may be threatened due to heavy siltation coming from both land effluents and riverine discharge, included stations within the southern reaches of the bay, e.g. Bahile, and Buenavista. Recent (2017 - 2020) broad-scale mapping of coral reefs for the *Allen Coral Atlas* project estimated 203.9 ha of seagrass within the Ulugan Bay AOI (excluding Oyster Bay) [14].

Palawan climate is characterized by a pronounced wet and dry season: heavy rainfall occurs from May to October (the wettest month with 271 mm rainfall) during the southwest monsoon, but the weather turns increasingly dry afterwards and there is usually little or no rain from January to April (the driest month with 95mm). High temperatures year round range between 29°C and 31°C, and May is the hottest month. The coolest month is February with an average maximum temperature of 29°C. The frequency of tropical cyclones hitting Ulugan Bay (Puerto Princesa) is low, however, Super Typhoon Rai (Odette) hit the region on December 2021, causing severe damage. The recommended time to conduct field assessments is February to April when the weather is drier and calmer and likely during the main growing season for seagrass.

The AOI for the mapping exercise included all shallow water (<15m depth) and reef habitats within the bay from Northwest Head to Broken Head in the north east, with the exception of Oyster Bay which is a Naval base. The field validation assessments would be conducted primarily from a vessel using a drop-camera assembly.

Roxas (Palawan), Philippines

The coastal Municipality of Roxas is located on the north-eastern coast of the island province of Palawan. Its population as determined by the 2020 Census was 69,624[19]. The coast of Roxas runs along Green Island Bay, which includes several islands and faces the Sulu Sea. The National Partner identified the northern section of Green Island Bay as the AOI for the seagrass mapping exercise, included all intertidal and subtidal areas from Tumarbong in the north to Roxas Port in the south.

Extensive areas of intertidal seagrass, next to mangroves and riverine habitats, have been reported within northern Green Island Bay. Broadscale maps of coastal seagrass extent from 1950 and 2013/2016 are available (Figure 2), however, these maps are incomplete, providing limited data on the extensive meadows surrounding the bay's islands (e.g. Green Island) or the subtidal meadows within the bay.

From March to June 2004, rapid surveys along transects were conducted on seagrass habitats around the islands in Green Island Bay and along the 18 km coastline of Roxas (Palawan) [20]. The meadows were narrow (<100 m) to moderately extensive (200 m), and average percentage cover was 32 ± 1%. Ten seagrass species were encountered in the Bay and mixes of three to nine species typically occurred. *Halodule uninervis* was the most common species along with *Enhalus acoroides*, followed by *Thalassia hemprichii, Cymodocea rotundata*, and *Halophila ovalis*. Other species included *Cymodocea serrulata, Halodule pinifolia, Halophila minor, Halophila spinulosa* and *Syringodium isoetifolium* [20]. Recent (2017 - 2020) broad-scale mapping of coral reefs for the *Allen Coral Atlas* project estimated 219.6 ha of seagrass area within the Green Island Bay, Roxa, AOI [14].

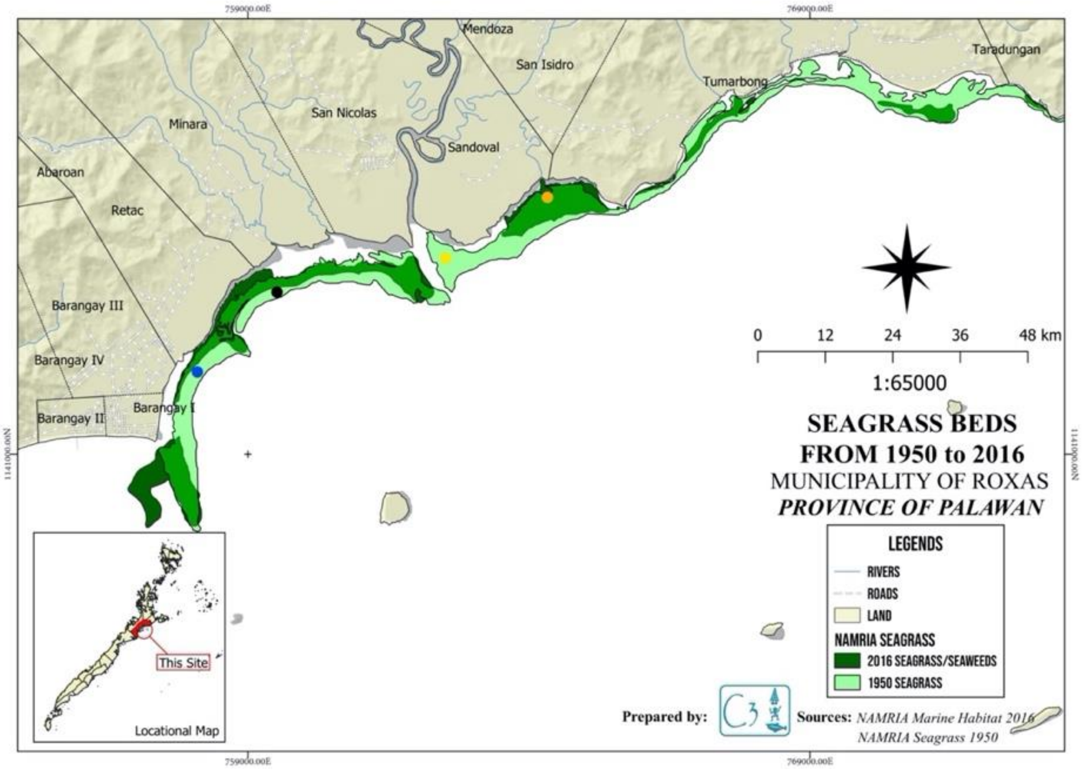


Figure 2. *Historic maps of seagrass meadows within northern Green Island Bay, Roxas, Palawan (courtesy C3 Philippines).*

Of concern has been the reported losses of seagrass in Palawan and Green Island Bay, attributed to siltation and sedimentation from deforestation, fishing and boating activities, and increased urban development in coastal areas which contributes to eutrophication, organic loading, and substrate damage through reclamation and dredging activities. In 2007, the seagrass meadows of Caramay and Johnson Island were incorporated within the marine protected areas of the Bay and formally recognized through a municipal ordinance.

The climate is tropical affected by monsoon winds. In the months of June to October the monsoon brings rain, whereas December to May are drier and hotter. Annual rainfall is 1,734 mm on average and October is the wettest month, while February is the driest. Temperatures range between 22°C and 31°C, and April is generally the hottest month.

The field validation assessments would be conducted primarily from a vessel using a drop-camera assembly, but supplemented with snorkel and foot *in situ* observations in shallow and intertidal areas (tides permitting).

Koh Libong (Trang), Thailand

Koh Libong lies along the southern Andaman coast of Thailand, in Trang province, just above the border with Malaysia. The adjacent mainland coast (Mod Ta Noi) is a stretch of rugged limestone cliffs and mangrove-lined beaches. The largest river is Trang River, which drains a narrow basin and floods between October and December each year, discharging into the Andaman Sea immediately adjacent to Koh Libong.

The region is tropical and seasons are divided based on occurrence of the Southwest monsoon (mid-May to mid-October,) with a rainy season (May–October) and summer (November–April) [21]. Trang has high temperatures year round ranging between 31°C and 34°C, with March being the hottest month and December the coolest. October is generally the wettest month (341mm of rain on average), while February is the driest month (43mm). December to April is the period of greatest sunshine. Tides are semidiurnal and at Koh Libong range from 0 to 3 m.

Trang Province has about 21,493 hectares of seagrass meadows, the largest area of seagrass in Thailand. In addition, Trang seagrass meadows are well known for supporting the largest dugong habitat in Thailand. The majority of meadows are dominated by *Enhalus acoroides* and *Halophila ovalis*. Some of the largest seagrass areas in the province are located around Koh Libong (12,200 ha, followed by Koh Mook nearby with 6,724 ha) and mostly found intertidally, with a small area in shallow subtidal waters [22]. Eleven seagrass species have been reported around Koh Libong and along the adjacent mainland (*Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halodule pinifolia*, *Halodule uninervis*, *Halophila beccarii, Halophila decipiens, Halophila major, Halophila ovalis*, *Syringodium isoetifolium* and *Thalassia hemprichii)* [23, 24]*. E. acoroides, C. serrulata, C. rotundata*, and *H. ovalis* were often at shallow areas (to a depth of 1.9 m), while only *H. ovalis* was dominant in deep areas (to 2.4 m) [23].

Seagrass abundance and extent at Koh Libong and Trang varies seasonally, decreased during the rainy season for most species and a clear seasonal variation is apparent in physical and chemical parameters as well as seagrass species composition, biomass, and reproduction. Water depth and light intensity were the limiting factors that influenced species composition, abundance, and reproduction [24]. A decadal assessment of seagrass extent at Koh Libong and the adjacent coast of Trang, reported a decline from 1999 to 2019 [25]. Temporal changes of the seagrass area were estimated every 5 years using Landsat imagery, reporting 1,012 ha in 1999 and 2004, but declining to 856 ha in 2009, and to 805 ha by 2019 [25]. Losses appear to be mainly of the transitory meadows (*Halophila* and *Halodule* dominated), which covered the greater area, while enduring meadows (of *Enhalus acoroides* and *Thalassia hemprichii*) which covered a much smaller area persisted for 20 years. These losses may be a consequence of a significant increase in the urban population during 1999 and 2004, and associated threats.

Threatening activities to seagrass in the region include destructive fishing (e.g. push nets), coastal development, dredging, nutrient discharge, sediment deposition, coastal erosion, tsunami, and shipping (marine transportation). A major threat is reduced water clarity in many areas, a result upland clearing along rivers and excess sediments and nutrients released in the ecosystem via terrestrial runoff (e.g. floods).

The AOI for the mapping exercise included all shallow subtidal areas and intertidal areas on the eastern shores of Koh Libong across to Modtanoi on the adjacent mainland. The field validation assessments would be conducted primarily from a vessel using a drop-camera assembly.

Pulau Setindan (Mersing), Johor, Malaysia

Pulau Setindan is located in the northern section of the Mersing archipelago, in the state of Johor. It is the focus of local and foreign visitors to Tenglu subdistrict, Mersing district. Positioned only 1.2 km off the coast, P. Setindan is connected to Tanjung Genting village on the mainland by a shallow intertidal bank. P. Setindan is positioned on the eastern portion of a south-east facing embayment (Mersing Bay), providing shelter from the prevailing winds.

Extensive areas of seagrass have been reported within Mersing Bay and surrounding parts of Pulau Setindan [26], however, little mapping of seagrass areas has occurred. Mapping activities in Mersing district have generally focused around the dugong and turtle hotspots of Pulau Sibu [27] and Pulau Tinggi [28]. The only detailed mapping in Mersing Bay to date has been for the now halted Mersing Laguna development EIA, which reported approximately 140.6 ha in 2009-2010 [29]. Seagrass meadows were concentrated on the shallow flats connecting Tg. Genting on the mainland to P. Setindan. Patchy growth was observed and inferred in other areas. A total of seven species were observed during the surveys. The proposed Mersing Laguna covers the vast intertidal sand/mud flats in Mersing Bay, the western side of P. Setindan, along Teluk Papan and Sg. Tenglu. The footprint of the reclamation would have resulted in a loss of 53 ha of Mersing Bay seagrass area. Additionally, dredging would have impacted a further loss of 13% of the seagrass area [29]. With concerns that possible future development may threaten the seagrass habitat for the local Mersing Bay dugong population [30], there is a critical need for more up-to-date maps of seagrass meadows in the area [26].

The region has a tropical climate governed by the monsoon and inter-monsoon seasons. The Northeast monsoon season dominates from November to March and can bring heavy rains and strong northerly winds to the region. The Southwest monsoon season usually lasts from June to early October and is much generally much weaker than the Northeast monsoon. April to May and October to early November are transition periods also known as intermonsoon periods. Annual average rainfall in the area is 2,378 mm. Winds at Mersing can be considered light with a monthly average maximum speed of less than 7 m/s. Pulau Setindan faces the vast South China Sea, thus experiencing the monsoon season with large waves at the end of the year due to the northeasterly winds. The Mersing River (SG. Mersing) is located approximately 4.5km south of P. Setindan near Mersing Town, and during the wet season discharges sediment laden waters from a drainage area of 232 km^2 towards P. Setindan and Mersing Bay. Waters remain warm throughout the year, hovering around 29 to 30°C, although it can drop a few degrees during the monsoon at the end of the year.

The AOI for the mapping exercise included all shallow subtidal areas and intertidal flats connecting Tg. Genting on the mainland to Pulau Setindan, from shore to approx 10m depth. The field validation assessments would be conducted primarily on foot or by UAV in intertidal area and from a vessel using a drop-camera assembly in the subtidal areas.

Northern Minahasa, Indonesia

Located in the core of the coral-triangle, the North Minahasa regency is one of the richest marine ecosystems in the world with its combination of islands, mangroves, seagrass meadows and coral reefs. The AOI identified by the National Partner was in the Likupang Barat district (*kecamatan*), centered around Bahoi village, and extending to Tarabitan in the west and Buluhi in the east.

Eleven seagrass species are reported from North Sulawesi, with nine within the AOI: *Enhalus acoroides, Halophila decipiens Halophila ovalis, Thalassia hemprichii, Cymodocea serrulata, Cymodocea rotundata, Halodule pinifolia, Halodule uninervis,* and *Syringodium isoetifolium* [31-34]. In 2016, seagrass meadows were assessed in the region along field transects from shore to reef edge

(50-250 m long and 200 m apart) between late-April and mid-May 2016 [31]. Approximately 287 ha of medium-dense seagrass was interpolated between transects by using Inverse Distance Weightings. *T. hemprichii* was the most dominant seagrass species followed by *E. acoroides* [31]. Recent (2017 - 2020) broad-scale mapping of coral reefs for the *Allen Coral Atlas* project estimated 246.2 ha of seagrass area within the Northern Minahasa AOI [14].

The district's population was 18,683 in 2022 and spread over 20 villages [35]. The majority of the population makes a living from fishing and farming. In decreasing order of importance, the fishermen fish on coral reefs, the deep sea and to a lesser extent in various habitats like mangroves, seagrass meadows and sand. More than one hundred fish species were reported from seagrass meadows in North-Sulawesi [36]. In general, fishers have basic fishing equipment such as hooks and lines, tide nets (used mainly in seagrass), and fishing arrows for spearfishing. Fishing practices are mostly non-destructive but there are still people with destructive fishing practices such as dynamite fishing and the use of poison.

The climate is tropical affected by monsoon winds. In the months of November to April the West winds bring rain on the north coast, whereas in May to October a dry south wind changes. Annual rainfall is 2128 mm on average and January tops as the wettest month over the long-term. In 2022, however, 3,320 mm was recorded in the district, and November was the wettest month [35]. August is generally the driest and sunniest month, with an average of 65mm of precipitation and 211 hours of sunshine. The region has high temperatures year round ranging between 28°C and 30°C, and September is generally the hottest month while January is the coolest. Water temperature are around 28 - 29°C on average (the warmest months are Apr-May and Nov).

The AOI for the mapping exercise included all fringing reef habitats from shore to approx 15m depth, from Tarabitan in the west to Pulau Tamperong in the east. The field validation assessments would be conducted primarily from a vessel using a drop-camera assembly.

Mapping approach and plans

The mapping approach agreed with the National Partners was Earth Observing from Space, coupled with on-site Near Earth and direct *in situ* Observing [37]. The near earth instrument of choice was a drop-camera (slaved to the surface via a WiFi extension cable) and the direct *in situ* observing would be conducted on foot or snorkel. The near earth and *in situ* observing provided the field validation necessary for the classification/analysis of the satellite acquired imagery.

Field validation within each AOI was conducted at a number of predetermined mapping points. A restricted random sampling design was used to position the mapping points. This ensured good dispersion of mapping points through the entire AOI while incorporating randomization in mapping point placement. A randomized tessellation stratified design was used in which a grid of tessellated hexagons served as the basis for locating the random mapping points. Depending on the strata, the tessellated hexagons varied between 2,500 m^2 and 10 hectares each; which provided flexibility for different sampling intensities, e.g. higher in intertidal (points every 2,500 m^2) and lower in subtidal (points every 10 ha) (Figure 3). Within each tessellated hexagonal cell a single randomly positioned point (set of latitude and longitude coordinates) was located (minimum distance between randomized points was set at 10m). The randomised points within some hexagons were moved slightly to ensure they fell within historically reported seagrass meadows or predicted areas of seagrass (e.g. Allen Coral Atlas [14]).

Figure 3. *Field survey plan for mapping seagrass meadows between Pulau Setindan and the mainland (Mersing, Malaysia), showing 2,500m^2, 1 ha and 5 ha tessellated hexagons with randomised points within each. Smaller hexagons cover the intertidally exposed banks, while the larger are positioned in the deeper turbid waters. Image capture 4th September 2022* [38].

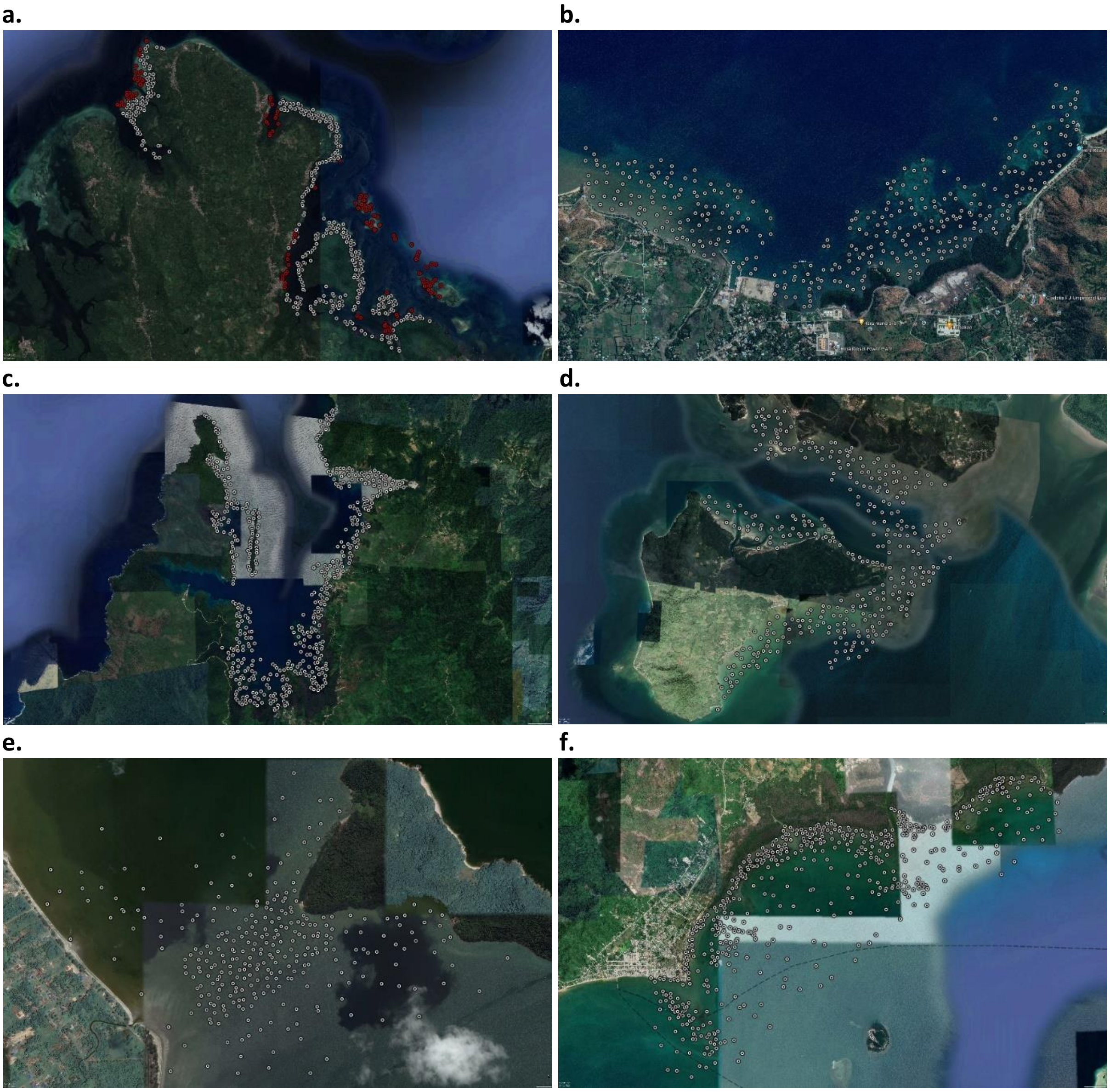


Figure 4. *Field mapping points planned for each AOI: a. Northern Minahasa, Indonesia; b. Hera, Timor-Leste; c. Ulugan Bay, Philippines; d. Trang, Thailand; e. Setindan, Malaysia; f. Roxas, Philippines.*

The field survey plan was developed though an iterative process, where the preliminary and subsequent plans were refined and improved in consultation with the National Partner to ensure the maximum coverage of the AOI within the resources available. Some mapping points were removed as they were positioned in locations where access was prohibited (e.g. military base and/or port), or provided a safety risk (e.g. deep waters, strong currents, distance from shore, *etc*). A very small fraction of the original cells could not be surveyed because they also fell entirely on land.

Once the survey plan was agreed, the optimal time to conduct the field assessment was dependent on environmental conditions (e.g. weather, tides) and the seagrass growing season (if known) at each AOI. In tropical regions, the weather is calmer during inter-monsoon periods. During these periods water clarity is greater and sea state is calmer. Also, the inter-monsoon prior to the rainy season is generally the main seagrass growing season, when both extent and abundance are at their greatest [39]. Tidal stage is also important, as intertidal meadows are more easily assessed during low spring tides, and subtidal meadows during neap tides when there is less water movement. After consultation with the National Partners, the optimal time for the field assessments was identified (Table 3)

Table 3. *Optimal time for conducting field assessments/mapping at project sites.*

Country	Location/Site	Time
Timor-Leste	Hera bay	October-November
Indonesia	Northern Minahasa, North Sulawesi	October
Thailand	Koh Libong + Koh Mook, Trang	February-April
Malaysia	Setindan, Johor Bahru	late May-June
Philippines	Ulugan Bay, Palawan	February-April
Philippines	Roxas, Palawan	February-April

Field data collection

Field surveys were conducted over a period of 1 to 6 months (depending on the National Partner) and followed the sampling design tailored to each AOI. During field validation assessments, the teams navigated to each mapping point using a handheld GPS (with ≤3 m positional accuracy) and collected photoquadrats or *in situ* observations from standardised quadrats (0.25 m^2) (Appendix 1).

A subtidal field validation mapping point was defined as a 10 m radius area around the GPS waypoint, determined by the length of the boat plus the potential error in reaching the precise coordinates. At each mapping point, subtidal seagrass was assessed using a drop-camera assembly which included a GoPro® HERO®8 camera mounted to a frame with a 0.25 m^2 quadrat in the field of view (Appendix 1). The HERO®8 captured professional-quality 4k video and the built-in Wi-Fi enabled live GoPro® image transmission via a high quality coaxial cable (cam-do.com, Figure 5) back to a surface Tablet (mobile operating system) providing real time video monitoring and control of the camera settings. Observers deployed the drop-camera assembly to the seabed, haphazardly raising and lowering the assembly at least three times while drifting 2-3m to collect digital photoquadrat imagery (still and/or video).

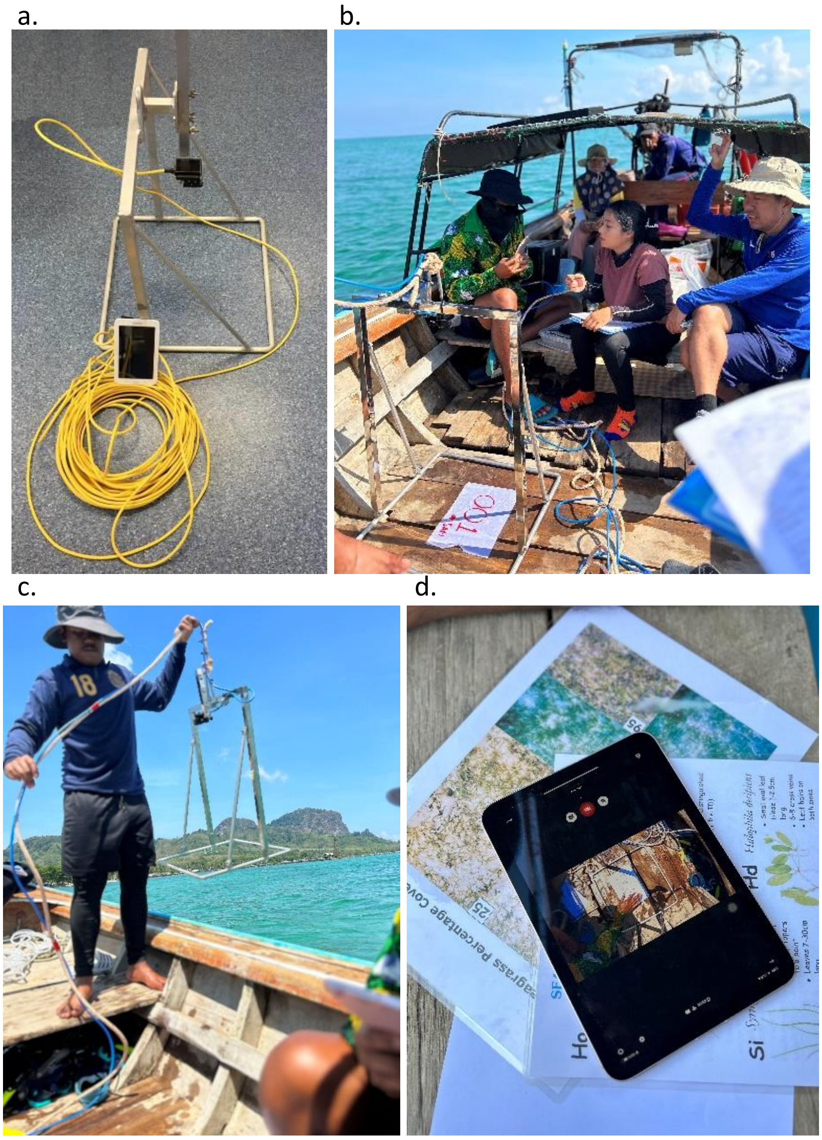


Figure 5. *Drop camera assembly (a) (stock image) and field deployment (b & C). Note GoPro® fixed at correct height to ensure 0.25m^2 quadrat is within field of view and focus, and (d) Tablet with App to control GoPro, view and record footage.*

In conjunction with the visual assessment at each site, a Van Veen grab was used to verify the seagrass species and determine the sediment grain description inferred from the camera (Figure 6, Appendix 1).

An intertidal field validation mapping point was defined as a 1-3 m radius area around the GPS waypoint. Observers walked to collect photoquadrats and/or *in situ* observations from three haphazardly placed quadrats (0.25 m^2). *In situ* observations included visual estimates of above-ground seagrass percent cover, seagrass species and macroalgae percent cover, using globally standardised Seagrass-Watch protocols. Substrate type was assessed at each mapping point by hand using standardised visual/tactile protocols.

All field point details and observations were recorded in the field on standardised waterproof datasheets or with the aid of the open-source mobile data collection platform ODK (https://getodk.org/).

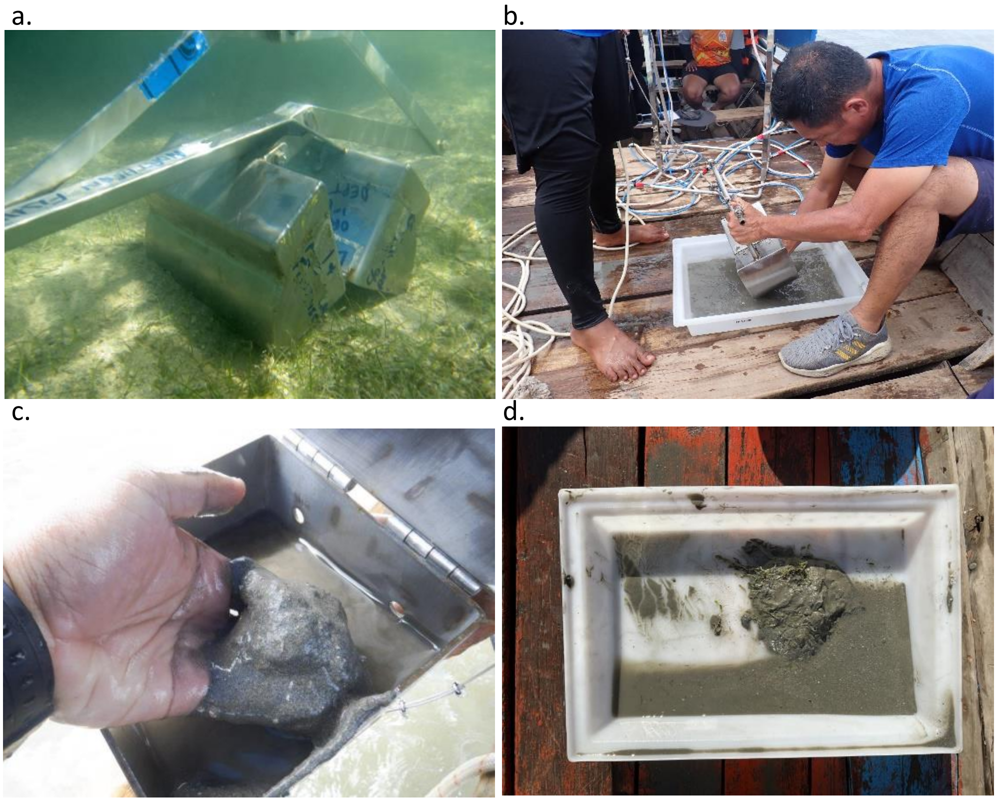


Figure 6. *Van Veen grab, required to check sediment grain size and verify seagrass species: (a) Van Veen grab deployed (stock image); (b) releasing sample from grab; (c) assessing grab sample for grain size; (d) checking seagrass species.* *Images courtesy of SAN and ZSL.*

Data management and post field assessments

Immediately following field assessments, all field data (including video footage, still images, GPS files, scans of datasheets, MS Excel spreadsheets and/or ODK download files) was submitted by the National Partners to Seagrass-Watch HQ via the file hosting service DropBox™.

Data from field datasheets was entered into a relational database (MS Access) and data supplied in MS Excel spreadsheets was imported into the database. All imagery was labelled with the code of the point where collected and then visually assessed by an expert at Seagrass-Watch HQ.

Digital video footage from the subtidal assessments was examined at Seagrass-Watch HQ, and still images (photoquadrats) were captured for each vertical drop of the camera frame to the seabed. Due to the turbid/low light conditions in the field, some post-processing was necessary to enhance image features and improve assessments.

All intertidal and subtidal photoquadrats were visually assessed by a trained and experienced scientist at Seagrass-Watch HQ for seagrass percentage cover, species composition, sediment classification, macroalgae abundance and epiphyte abundance. Data followed standard Seagrass-Watch QAQC and data management protocols (see www.seagrasswatch.org).

Additional mapping point data was accessed from Seagrass Spotter (https://seagrassspotter.org/) where possible. For all sightings with each AOI, images were checked for presence of seagrass and species verified where image was of sufficient quality/resolution, before data was accepted in the relational database.

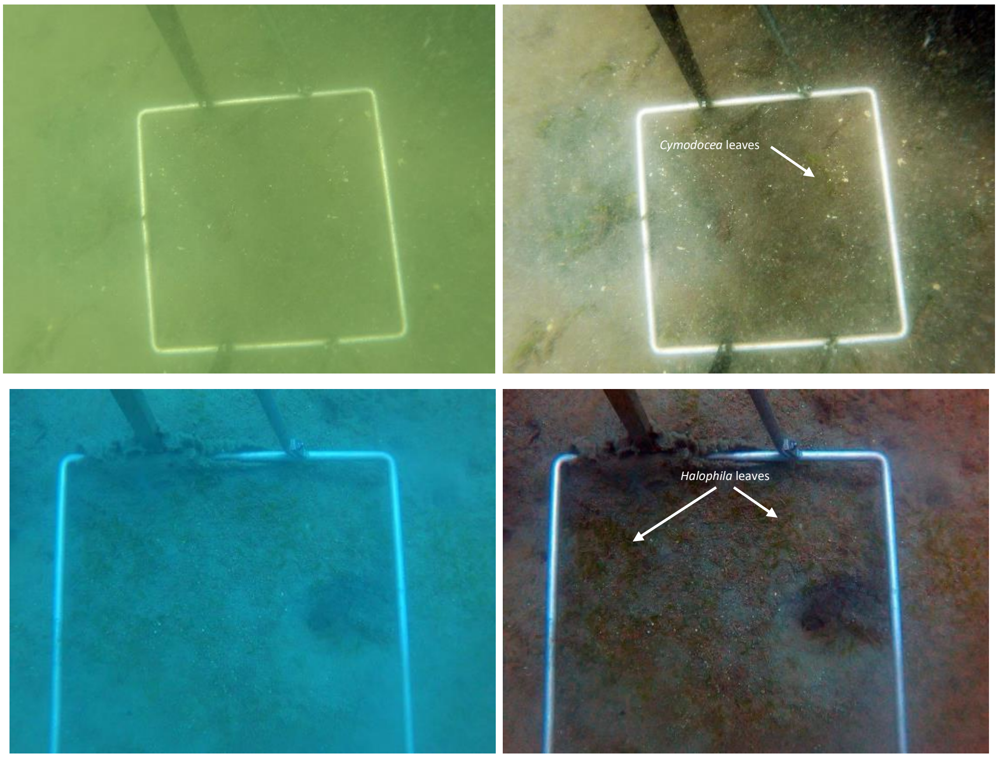


Figure 7. *Example of image captured from Ulugan Bay (Philippines) and Koh Libong (Trang, Thailand) sites pre- and post-processing.*

Satellite imagery (PlanetScope Dove, with 3.7 m × 3.7 m pixels (nadir viewing) with RGB (red, green, blue) and for some sensors also half NIR (near-infrared) [40]) was acquired from the PlanetScope archive [38]. This imagery is captured daily as a result of a constellation of 170+ dove cube satellites. With Blue band 455 nm to 515 nm, green 500 nm to 590 nm, red 590 nm to 670 nm, NIR 780 nm to 860 nm [40]. Imagery was provided orthorectified and radiometrically corrected to surface reflectance (SR) product [40]. We acquired PlanetScope images coinciding as close as possible to the field-surveys.

Map creation

For each AOI, a package of four maps were created, including: a point map of field validation points, a polygon boundary map of seagrass presence/absence, a “heat map” of interpolated seagrass abundance, and a polygon category map of dominant seagrass communities. The maps were provided as layers within the interactive web mapping and data visualization application Map Viewer; the map making tool in ArcGIS™ Online (ESRI®'s web-based mapping software).

Field point validation maps

Point shapefiles to visualize the location of field validation data (e.g. SpotCheck, Seagrass Spotter sighting) within each AOI were created using the positional data (geographic latitude/longitude) from each field point. At each point, seagrass and benthic attributes were aggregated from the photoquadrats (1 to 5) and additional environmental data captured within an area of 10 m radius for each subtidal point and 1-3 m radius for intertidal point. The various attributes (including seagrass percentage cover, species composition, sediment classification, macroalgae abundance and epiphyte abundance) were then aggregated for each mapping point by taking the mean of the numerical fields and most occurring value for the text field.

Seagrass presence/absence

Spatially explicit maps of seagrass within each AOI were created from Planetscope Dove (3.7 m × 3.7 m pixel) imagery (Table 4), and the classification was conducted in R using a machine-learning model (Random Forest) with the caret package [41]. Classified polygons (reference segments) were created by segmenting the image in ArcGIS™ Pro and then manually assigning a label through expert interpretation of the imagery and field data. A 80-20% random split of the reference segments was used to train and validate the model, respectively. The model was trained on individual pixels within the reference segments with a 10-fold cross-validation (mtry=6 and ntree=500). The predictors used in the model were the 8 bands of the Planetscope imagery, the water depth measured during field surveys, the geomorphic zonation from the Allen Coral Atlas [14] and the bathymetry from NOAA [42]. The overall accuracy of the model was 71% to 94% on the test dataset (Table 4). The area of seagrass represented is based on a the model output probability of threshold of 60% and 100%. The raw map output was post-processed in ArcGIS™ Pro (Majority filter and Nibble tools). Manual editing was performed to include areas of seagrass around in situ points where seagrass was present and exclude areas where it was not.

Table 4. *Details of remote sensing models used for each project sites.*

Country	Location/Site	Date of imagery	Model predictors	Model accuracy
Timor-Leste	Hera bay	10/01/23	- 8 bands imagery - Geomorphic Allen Coral atlas - Bathymetry Allen Coral atlas - Bathymetry NOAA	77%
Indonesia	Northern Minahasa, North Sulawesi	11/08/23	- 8 bands imagery - Geomorphic Allen Coral atlas - Benthic Allen Coral atlas - Bathymetry Allen Coral atlas	90%
Thailand	Koh Libong / Koh Muk	29/03/23	- 4 bands imagery	71% / 94%
Philippines	Ulugan Bay, Palawan	10/09/23	- 8 bands imagery - Geomorphic Allen Coral atlas - Benthic Allen Coral atlas - Bathymetry Allen Coral atlas	78%

Seagrass abundance maps

To visualise seagrass abundance (% cover) across each AOI, a map was produced using inverse distance weighted (IDW,) in ArcGIS™ Pro point interpolation analysis from the field validation point data. The area used for the percent cover prediction was the area of seagrass from the presence model output probability of threshold of 60% and the manually digitised seagrass areas. The raw output was rounded to 1 decimal for cover between 0 and 1, and rounded to no decimal for cover percentages above 1.

Seagrass dominant species maps

To catagorise the mosaic of seagrass communities within the seagrass meadow, dominant species maps were produced using inverse distance weighted (IDW, power = 4) point interpolation analysis from the species percent composition survey point data in R [43]. The area used for the percent cover prediction was the area of seagrass from the model output probability of threshold of 60% and the manually digitised seagrass areas. For each grid cell of the model, all species percentage composition were estimated. Then the cells with highest percent composition (dominant species) were computed, grouped and converted to polygons. The average composition from the model was calculated for each of the polygon created. The species community label was obtained taking the average of the species composition across all polygons for each dominant species and listing all secondary species with more than 5% in decreasing compositon order.

RESULTS & DISCUSSION

Methodological Tool Development

Activity WP1-1: Modify or develop new methodological tools for monitoring seagrass, SES (including carbon sequestration) and biodiversity (including marine megafauna), designed for community participation	New mapping protocols (subtidal and intertidal) developed and globally standardised monitoring protocols modified to local seagrass communities.

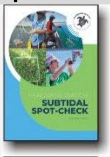
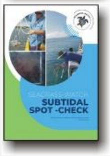
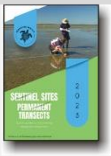
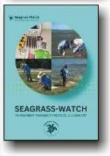
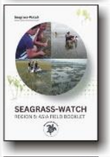
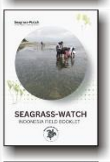
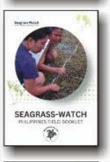
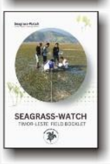
New and emerging technologies are changing the ways we assess seagrass meadows. Traditionally, seagrass mapping was conducted predominately by *in situ* observational approaches [39], necessitating a high level of scientific/seagrass knowledge and training to ensure that the data was of a suitable standard that could be used for creating maps of moderate to high confidence. In the last couple of decades, significant technological advances in earth observing, computing, digital image and positional capture (e.g. GPS or geotagging) have provided opportunities to revise/modify approaches to mapping seagrass meadows [37]. These improvements, also include access to equipment which had previously been prohibitively expensive for the safe collection of data in remote or challenging environments, e.g. deeper waters or locations with dangerous marine animals.

Following discussions and consultation with experts in marine mapping and remote sensing technologies (e.g. University of Queensland and the Scientific Committee on Oceanic Research Working Group for Coordinated Global Research Assessment of Seagrass Systems), existing seagrass field mapping protocols were modified and developed to enable collection of higher quality data (high resolution imagery coupled with higher positional accuracy) than previously enabled by individuals with limited experience in mapping and/or working in seagrass ecosystems, and with limited capacity (including funds). These protocols include the Global Ocean Observing System's (GOOS) Essential Ocean Variables (EOV) for seagrass cover and composition, and are globally standardised.

The globally standardised protocols used were developed using design thinking[44], where various scientific techniques were trialled and modifications fashioned on feedback from scientists and the broader community. The methodological tools developed/modified for the IKI SES Project included a suite of booklets and field guides which detail the collection of quantitative data seagrass on seagrass condition using subtidal and Intertidal spot checks (Table 5). The intertidal seagrass monitoring methodological tools were developed in 1999, but the field guides and booklets were tailored during the IKI SES Project for the National Partners (Table 5).

To encourage participation by a wider constituency of participants, Project Seagrass (a project Technical Partner) also updated and tailored the online app Seagrass Spotter to the countries of the NPs, to enable capture of seagrass spatial data by citizen scientists to supplement the quantitative mapping.

Table 5. *Methodological tools developed. *see also WP1-2*

Methodological Tool	Type	URL
Subtidal/Intertidal spot checks	**Instructional Guide/booklet**	
	Subtidal Spot-check mapping methods summary booklet	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	Instructional Field guide: How to conduct subtidal spot-checks	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	Instructional Field guide: How to conduct intertidal spot-checks	*https://www.seagrasswatch.org/iki-seagrass-resources/*
Intertidal Seagrass Monitoring	**Instructional Guide/booklet**	
	Instructional Field guide: How to conduct intertidal seagrass monitoring	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	Intertidal methods summary guide	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	Instructional Field guide: How to conduct intertidal seed monitoring	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	Region 5: Asia Field booklet	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	Region 5: Indonesia Field booklet	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	Region 5: Philippines Field booklet	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	Region 5: Timor-Leste Field booklet	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*

Methodological Tool deployment / training

Activity WP1-2: Five trainings provided to local stakeholders on assessment of seagrass status and SES.	Online instructional training videos developed for assessment of seagrass status (mapping and monitoring)

Due to COVID-19 travel restrictions from 2020 to 2022, the originally planned in-country training workshops were replaced with on-line training. Resources were directed to the preparation of a series of detailed instructional training videos, which required storyboarding and capture of specific imagery (video and stills) from both in-field and laboratory settings.

Mapping seagrass

The series of instructional training videos for mapping seagrass provided easy to follow step by step instructions on how quantitative data can be collected at field validation points in a variety of habitats (intertidal and subtidal), using alternate approaches. For example, how to collect georeferenced/geotagged photoquadrats from a spot-check intertidally on foot or subtidally using a drop-camera (Table 6).

The training videos ensured all National Partners collected data in a globally standardised way. The subtidal/intertidal spot-check videos offered comprehensive training and guidance on the assembly of a collapsible drop-camera frame, linking a smart device, conducting spot-checks with a drop camera, proper usage of a subtidal drop camera, deploying a Van veen grab, and executing intertidal spot-checks and phototransects.

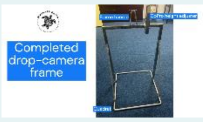
After NPs were given guidance on use and application of on-line resources by Seagrass-Watch, they were encouraged to practice the assembly of equipment and conduct field trials. Instructional videos were reviewed and improved following feedback given by NPs at virtual meetings.

National Partners also used the videos when training members from broader community who may have participated in field data collection, including fishers, gleaners, local leaders, NGOs and representatives from the national government (Figure 8).

Figure 8. *Blue Ventures Timor-Leste staff training local fishers in how to collect percentage cover measures in the field (December 2022). Image courtesy Alex Bartlett.*

Seagrass-Watch also supported on-site visits by Alex Bartlett (Project Seagrass) who visited with Blue Ventures (Timor-Leste) team in December 2022, the Save the Andaman Network (SAN) team in Trang (Thailand) in March 2023, and the Community Centred Conservation (C3) (Philippines) team in April 2023. During these on-site visits, Alex demonstrated subtidal and intertidal spot-checks, including the use of Seagrass Spotter.

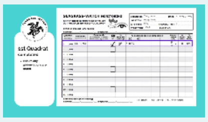
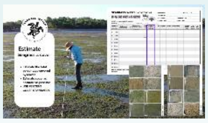
Table 6. *Training on deployment/application on methodological tools to conduct mapping field validation spot-checks (see also WP1-1).*

Methodological Tool: Spot checks (seagrass habitat)	Training video	URL
Drop-camera *(subtidal)*		
	Materials to set up a Drop Cam Kit	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to assemble a collapsible frame	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to link smart devices with GoPro	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to assemble drop-camera	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to conduct subtidal spot-checks	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to avoid bad drops	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to use a Van veen grab	*https://www.seagrasswatch.org/iki-seagrass-resources/*
In situ (intertidal)		
	How to conduct intertidal spot-check	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	How to conduct photo transects	*https://www.seagrasswatch.org/iki-seagrass-resources/*

Intertidal seagrass monitoring.

It was originally planned to conduct in-country training immediately after creation of the seagrass maps, as this would identify suitable meadows and sites for long-term monitoring. However, due to administrative issues with the IKI SES Project management team (CMS Dugong MOU), all project activities were suspended from mid-May - 31 July 2023, and as a consequence, no suitable tides were available and training could not be undertaken within the timeframe of the project. Nevertheless, Seagrass-Watch produced a series of instructional training videos for monitoring intertidal seagrass (Table 7). The intertidal seagrass monitoring training videos provide essential information regarding permanent transects, including selecting a location for monitoring, setting up a permanent transect site, pre-monitoring procedures, marking a site, filling out datasheets, placement of quadrats, photographing photoquadrat, monitoring a permanent transect site, and monitoring for seeds.

Table 7. *Training on deployment/application of methodological tools to conduct intertidal seagrass monitoring.*

Training video		URL
	What is a Permanent transect?	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to select your location and site	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to set up a Permanent transect site	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	Pre-monitoring steps	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to mark your site	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to fill out datasheets	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to record sediment *	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	What to record for comments	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to place a quadrat	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to take a photoquadrat	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to estimate cover and composition	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to record canopy/water heights	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to record algae and epi cover	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	How to monitor a site	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*
	Seed monitoring	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources*

Seagrass mapping and monitoring

Activity WP1-4: Data collected using community-participatory methodological tools on status of and threats to seagrass meadows at all five project sites	Mapping plans prepared for six project sites, however, mapping implemented and completed at four project sites within project duration.

Once National Partners had agreed on the seagrass mapping plans developed for each project site, field data collection was conducted. Although a suite of methodological tools were also modified/developed for intertidal seagrass monitoring (Table 7), National Partners were unable to proceed with intertidal monitoring activities as they were not provided with the required equipment by the IKI SES Project Management/Coordination Team (CMS Dugong MOU). Nevertheless, based on the maps created in this project, suitable locations/sites for establishing long-term monitoring sites can be identified in collaboration with the NPs. These sites would be best placed in enduring meadows (present for five years or more under natural conditions [45]) which are representative of the overall seagrass resource.

Mapping field data collection was only conducted/completed at four project sites due to logistic constraints and suitable field conditions within the project time remaining (Table 2).

Figure 9. *Field data collection using community-participatory methodological tools at project sites: Timor-Leste team planning mapping exercise (a), deploying drop-camera at Hera Bay (b); YAPEKA team member deploying drop camera at Northern Minahasa (d); SAN team in Trang (Thailand) locating mapping point (e), deploying Van Veen grab to verify species (f), conducting early morning in situ intertidal spot-checks (g); ZSL team (Ulugan Bay, Philippines) on site with drop-camera (h), conducting in situ intertidal spot-checks (i).*

For each of the four project sites, a map package was created including: a survey spot-checks map/layer of field validation points; an extent map layer of seagrass presence (satellite remote sensing, min and max); a raster/polygon layer of interpolated seagrass abundance (% cover); and a polygon layer of seagrass communities.

Hera Bay (Timor-Leste)

Seagrass meadows within the bay at Hera, northern Timor-Leste, were assessed between the 30 November 2022 and 08 March 2023. A total of 358 individual points were examined, of which 214 were collected in situ and 83 from Seagrass Spotter. Seagrass was present at 260 of the mapping points, with percentage cover ranging from 0.7 to 100%, and with an average of 36.8%. Ten seagrass species were identified: *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halophila decipiens*, *Halophila ovalis*, *Halodule pinifolia*, *Halodule uninervis*, *Syringodium isoetifolium*, *Thalassodendron ciliatum*, and *Thalassia hemprichii*. The most frequently encountered being *Enhalus acoroides*, *Thalassia hemprichii* and *Halodule uninervis* (39.6%, 23.6% and 10.1% cover, respectively). The deepest field validation point examined was 12 m, with the deepest occurrence of seagrass at 9 m (*Halophila decipiens*).

A total of 130.92 to 247.68 hectares of seagrass meadows were mapped within Hera bay. Two main seagrass areas were identified. Based on the field validation data and the spaceborne imagery, these are mostly continuous meadows and extend up until the edge of the reef. The first area to the west covered up to 62 ha and was composed of a mosaic of meadows mainly dominated by *Halodule uninervis* (Figure 11a) or *Thalassia hemprichii*, with smaller sections dominated by *Halophila ovalis* and *Syringodium isoetifolium* (Figure 11b). The second main seagrass area was to the east and was much larger, covering up to 173 ha. This larger area was similarly a mosaic of meadows mainly dominated by *Enhalus acoroides* or *Thalassia hemprichii*, with smaller scattered sections dominated by *Halophila ovalis*, *Halodule pinifolia, Cymodocea rotundata* or *Syringodium isoetifolium* (Figure 11c). The outer sections of the seagrass, toward the reef crest, were often dominated by *Thalassodendron ciliatum*(Figure 11d).

The extent of seagrass is greater than predicted by the Allen Coral Atlas, which estimated 156.7 ha of seagrass within the Hera AOI [14]. Also of note, is that the Allen Coral Atlas overestimated in the eastern reef dominated habitats, and underestimated in the western sand dominated habitats.

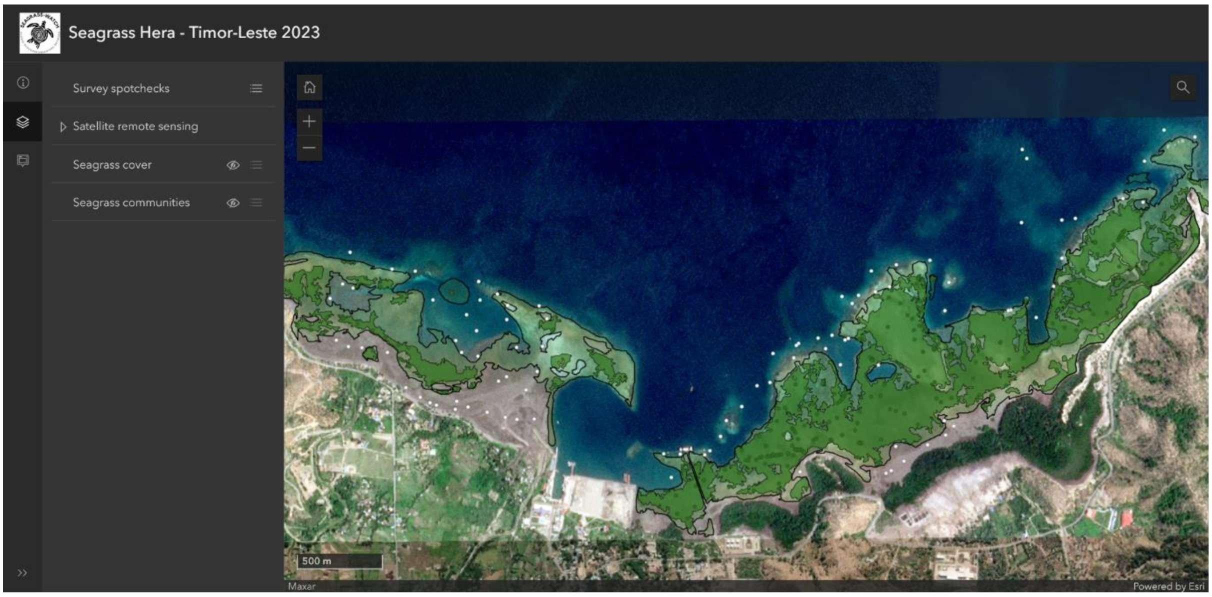


Figure 10. *Map Viewer showing field validation point layer (survey spotchecks), and extent map layers of seagrass presence (satellite remote sensing, min and max), seagrass cover and seagrass communities within Hera Bay, Timor-Leste (https://www.seagrasswatch.org/iki-seagrass-timor-leste/).*

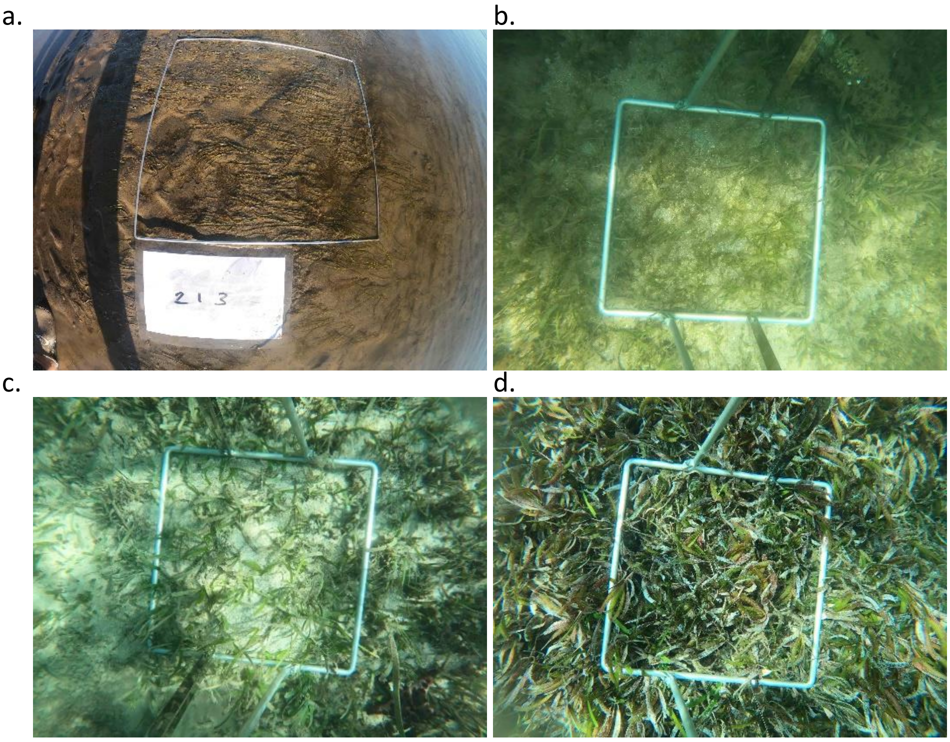


Figure 11. *Examples of the main seagrass communities within Hera Bay (Timor-Leste): (a) Halodule uninervis dominated meadow (point# 213); Thalassia hemprichii with Halophila ovalis and Syringodium isoetifolium (point# 208); (c) Thalassia hemprichii dominated meadow with Enhalus acoroides Halophila ovalis, Halodule pinifolia, Cymodocea rotundata and Syringodium isoetifolium (point# 63); (d) Thalassodendron ciliatum dominated meadow (point# 68) Images courtesy of Blue Ventures.*

Northern Minahasa, North Sulawesi (Indonesia)

Seagrass meadows in Northern Minahasa were assessed between the 18 January and 26 June 2023. The surveys data from Indonesia North Minahasa was composed of a total of 462 individual points, of which 424 were collected from drop-camera, 8 from *in situ* sampling and 37 from Seagrass Spotter (sightings between 28 March 2019 to 31 July 2022). A total of 372 points had seagrass present with a percentage cover ranging from 0.3 to 96.7 with an average of 30.2. A total of 9 different seagrass species were identified: *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halophila minor*, *Halophila ovalis*, *Halodule pinifolia*, *Halodule uninervis*, *Syringodium isoetifolium*, and *Thalassia hemprichii*. The most frequently encountered being *E. acoroides*, *T. hemprichii* and *C. rotundata* (49.8%, 32.9% and 4.9% respectively). The deepest field point assessed was 7 m, and the deepest seagrass was observed was 5 m (*E. acoroides*, *H ovalis*, *T. hemprichii*).

The extent of seagrass meadows within the Northern Minahasa Area of Interest (AOI) was between 129.2 to 221.1 ha (from remote sensing) with an additional 21.2 ha manually digitized from subtidal and/or turbid area where imagery would not enable reliable predictions. The seagrass meadows of the western coast around Tarabitan, were composed of *Enhalus acoroides* dominated community close to shore and *Thalassia hemprichii* dominated community toward the reef edge (Figure 13a). Around Serei in the north, the seagrass meadows were predominantly *Thalassia hemprichii* communities with some small patches dominated by *Syringodium isoetifolium* and *Enhalus acoroides* (Figure 13b). Moving southeast towards Bulutui, seagrass meadows were mostly dominated by *Enhalus acoroides* (Figure 13c). Similar species assemblages are found in the more turbid coastal waters between the mainland and the islands of Pulau Tamperong and Pulau Resaan. Meadows adjacent to these islands were also mainly dominated by *Enhalus acoroides* and *Thalassia hemprichii* (Figure 13d).

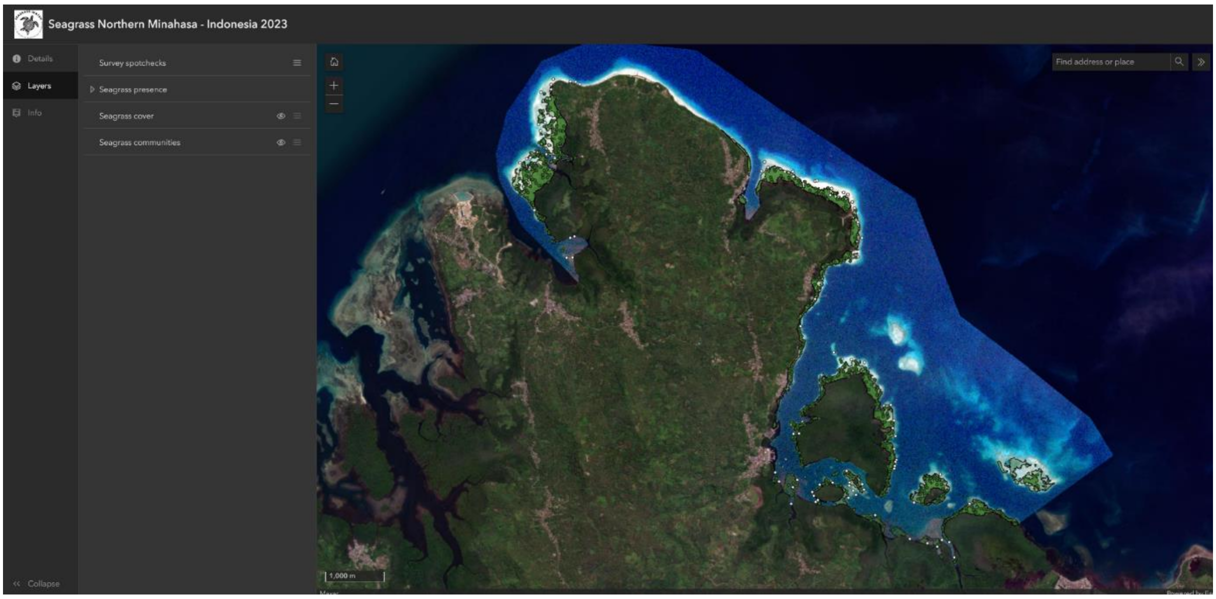


Figure 12. *Map Viewer showing field validation point layer (survey spotchecks), and extent map layers of seagrass presence (satellite remote sensing, min and max), seagrass cover and seagrass communities around Northern Minahasa, Indonesia (<https://www.seagrasswatch.org/iki-seagrass-indonesia/>).*

a. b. c. d.

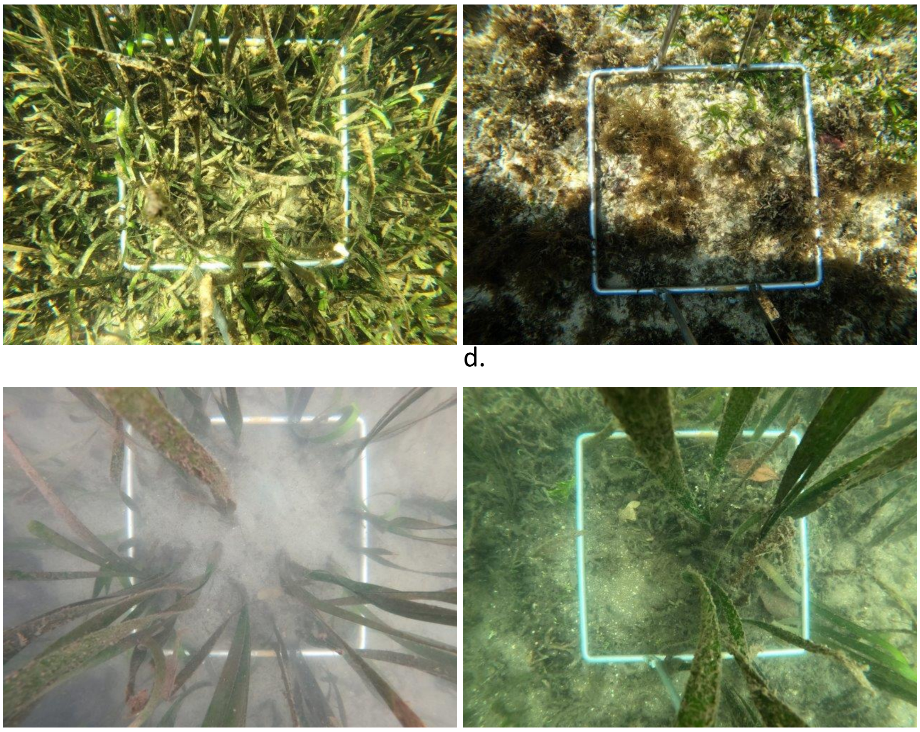


Figure 13. *Examples of the main seagrass communities within Northern Minahasa (North Sulawesi, Indonesia): (a) Enhalus acoroides dominated meadow with Thalassia hemprichii (point# NM329); (b) Thalassia hemprichii dominated meadows with Syringodium isoetifolium and Enhalus acoroides (point# NM207); (c) Enhalus acoroides dominated meadow (point# NM037); (d) Enhalus acoroides and Thalassia hemprichii dominated meadows (point# NM306). Images courtesy of Yapeka.*

Koh Libong, Modtanoi, and Koh Mook, Trang (Thailand)

Seagrass meadows surrounding Koh Libong, Modtanoi, and Koh Mook in Trang, were assessed between 03 April and 12 May 2023. A total of 357 individual field validation points were examined, of which 145 were collected from drop-camera and 448 from *in situ* sampling. An additional 250 points were also accessed from Seagrass Spotter (sightings between 21 November 2017 to 24 March

2023). Seagrass was present at 401 of the mapping points, with percentage cover ranging from 0.2 to 48%, and with an average of 14.9%. Nine seagrass species were identified: *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halophila minor*, *Halophila ovalis*, *Halodule pinifolia*, *Halodule uninervis*, *Syringodium isoetifolium*, and *Thalassia hemprichii*. The most frequently encountered being *Halophila ovalis, Enhalus acoroides* and *Cymodocea rotundata* (36.3%, 32.6% and 19.0% average cover respectively). The deepest field validation point assessed was 10 m, and the deepest seagrass was observed was 5 m (*E. acoroides*).

A total of 200.3 to 763 hectares of intertidal/shallow seagrass meadows, with an additional 225 hectares in subtidal (turbid) waters was mapped in the Trang AOI. Surrounding Ko Libong, the seagrass presence map obtained from remote sensing showed seagrass covering between 200.3 to 763.0 ha with an additional 225 ha from subtidal/turbid areas that were manually digitized. The intertidal meadows of the islands southeastern bay were mostly composed of *Cymodocea rotundata, Enhalus acoroides* and *Thalassia hemprichii*. Meadows in the southwestern part of bay, surrounding Leekpai Pier (and dugong viewing tower), were predominantly composed of *Enhalus acoroides* close to shore (Figure 15a) and *Halophila ovalis* in the subtidal offshore areas. Similar species assemblages were found in the subtidal meadows between Koh Libong and Modtanoi on the mainland, with also some *Cymodocea rotundata.* The seagrass of the northern coast of Koh Libong was scarcer with aggregated patches predominantly composed of *Halophila ovalis* and *Halodule pinifolia* (Figure 15b). The coastal seagrass meadows of Modtanoi (mainland Trang) covered approximately 178 ha (from expert driven map digitization) and were composed of mostly *Enhalus acoroides*, *Halophila ovalis* and *Cymodocea rotundata* (Figure 15c).

At Koh Mook, seagrass presence (Figure 15d) was estimated between 36.4 and 71.7 ha by remote sensing. However, the confidence in the output is moderate to low as only Seagrass Spotter data was available and points were concentrated in close proximity. Therefore, the training data used for the remote sensing model was mostly visual interpretation of the imagery without in-situ validation data.

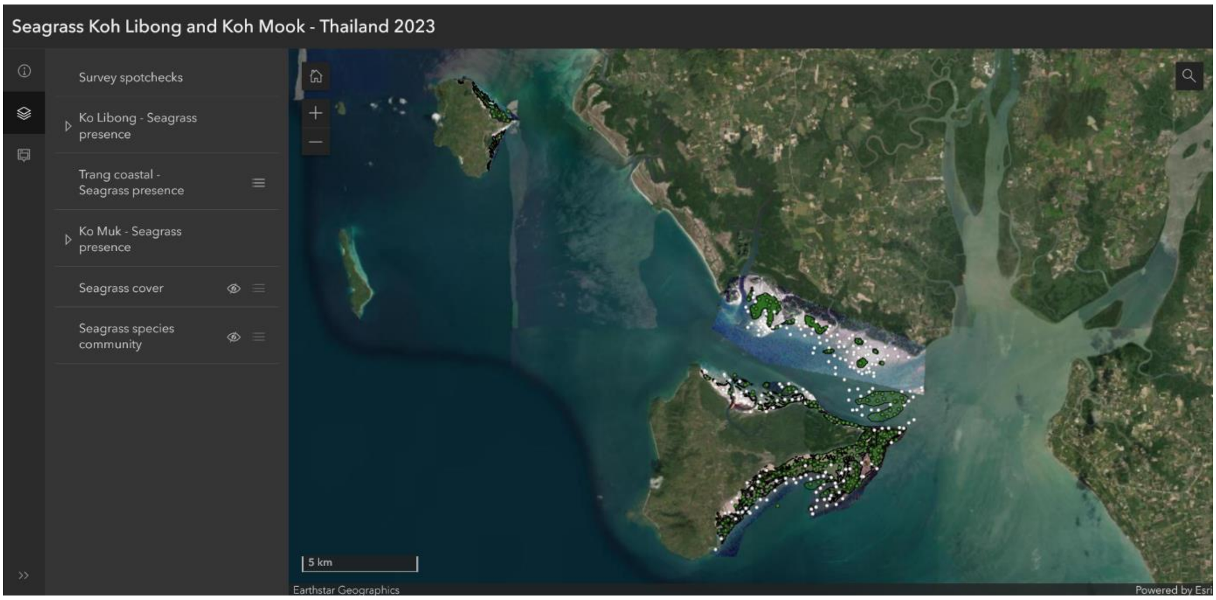


Figure 14. *Map Viewer showing field validation point layer (survey spotchecks), and extent map layers of seagrass presence (satellite remote sensing, min and max), seagrass cover and seagrass communities around* Koh Libong and Modtanoi *(https://www.seagrasswatch.org/iki-seagrass-thailand/).*

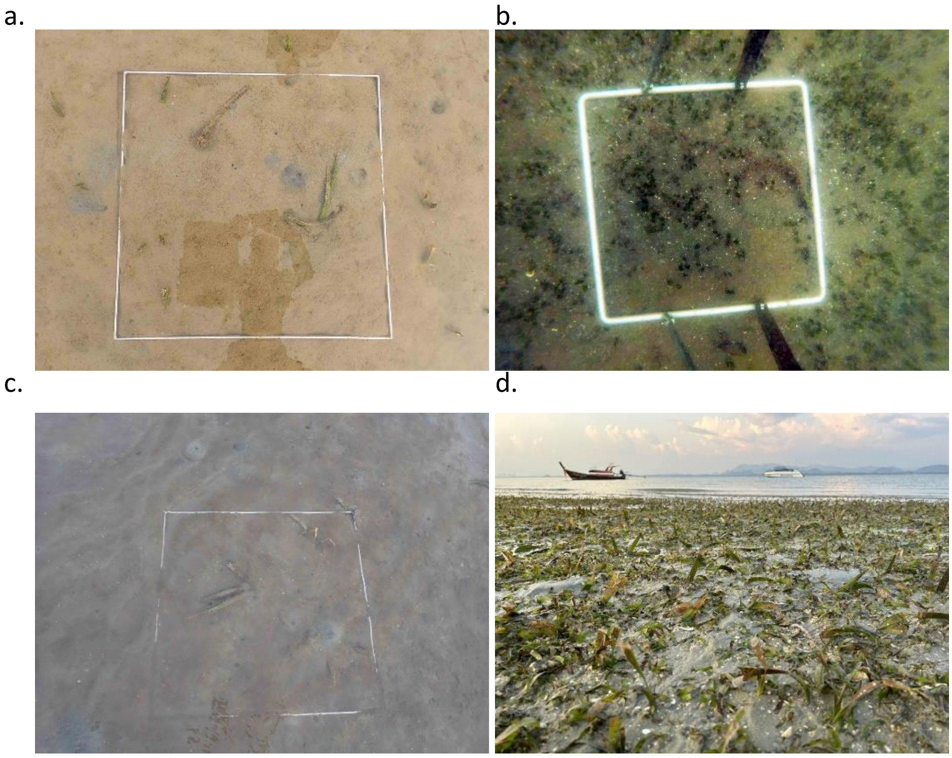


Figure 15. Examples of the main seagrass communities at Koh Libong, Modtanoi, and Koh Mook (Trang, Thailand): (a) sparse Enhalus acoroides meadow close to shore (point# 7); (b) aggregated patches predominantly composed of Halophila ovalis (point# 159); (c) sparse coastal Enhalus acoroides meadow (point# 300); (d) Thalassia hemprichii/Enhalus acoroides with Cymodocea rotundata and Halophila ovalis meadow (point# 6827). Images courtesy of SAN and Seagrass spotter

Ulugan Bay, Palawan (Philippines)

Seagrass meadows within Ulugan Bay, Palawan, were assessed between the 13 October 2022 and 19 April 2023. The surveys data from Ulugan Bay in the Philippines was composed of a total of 457 individual points, of which 417 were assessed from a drop-camera, 25 from a Van Veen grab and 15 from *in situ* sampling. An additional 166 points assessed during a reconnaissance survey in October 2020 by *in situ* sampling, and a further 69 points were accessed from Seagrass Spotter (sightings between 05–11 September 2022 and 08–09 May 2023). A total of 309 points had seagrass present with percentage covers ranging from 0.1 to 100 and an overall average of 20.8%. A total of ten different seagrass species were identified in the Area Of Interest: *Cymodocea rotundata*, *Cymodocea serrulata*, *Enhalus acoroides*, *Halophila decipiens*, *Halophila ovalis*, *Halodule pinifolia*, *Halodule uninervis*, *Syringodium isoetifolium*, *Thalassodendron ciliatum* and *Thalassia hemprichii*. The most frequently encountered being *Enhalus acoroides*, *Halophila ovalis* and *Thalassia hemprichii* (36.2%, 15.4% and 10.9% respectively). The deepest point assessed was 30m in October 2022, while the deepest seagrass observed was at 20m (*H. ovalis*).

The seagrass presence map obtained from satellite imagery showed that seagrass covered between 86.8 to 323 ha with an additional 10.2 ha manually interpolated from subtidal and/or turbid area where imagery does not allow for reliable predictions. The southern coastal seagrass meadows, around Macarascas barangay, were primarily composed of *Enhalus acoroides* dominated communities on mud/sand substrates close to shore, with some smaller areas with *Thalassia hemprichii*, *Halophila ovalis* and *Syringodium isoetifolium* dominated community near the reef edge. The area is heavily influenced by the discharge from the four rivers in the district.

On the east coast, the seagrass communities going north switch from *Enhalus acoroides* dominated to *Thalassia hemprichii,* and back to *E. acoroides* with a greater diversity about halfway around Buenavista barangay where smaller patches of different communities occur, including meadows of various extent dominated by *Cymodocea rotundata, Halodule uninervis* and *Thalassodendron ciliatum*. Some of the largest meadows in the bay occur in the section. The western side of the bay, Bahile barangay, had much less seagrass in comparison and were mostly composed of *Halophila ovalis* and *Thalassia hemprichii* dominated meadows except for Rita Island which also had some *Halodule uninervis* dominated meadows.

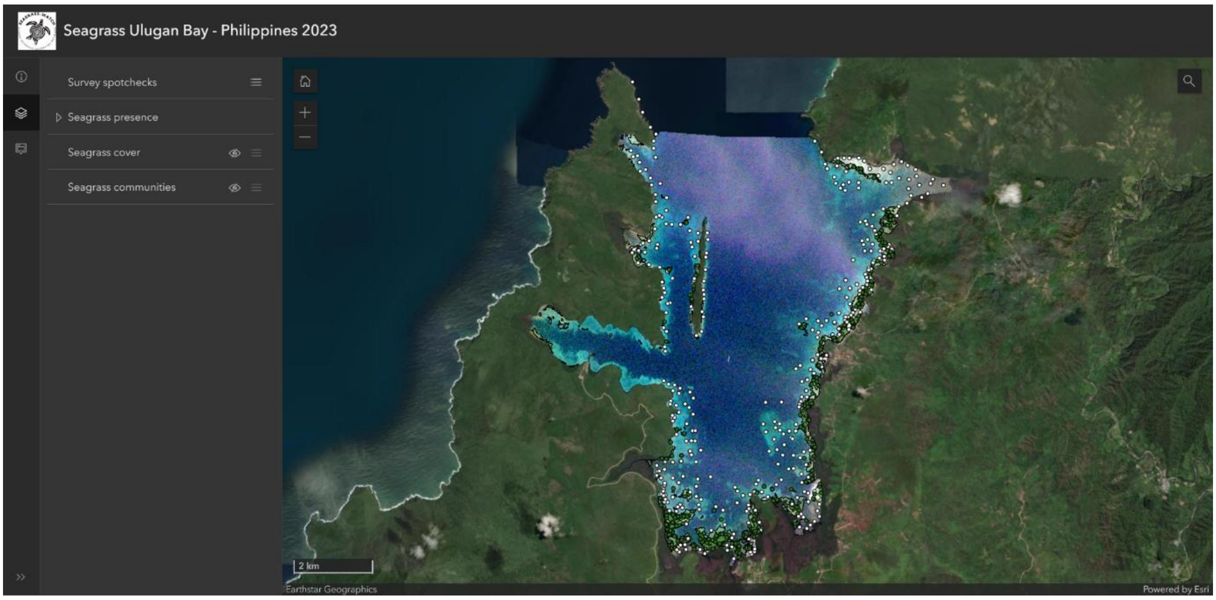


Figure 16. *Map Viewer showing field validation point layer (survey spotchecks), and extent map layers of seagrass presence (satellite remote sensing, min and max), seagrass cover and seagrass communities around Ulugan Bay, Palawan, The Philippines (https://www.seagrasswatch.org/iki-seagrass-philippines/).*

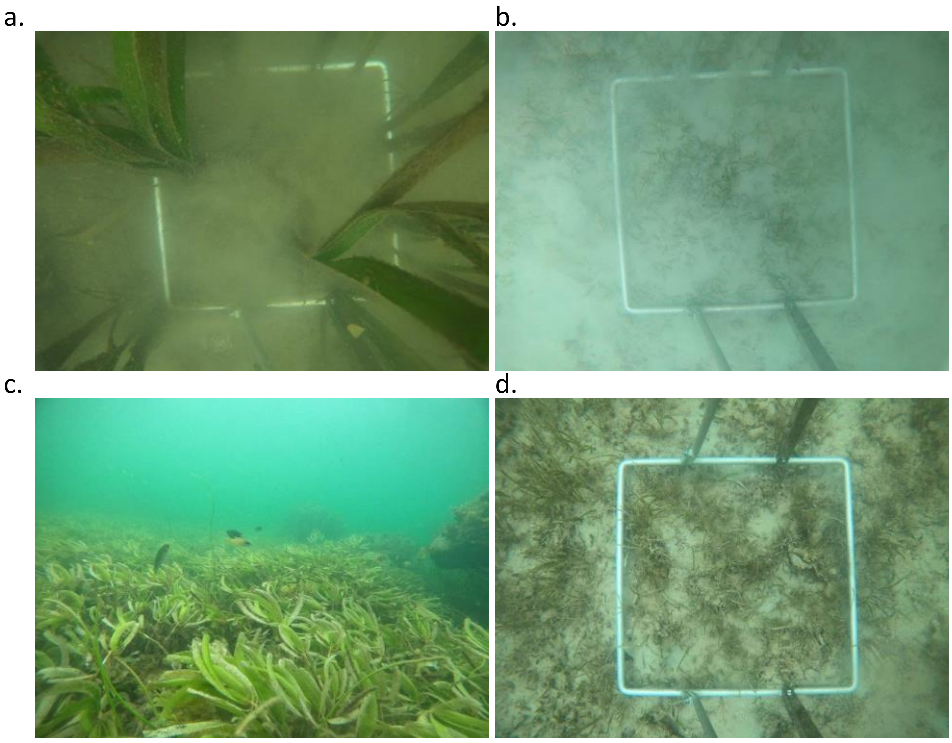


Figure 17. *Examples of the main seagrass communities within Ulugan Bay (Palawan, Philippines): (a) Enhalus acoroides meadows around Macarascas barangay (point# UB171); (b) Thalassia hemprichii dominant meadows (point# UB15); (c) Thalassodendron ciliatum meadows around Buenavista barangay (point# UB5627); (d) Halodule uninervis dominated meadows Rita Island (mapping point #UB292). Images courtesy ZSL and Seagrass Spotter.*

SES Assessment and Valuation

Activity WP2-1: SES data collection, analysis, and assessment at all five sites to determine the different ways in which seagrass is providing value and what the loss of these services would cost.	Database on extent and abundance of each seagrass community within each of the four project site areas of interest provided

A critical element to quantifying seagrass ecosystem services is reliable data on seagrass spatial extent, abundance and species composition (i.e. subvariables). Often quantifications (including valuations) use global averages where seagrass is considered generic and not species or community specific. Such quantifications can grossly over- or under-estimate ecosystem services, reducing confidence in the evidence base and, as a consequence, undermine the importance of the services as perceived by the broader community. To ensure a reliable evidence-base, comprehensive ecosystem service quantifications require detailed subvariables of the local seagrass resource. By improving the quality of the data underpinning calculations, accuracy is greater, which results in higher visibility/inclusion of seagrasses in governance and policy. The maps of seagrass community/meadow extent and abundance collected from the four project sites (Table 8) provide a solid reliable evidence-base from which seagrass ecosystem services can now be quantified for the areas of interest.

By implementing globally standardised Essential Ocean Variables (EOVs) of extent and cover/abundance, the data from this project can be integrated at various scales (local to global) and more widely by the scientific and academic community. The advantage of using the EOVs, is that biomass models can also be created and applied to the species and cover maps to estimate seagrass above- and below-ground biomass in seagrass ecosystems over spatial scales larger than can be tractably assessed using current point-based measurement approaches, and at scales that are required to understand and manage seagrass systems to tackle anthropogenic climate change and other impacts [46].

Seagrass above-ground biomass is highly correlated to seagrass percentage cover, and the relationship is further improved by factoring seagrass canopy height into the calibration [47]. Currently, however, these models are limited to *Cymodocea serrulata, Halophila ovalis*, *Halodule uninervis, Syringodium isoetifolium* and *Zostera muelleri* [46, 47]. Below ground biomass can similarly be estimated using models when only above-ground biomass is measured/estimated. The predictor variables have been shown to explain 84–97% of variance in below-ground biomass on the log-scale, depending on the species[48]. However, such models are currently limited to *Cymodocea serrulata, Halophila ovalis, Halodule uninervis, Thalassia hemprichii*, and *Zostera muelleri* [48]. To improve the quantification of seagrass ecosystem services, it is recommended the existing above- and below-ground models be expanded to include the remaining dominant species in each habitat type, including: *Cymodocea rotundata, Enhalus acoroides, Syringodium isoetifolium*, *Thalassodendron ciliatum*, and *Thalassia hemprichii*. This can be accomplished by harvesting biomass cores in combination with photoquadrats, processing the harvested cores to measures above- and below-ground plant organs/structures of each species, and then assessing using Generalized Linear Models.

Until such time as the seagrass biomass components can be modelled, the existing data (Table 8) provides a significant improvement in the quality of data previously available for quantifying seagrass ecosystem services.

Table 8. *Area (maximum and minimum extent probability), meadow community type extent (hectares, minimum extent probability), and average percentage cover of seagrass meadows at project sites. Seagrass species codes: CR = Cymodocea rotundata, EA = Enhalus acoroides, HD = Halophila decipiens, HM = Halophila minor, HO = Halophila ovalis, HP = Halodule pinifolia, HU = Halodule uninervis, SI = Syringodium isoetifolium, TC = Thalassodendron ciliatum, TH = Thalassia hemprichii. Sum of seagrass community areas may not equal seagrass presence areas due to rounding.*

Location/Site (Country)	Seagrass meadow/community	Average % cover ±SE (min - max)	ha
Hera bay (Timor-Leste)	Seagrass presence- max probability (100%)	37.3 ±2.1 (0.7 - 100)	130.9
	Seagrass presence- min probability (60%)	36.9 ±2.1 (0.7 - 100)	247.7
	CR with TH, EA and SI	36.7 ±6.5 (11 - 55)	4.38
	EA with SI and TH	29.3 ±2.8 (0.7 – 96)	99.84
	HD with HU and TH	5.0	2.28
	HO with TC and TH	10.8 ±4.2 (2.7 – 31)	7.13
	HP with EA, TH and HU	32.7 ±6.5 (11 – 63)	4.66
	HU with EA and TH	13.9 ±2.5 (1.7 – 40)	32.68
	SI with EA, TH and TC	61.3 ±6.7 (27 - 83)	12.54
	TC with TH, EA and SI	83.0 ±4.0 (45 - 100)	12.56
	TH with EA, CR and SI	42.5 ±3.5 (3 - 92)	71.60
Northern Minahasa, North Sulawesi (Indonesia)	Seagrass presence- max probability (100%)	32.9 ±1.5 (0.3 - 96.7)	129.2
	Seagrass presence- min probability (60%)	30.3 ±1.2 (0.3 - 96.7)	242.3
	CR with TH and EA	34.7 ±4.0 (23.7 - 42.7)	1.44
	EA with TH and HO	23.5 ±1.5 (0.3 - 88.3)	116.91
	HO with EA and TH	20.1 ±5.5 (0.3 - 86)	8.55
	HP with HO, EA and CR	20.5 ±18.8 (1.7 - 39.3)	0.83
	HU with HO and TH	25.3 ±3.0 (21 - 31)	1.49
	SI with TH and EA	57.6 ±10.2 (13.3 - 85)	4.21
	TH with EA and SI	38.5 ±1.9 (1.7 -96.7)	108.90
Trang AOI (Thailand)	Seagrass presence- max probability (100%)	14.9 ±1.6 (0.2 - 48)	414.8
	Seagrass presence- min probability (60%)	15 ±1.2 (0.2 - 48)	1,237.9
Koh Libong + Modtanoi	Seagrass presence- max probability (100%)	14.9 ±1.6 (0.2 - 48)	378.5
	Seagrass presence- min probability (60%)	15 ±1.2 (0.2 - 48)	1,166.2
	CR with HO and TH	10.4±1.5 (0.2-34.7)	262.38
	EA with HO, CR and TH	4.2±0.5 (0.3-18.3)	371.93
	HM with EA	45.0	2.95
	HO with HP, CR and EA	27.1 ±1.7 (0.3 - 48)	440.19
	HP with HO	7.2 ±1.4 (0.3 - 11.7)	33.63
	HU with HO	31.7	6.58
	TH with CR, HO and EA	12.7 ±3.9 (5.2 - 25)	48.52
Koh Mook	Seagrass presence- max probability (100%)	NA	36.4
	Seagrass presence- min probability (60%)	NA	71.7
Ulugan Bay, Palawan (Philippines)	Seagrass presence- max probability (100%)	24.0 ±3.2 (0.3 – 100)	86.8
	Seagrass presence- min probability (60%)	23.0 ±2.3 (0.1 – 100)	333.2
	CR with TH and EA	49.6 ±5.3 (5 – 100)	10.56
	EA with SI, HO and HU	12.1 ±1.6 (0.7 - 63.8)	173.27
	HD with HO	7.0 ±0.7 (6.3 - 7.7)	3.93
	HO with EA	10.7 ±3.9 (1.3 - 85)	44.55
	HU with EA, HO and CR	13.2 ±6.4 (0.3 - 41.7)	13.41
	SI with EA and HO	27.0 ±9.3 (0.1 - 58.3)	20.85
	TH with EA, HO and SI	12.5 ±2.5 (0.7 - 28.3)	66.58

Stakeholder/policy needs assessment

Activity WP3: Stakeholder and policy needs assessment done at each project site, targets for key seagrass ecosystem services identified, policy priorities identified.	• Maps of seagrass areas provide evidence base for development of conservation approaches • Policy recommendations for integration of seagrasses into management developed

Seagrass ecosystems across southeast Asia are recognised as important marine habitats, however they are often underrated and marginalised in marine policy. Facilitating the conservation of seagrass ecosystems requires strong policies. The bottom-up approach executed by this project was designed to empower local communities to contribute to the data needed to inform decision-makers and to develop sustainable financing for the conservation of seagrasses and associated biodiversity that are tailored to the specific environmental and economic contexts of the five target countries.

In September 2023, maps/datasets of Hera (Timor-Leste) seagrass meadows created by Seagrass-Watch in partnership with Blue Ventures Timor-Leste, local NGO Konservasaun Flora no Fauna (KFF) and Project Seagrass were presented at a two day workshop to understand how artisanal fishers can benefit from protecting the seagrass meadows. The event was attended by over 100 people, including fishers and gleaners, local leaders, NGOs and representatives from the national government. The data provided was the first of its kind where the community themselves were able to validate the data, to ensure broad acceptance of the need for conservation. As a consequence, attendees declared their collective interest to develop the first locally managed marine area (LMMA) in Hera [49].

Although the Seagrass-Watch team were not invited to participate in any IKI SES Project workshops on policy needs assessment, during the initial phase of the project NPs were asked what they would like to achieve from the project. Their following responses inform policy and management needs:

- Natural resources governance
- Long-term observation of seagrass and connectivity to adjacent ecosystems (coral reef, mangrove)
- Improved dugong and sea turtle populations
- Socio-ecological research in small islands, including traditional knowledge and wisdom
- Small-scale fisheries and food security
- Gain evidence of the role of seagrasses in food security to push for multi-habitat MPAs,
- Findings on economic importance of seagrasses to campaign for the seagrass policies and conservation projects,
- Lobby for the creation of Ordinances to protect seagrasses against inappropriate mangrove planting practices (i.e., reforesting on seagrass meadows)
- Gain experience working with other teams/organizations on dugong conservation to refine our MPA establishment protocols
- Identification and valuation of seagrass ecosystem services
- Improve local economic conditions in the area
- Lead to actions to conserve dugongs and seagrass
- Training on SES for strategy design
- Legacy tools (e.g. standard protocols) that NGOs & LG can maintain beyond project
- Mapping skills
- Blue Carbon – strong desire to grab national focus.

To strengthen the conservation of seagrass ecosystems and the goods and benefits to people's quality of life in the region, we recommend the following broad policies:

- identify and protect high value seagrass areas & areas favorable for seagrass colonisation
- support ecological linkages that maintain seagrass resilience (e.g. trophic linkages).
- identify and protect key species that sustain seagrass resilience
- identify and protect important cultural, social and economic values
- improve compliance and spatial planning
- develop guidelines and policies that enable seagrass interventions

- eliminate of critical knowledge gaps
- embrace new and emerging technologies
- implement more effective communication & awareness-raising initiatives
- foster partnerships, support public participation & empower people

Other broad policies for consideration:
- Encourage citizen scientists to conduct spot checks to fill information gaps and validate seagrass species occurrence, using SeagrassSpotter;
- Expand seagrass ecosystem health monitoring programs such as Seagrass-Watch across the region
- Encourage seagrass scientists across the region to participate in established networks to foster collaboration and knowledge exchange.
- Undertake spatial mapping of seagrass meadows within and across data depauperate regions
- Promote seagrass conservation through development of locally relevant educational and outreach materials
- Support socio-economic and cultural valuation of seagrass ecosystems and their contributions to people;
- Support the gathering of local specific scientific evidence;
- Increase effort to translate science into policy;
- Encourage scientists and policy makers to work together to couple knowledge (evidence base) with legislation and ensure informed decisions are translated into sound practice for people to drive social change;
- Ensure policy-making is open and receptive for scientific advice and public scrutiny, and integrated with existing and planned conservation policies;
- Support novel initiatives which enhance seagrass ecosystem resilience or rewilding;
- Build scientific literacy and awareness through outreach initiatives to ensure confidence and local stewardship.

Communication

Activity WP6: Seagrass ecosystems, key seagrass ecosystem services, and dependent biodiversity widely promoted among decision-makers, businesses, local communities and academia.	• Dedicated project website and social media accounts linked to existing partner websites and accounts established to enable information sharing and cross-promotion • Project-derived seagrass ecosystem services knowledge shared in scientific and academic communities.

Dedicated IKI SES Project webpages

A key component of Seagrass-Watch's support of the IKI SES Project, was to create a dedicated IKI SES project webpage (https://www.seagrasswatch.org/iki-seagrass-ecosystem/) in June 2021, to enhance the overall media presence and out-reach capacity of the project. The official Seagrass-Watch website (www.seagrasswatch.org) receives over 5,500 unique visitors per month, and provides excellent visibility for the IKI SES Project.

The original landing page for the IKI SES Project provided little information beyond project background, introducing the project partners and linking to the Dugong and Seagrass Hub (https://www.dugongseagrass.org/projects/seagrass-ecosystem-services-project/). However, over the following 12 months, Seagrass-Watch developed a suite of IKI SES Project webpages aimed at promoting IKI SES activities, Seagrass-Watch methodological tools and training, project status, and project results for National Partners, decision-makers, local communities and academia. The pages were regularly updated as the project progressed. For example, the SES project current status page was replaced by individual country status pages, which were later superseded by individual country results pages (Figure 18).

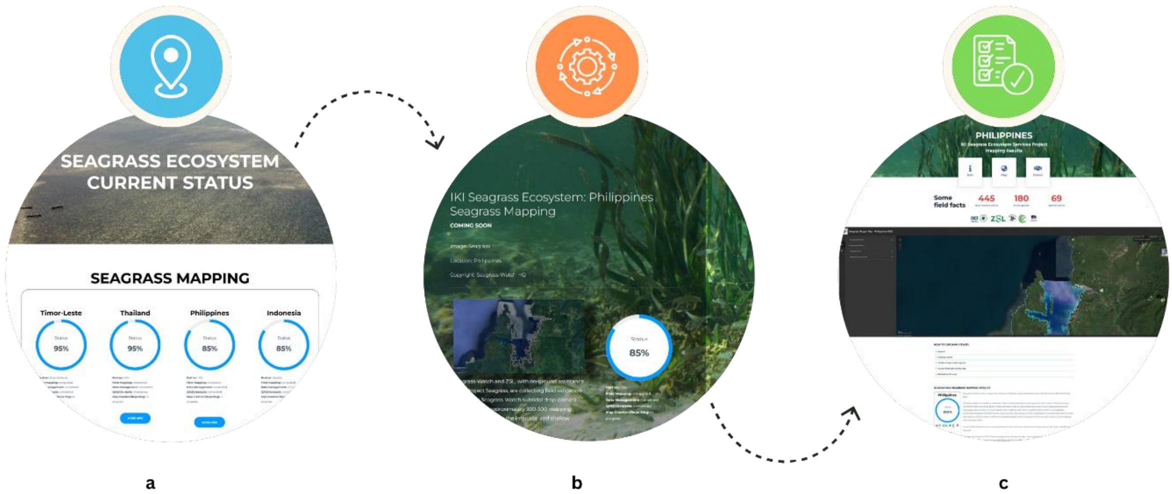


Figure 18. *Progression of webpage updates over life of the project: (a) introduction of dedicated project status webpage with information on how mapping activities were progressing for all National partners; (b) creation of individual country status pages as 70- 80% of the mapping activity was completed; (c) creation of individual country open-access result pages, once all mapping had been submitted/entered/passed QAQC and maps created (when a mapping result page went live, this was accompanied with social media posts informing general public of the page status).*

The IKI SES Project landing page on the Seagrass-Watch website in the first 12 months averaged between 100 and 200 unique visitors per month, but the number of visitors increased from July 2022 (Figure 19), when the suite of additional IKI SES Project pages went live.

The suite of IKI SES webpages (10 in total) were created and hosted by Seagrass-Watch from July 2022 (Table 9). These webpages contained methodological tools and training materials for both subtidal/intertidal spot-checks, intertidal seagrass monitoring, mapping status at Project sites (as discussed above), and Individual country results when available.

Table 9. *List of IKI SES Project webpages hosted on the official Seagrass-Watch website (seagrasswatch.org)*

IKI SES Project webpages Page number, activity and description		**URL**
	1. **IKI SES Project landing page** Dedicated webpage (created and hosted) on Seagrass-Watch website, promoting IKI SES activities, with links to Dugong and Seagrass Hub, general information and National partners	*https://www.seagrasswatch.org/iki-seagrass-ecosystem/*
	2. **Activity WP1-1 and WP1-2**: Dedicated resource page for subtidal/intertidal spot-checks including methodological tools and training videos.	*https://www.seagrasswatch.org/iki-seagrass-resources/*
	3. **Activity WP1-1 and WP1-2:** Dedicated resource page for intertidal seagrass monitoring including methodological tools and training videos.	*https://www.seagrasswatch.org/iki-seagrass-intertidal-resources/*
	4. **Activity WP1-4**: National partner (Indonesia) dedicated page for results feedback	*https://www.seagrasswatch.org/iki-seagrass-indonesia/*
	5. **Activity WP1-4**: National partner (Timor-Leste) dedicated page for results feedback	*https://www.seagrasswatch.org/iki-seagrass-timor-leste/*
	6. **Activity WP1-4**: National partner (Thailand) dedicated page for results feedback	*https://www.seagrasswatch.org/iki-seagrass-thailand/*
	7. **Activity WP1-4**: National partner (Philippines) dedicated page for results feedback	*https://www.seagrasswatch.org/iki-seagrass-philippines/*
	8. **IKI SES Status webpage** Status overview webpage that provided updates on the progress of overall mapping activities.	*superseded.*
	**9.** Individual National partner (eg., Philippines) status update	*superseded*

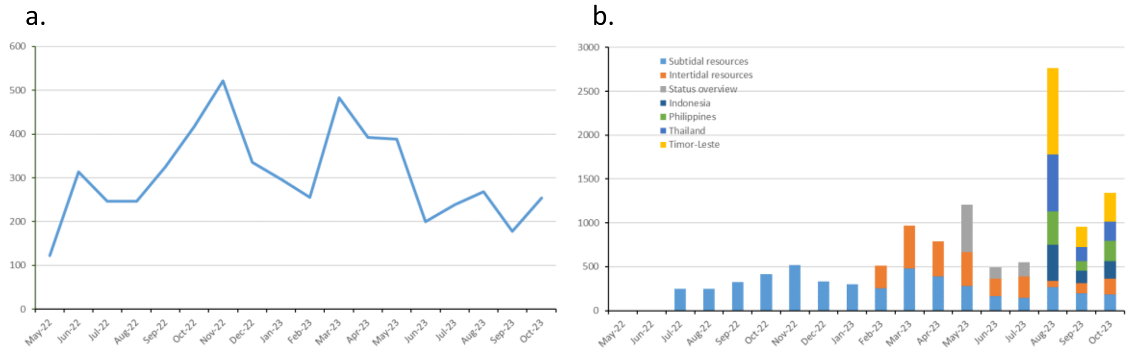


Figure 19. *Number of unique visitors to the IKI SES Project landing page on the Seagrass-Watch website (a), the resource pages and the results pages for individual project sites (countries).*

The resource pages were visited the most in October-November 2022, and March-May 2023, coinciding with the periods that the National Partners were conducting field data collection. The number of downloads of the training videos similarly peaked during the same periods (Figure 20).

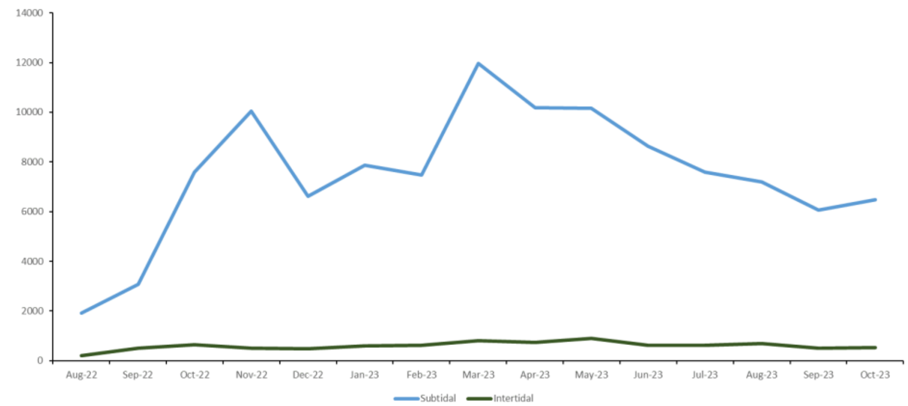


Figure 20. *Number of downloads per month of methodological tool training videos for collection of subtidal and intertidal mapping data.*

Social media (outreach)

Social media includes the interactive technologies that enable content to be shared via virtual networks and communities. Social media has become a powerful tool for individuals, businesses, and organizations to connect, share information, and build relationships. Social media's worldwide reach is vast, and therefore Seagrass-Watch uses social media platforms that focus on communication, community-based input, interaction, content-sharing, and collaboration.

Seagrass-Watch dedicated significant resources to the promotion of the IKI SES Project, including information on progress and deliverables, on the social media platforms Facebook (www.facebook.com/seagrasswatch/) and Instagram (@seagrasswatch). From December 2022 (Figure 21), Instagram posts were particularly popular with followers when project sites conducted field activities and the mapping of seagrass was progressing. Some individual post achieved nearly 2,000 views (e.g., Figure 22).

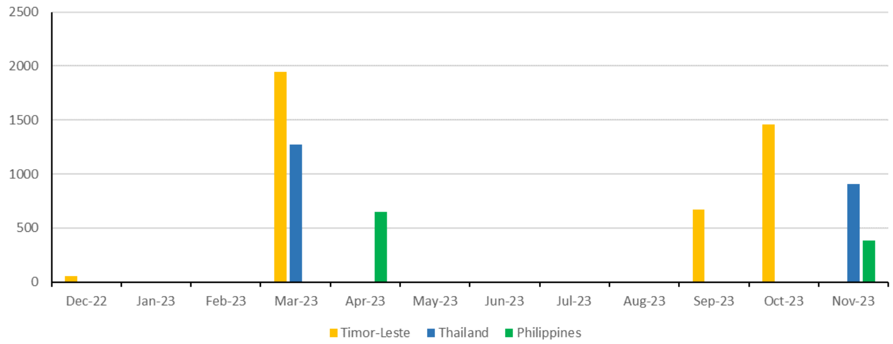


Figure 21. *Number of views of Instagram posts by Seagrass-Watch on IKI SES Project activities for project sites.*

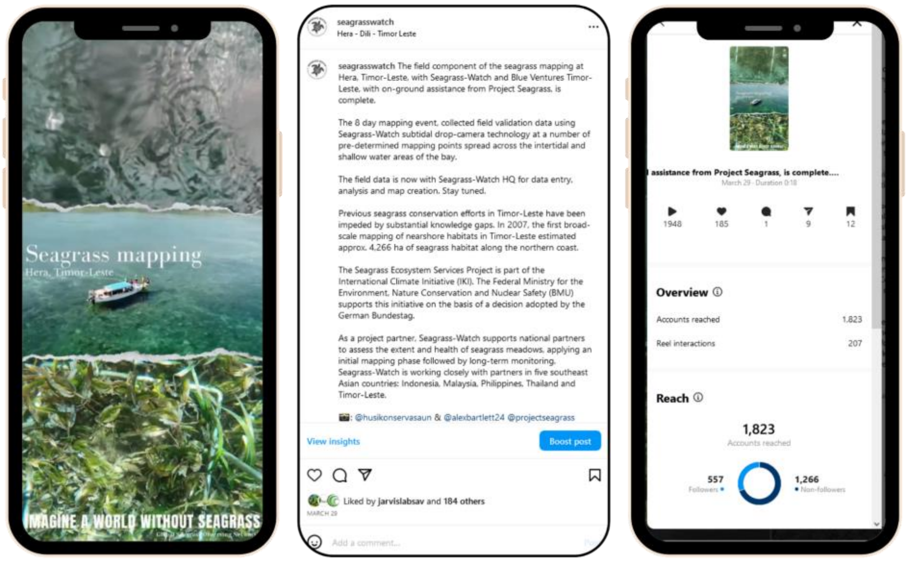


Figure 22. *Example of social media post by Seagrass-Watch on Instagram about the IKI SES Project.*

SES knowledge sharing (data/outputs)

Seagrass-Watch used a number of different instruments to share project-derived seagrass ecosystem services knowledge, data and outputs from the IKI SES Project. Although social media was one instrument for knowledge sharing (e.g., Figure 23), it essentially only advertises where to find the maps or data outputs. To raise awareness of the importance of seagrass and the ecosystem services they provide, the types of instruments used varied depending on the audience.

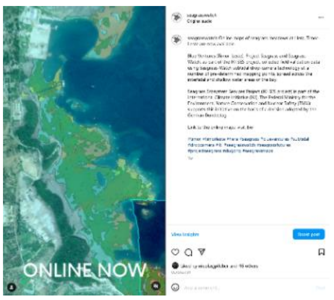


Figure 23. *Example of social media post by Seagrass-Watch on Instagram advising followers about results of the IKI SES Project mapping and where to view the data.*

Broader community

Seagrass-Watch contributed to building scientific literacy, knowledge and understanding of seagrass ecosystems and the services (goods and benefits) they provide at the local project sites, through a number of outreach events/exhibits.

In November 2020, Seagrass-Watch participated in the MareCet *Sayang Sayang Seagrass Virtual Festival 2020*. The festival included live events, the screening of a documentary which Seagrass-Watch contributed, and a panel discussion "The power and future of seagrass in a changing world" (Figure 24). Seagrass-Watch also presented information about the IKI SES Project, and the importance of mapping and monitoring to understand the ecosystem services they provide.

Figure 24. *Social media posts and flyers from the Sayang Sayang Seagrass Virtual Festival 2020 (https://www.cms.int/dugong/en/news/marecet-sayang-sayang-seagrass-virtual-festival-2020).*

Seagrass-Watch has also provided text and illustrations of seagrass species and habitats to National Partners to assist with outreach activities, such as public displays and information boards (e.g., Figure 25).

Figure 25. Public information board at Hera (Timor-Leste) which includes illustrations of seagrass species from Seagrass-Watch.

Scientists and academics

Scientists and academics are able to view the seagrass data/maps packages on the open access portal through the Seagrass-Watch website. To make the scientific community aware of Project-derived seagrass ecosystem services data, Seagrass-Watch has also reached out to the many scientific networks in which it participates. Information was provided via participation in international conferences (e.g. International Seagrass Biology Workshop) and international working groups. For example, as a core member of the International Science Council Scientific Committee on Oceanic Research (SCOR) Working Group 158, on Coordinated Global Research Assessment of Seagrass Systems (C-GRASS) (SCOR C-Grass), the IKI SES Project provided an opportunity to demonstrate how local stakeholders can collect globally standardised EOVs and collect field validation data which is critical for the creation of maps.

Seagrass-Watch advocates the publication of data and results in open access formats. Project-derived seagrass ecosystem services data is being published on Pangaea (pangaea.de), which enables sharing with open-access databanks, e.g., Global Biodiversity Information Facility (gbif.org). The data publications are currently in review, but acceptance is expected before the end of 2023, at which time each dataset will be assigned a DOI and data openly accessed from the publisher. The publications currently under review include:

Gomes, J., Lay, C.M., Ximenes, P., Dos Reis Pereira, A.F., Martins, J.D., Amaral, N.M.S., Bartlett, A., Lewis, R., Langlois, L., Yoshida, R.L., and McKenzie, L.J. (2023). Seagrass community data derived from field surveys at Hera Bay, Timor-Leste, conducted between 30 November 2022 and 08 March 2023. *PANGAEA* [In Review].

Palahan, R., Sanitmat, O., Mueangklang, P., Juthamat, C., Jitpakdee, T., Buadoktoom, K., Choongan, R., Kongtee, C., Wirachwong, P., Pengkasit, K., Langlois, L., Yoshida, R.L., and Mckenzie, L.J. (2023). Seagrass community data derived from field surveys at Koh Libong, Modtanoi, and Koh Mook (Trang, Thailand) conducted between 03 April and 12 May 2023. *PANGAEA* [In Review].

Lopez, M.R.C., Ibrahim, A.A., Langlois, L., Yoshida, R.L., and Mckenzie, L.J. (2023). Seagrass community data derived from field surveys within Ulugan Bay, Palawan (Philippines) conducted between 13 October 2022 and 19 April 2023. *PANGAEA* [In Review].

Digdo, A.A., Dandoro, A.A., Septiani, C., Sagai, B., Arendege, J., Langlois, L., Yoshida, R.L., and Mckenzie, L.J. (2023). Seagrass community data derived from field surveys around Northern Minahasa, North Sulawesi (Indonesia) conducted between 18 January and 26 June 2023. *PANGAEA* [In Review].

CONCLUSIONS

The IKI SES Project demonstrated that identifying the needs of local communities and building the capacity of groups to assess critical seagrass habitats can be successfully achieved for conservation outcomes.

The IKI SES Project successfully implemented a new, collaborative approach bringing together a variety of stakeholders, local NGOs and technical partners to map the extent and health of seagrass meadows using a combination of remote sensing, field validation and machine learning. Significant knowledge gaps have been filled, providing the critical underlying data for quantification of seagrass ecosystem services. We have also suggested a pathway to improving the quantification of seagrass ecosystem services, by expanding the existing models to include local seagrass species.

A key finding from the project was a high interest in assessment and monitoring beyond intertidal habitats. The inclusion of new technologies was embraced by the National Partners as this now provides them with the capacity to assess subtidal seagrass resources which tend to be greatly overlooked. National Partners now have the demonstrated skills and capacity to continue collecting field validation data on seagrass resources, globally standardised protocols, beyond the current project area of interest, and the tools to establish long-term monitoring at suitable sites.

A number of challenges were faced during the implementation of the IKI SES Project, the greatest of which was the COVID-19 pandemic. With a project firmly grounded on field work and on-ground training, project partners and the project management team had to be flexible and change approach as a consequence of travel restrictions, using innovated approaches to ensure project deliverables. The other challenge was in relation to the overall project management by CMS Dugong MOU. The original personnel had been deeply involved in the project from the inception, and had built strong, respectful and trusting partnerships with both Technical and National Partners. With a change of personnel in early 2022, the partnerships and coordination of the project suffered greatly. This highlighted the critical importance of recruiting personnel with the necessary skills, abilities and experience to manage a complex and multi-faceted project such as the IKI SES Project. Despite these challenges, Seagrass-Watch was able to deliver significant contributions to the project overall.

Seagrass-Watch is committed to continuing the genuine partnerships developed with the NPs beyond the completed of the IKI SES project, by co-designing and co-developing projects which support long-term monitoring efforts and research.

REFERENCES

1. Fourqurean, J.W., C.M. Duarte, H. Kennedy, N. Marba, M. Holmer, M.A. Mateo, E.T. Apostolaki, G.A. Kendrick, D. Krause-Jensen, K.J. McGlathery, and O. Serrano. 2012, Seagrass ecosystems as a globally significant carbon stock. *Nature Geoscience, 5*(7), 505-509. doi: 10.1038/ngeo1477
2. Waycott, M., C.M. Duarte, T.J.B. Carruthers, R.J. Orth, W.C. Dennison, S. Olyarnik, A. Calladine, J.W. Fourqurean, K.L. Heck Jr., A.R. Hughes, G.A. Kendrick, W.J. Kenworthy, F.T. Short, and S.L. Williams. 2009, Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences USA, 106*(30), 12377-12381. doi: doi:10.1073/pnas.0905620106
3. Agardy, T., J. Alder, P. Dayton, S. Curran, A. Kitchingman, M. Wilson, A. Catenazzi, J. Restrepo, C. Birkeland, S. Blaber, S. Saifullah, G. Branch, D. Boersma, S. Nixon, P. Dugan, N. Davidson, and C. Vörösmarty, 2005, Coastal systems. In: R. Hassan, R. Scholes, and N. Ash (Eds.), Ecosystems and Human Well-being: Current State and Trends. Island Press, Washington, pp. 513-549.
4. Lee Long, W.J., L.J. McKenzie, M.A. Rasheed, and R.G. Coles, 1996, Monitoring Seagrasses in Tropical Ports and Harbours. In: J. Kuo, et al. (Eds.), Seagrass Biology: Proceedings of an International Workshop, Rottnest Island, Western Australia 25-29 January, 1996. Faculty of Sciences, The University of Western Australia, Perth, pp. 345-350.
5. Duffy, E. 2018, Essential Ocean Variables (EOV) for Biology and Ecosystems: Seagrass cover. *GOOS Framework-BioEcosystems*, 12.
6. Republika Demokratika Timor-Leste. (2016). Timor-Leste Population And Housing Census 2015 iha Wayback Machine (rai 2016-12-31) Retrieved 03 November 2023, from https://web.archive.org/web/20161231161557/http://www.statistics.gov.tl/wp-content/uploads/2016/11/1_2015-V4-Households-Population-by-5-year-age-group.xls
7. Audley-Charles, M.G. 2004, Ocean trench blocked and obliterated by Banda forearc collision with Australian proximal continental slope. *Tectonophysics, 389*(1), 65-79. doi: https://doi.org/10.1016/j.tecto.2004.07.048
8. Boggs, G., K. Edyvane, N. de Carvalho, S. Penny, J. Rouwenhorst, P. Brocklehurst, I. Cowie, C. Barreto, A. Amaral, N. Smit, J. Monteiro, P. Pinto, R. Mau, J. Amaral, and L. Fernandes, 2009, Marine and Coastal Habitat Mapping in Timor Leste (North Coast) – Final Report. Ministry of Agriculture & Fisheries, Government of Timor Leste, Dili, Timor Leste.
9. Asian Development Bank, 2014, State of the Coral Triangle: Timor-Leste. Asian Development Bank, Mandaluyong City, Philippines.
10. Boggs, G., K. Edyvane, N. de Carvalho, S. Penny, J. Rouwenhorst, P. Brocklehurst, I. Cowie, C. Barreto, A. Amaral, J. Monteiro, P. Pinto, R. Mau, N. Smit, J. Amaral, and L. Fernandes, 2012, Marine and Coastal Habitat Mapping in Timor Leste (North Coast) – Final Report. Project 1 of the Timor Leste Coastal-Marine Habitat Mapping, Tourism and Fisheries Development Project. Ministry of Agriculture & Fisheries, Government of Timor Leste, Dili, Timor Leste.
11. Joyce, K., 2013, Mapping and assessment of the coastal-marine habitats of Timor- Leste: South and northwest coasts. Charles Darwin University, Darwin, NT.
12. Erdmann, M., and C. Mohan (Eds.), 2013, A Rapid Marine Biological Assessment of Timor-Leste, RAP Bulletin of BiologicalAssessment 66. Conservation International, Coral Triangle Support Partnership, Dili, Timor Leste.
13. House, J.E., X. Magno, J. Monteiro, J. Lopes, S. de Araujo, R. Mendes, J. Gomes, D. Joaquim, N. Piludu, and L.J. McKenzie. 2020, Seagrass community data derived from field surveys at Atauro Island and north coast Timor-Leste, conducted April 2017 to June 2018. *PANGAEA*. doi: https://doi.org/10.1594/PANGAEA.912824
14. Allen Coral Atlas. (2020). Imagery, maps and monitoring of the world's tropical coral reefs. doi.org/10.5281/zenodo.3833242 Retrieved 01 February 2020, 2020, from allencoralatlas.org
15. UNESCO, 2002, An ecological assessment of Ulugan Bay, Palawan, Philippines. CSI info N° 12. United Nations Educational, Scientific and Cultural Organization, Paris.
16. Fortes, M., 2008, National report on seagrass in the South China Sea – Philippines. In: UNEP (Ed.), National reports on seagrass in the South China Sea. UNEP/GEF/SCS Technical Publication No. 12. United Nations Environment Programme, Bangkok, Thailand, p. 20.
17. Fortes, M., and S. Fazi, 2001, Ecology of Ulugan Bay. In: S. Fazi and P. Flewwelling (Eds.), Coastal resources management:Ecology, culture and socio-economics UNESCO, Environmental and Development in Coastal Region and Small Islands, Jakarta, pp. 1–43.
18. PCSDS. 2006, Baseline Report on Coastal Resources for Puerto Princesa City. 183.
19. Census of Population. 2020, "Mimaropa". Total Population by Province, City, Municipality and Barangay.

20. WWF-Philippines, 2008, Roxas, Palawan, Philippines: A Coastal Environmental Profile. Baseline Survey Reports 2004-2005. Compiled by the Roxas Population, Health and Environment (PHE) Project. WWF-Philippines, Roxas, Palawan.
21. Thai Meteorological Department. (2022). http://www.tmd.go.th/en Retrieved 3 April 2022
22. Department of Marine and Coastal Resources. 2016, Guidelines for conservation and seagrass restoration methods by transplanting. 45.
23. Nakanishi, Y., S. Hosoya, Y. Nakanishi, N. Arai, and A. Kanjana. 2005, The distribution of dugong trenches in the seagrass beds of Libong Island, Thailand. *Journal of Advanced Marine Science and Technology Society, 11*(1), 53-57. doi: 10.14928/amstec.11.1_53
24. Khogkhaoa, C., K.-i. Hayashizakib, P. Tuntiprapasa, and A. Prathepa. 2017, Changes in seagrass communities along the runoff gradient of the Trang river, Thailand. *ScienceAsia, 43*, 339-346. doi: doi: 10.2306/scienceasia1513-1874.2017.43.339
25. Stankovic, M., K.-I. Hayashizaki, P. Tuntiprapas, E. Rattanachot, and A. Prathep. 2021, Two decades of seagrass area change: Organic carbon sources and stock. *Marine Pollution Bulletin, 163*, 111913. doi: https://doi.org/10.1016/j.marpolbul.2020.111913
26. Dugong MOU. (2011). *UNEP/CMS for Southeast Asia Sub-Regional Meeting on Dugongs and Workshop on Developing Standardised Analysis Protocols for Dugong Questionnaire Survey Project Data for South East Asia region*, Sri Malaysia Hotel, Lawas, Sarawak, Malaysia on 26 – 29 July 2011.
27. Heng, W.-K., J.L.-S. Ooi, and L.S. Ponnampalam. 2018, Strategic or Opportunistic? – Subtidal Seagrass Use by Dugongs in the Sibu-Tinggi Archipelago, Johor, Malaysia. Poster for the *4th Asia-Pacific Coral Reef Symposium : Coral reefs of the Asia-Pacific: working together amidst contemporary challenges, 4-8 June 2018,* .
28. Ooi, J.L.S., and A.C.O. Lim. 2019, Seagrasses and Syngnathid fish of Pulau Sibu, Johor. *Malayan Nature Journal 71*(3), 361-365.
29. Firdauz, S.N., T. Golingi, and M. Oliver. 2008, Detailed Environmental Impact Assessment and hydraulic studies for the proposed Mersing Laguna reclamation. 88.
30. Ponnampalam, L.S., J.H. Fairul Izmal, K. Adulyanukosol, J.L.S. Ooi, and J.E. Reynolds. 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
31. Bonnet, A., 2016, Status of dugongs in relation to intertidal and shallow subtidal seagrass beds and human induced threats in North Sulawesi, Indonesia: Internship report. French National Agronomy Engineering Faculty, INP-ENSAT, Toulouse, France.
32. Tolule, K., A.D. Kambey, and A.B. Rondonuwu. 2016, Community Structure of Seagrass in Coastal Waters of Bahoi Village, West Likupang Sub-district, North Minahasa Regency, North Sulawesi Province. *Jurnal Ilmiah Platax, 3*(2), 63-67.
33. Takaendengan, K., and M.H. Azkab. 2010, Struktur Komunitas Lamun di Pulau Talise, Sulawesi Utara. *Oseanologi dan Limnologi, 36*(1), 85-95.
34. Kamarrudin, Z.S., S.B. Rondonuwu, and P.V. Maabuat. 2016, Keragaman Lamun (Seagrass) di Pesisir Desa Lihunu Pulau Bangka Kecamatan Likupang Kabupaten Minahasa Utara, Sulawesi Utara. *Jurnal MIPA, 5*(1), 20-24.
35. Badan Pusat Statistik, 2023, Kecamatan Likupang Barat, Dalam Angka (Likupang Barat Subdistrict in Figures) 2023. Central Bureau of Statistics, Jakarta.
36. Syahailatua, A., and S. Nuraini. 2011, Fish species composition in seagrass beds of Tanjung Merah (north Sulawesi), Indonesia. *Marine Research in Indonesia, 36*(2), 1-10.
37. McKenzie, L.J., L.A. Langlois, and C.M. Roelfsema. 2022, Improving Approaches to Mapping Seagrass within the Great Barrier Reef: From Field to Spaceborne Earth Observation. *Remote Sensing, 14*(11), 2604. doi: doi:10.3390/rs14112604
38. Planet Team. 2017, Planet Application Program Interface: In Space for Life on Earth.
39. McKenzie, L.J., M.A. Finkbeiner, and H. Kirkman, 2001, Methods for mapping seagrass distribution. In: F.T. Short and R.G. Coles (Eds.), Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam, pp. 101-121.
40. Planet. 2021, Planet imagery product specifications. 100.
41. Kuhn, M. 2008, Building Predictive Models in R Using the caret Package. *Journal of Statistical Software, 28*(5), 1-26. doi: doi:10.18637/jss.v028.i05
42. GEBCO Compilation Group. 2023, General Bathymetric Chart of the Oceans (GEBCO) 2023 Grid. doi: doi:10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b
43. Pebesma, E. 2004, Multivariable geostatistics in S: the gstat package (version 2.1-0). *Computers & Geosciences, 30*, 683-691.

44. Jones, B.L., R.K.F. Unsworth, L.J. McKenzie, R.L. Yoshida, and L.C. Cullen-Unsworth. 2018, Crowdsourcing conservation: The role of citizen science in securing a future for seagrass. *Marine Pollution Bulletin, 134*, 210-215. doi: https://doi.org/10.1016/j.marpolbul.2017.11.005

45. Kilminster, K., K. McMahon, M. Waycott, G.A. Kendrick, P. Scanes, L. McKenzie, K.R. O'Brien, M. Lyons, A. Ferguson, P. Maxwell, T. Glasby, and J. Udy. 2015, Unravelling complexity in seagrass systems for management: Australia as a microcosm. *Science of The Total Environment, 534*, 97-109. doi: http://dx.doi.org/10.1016/j.scitotenv.2015.04.061

46. Lyons, M., C. Roelfsema, E. Kovacs, J. Samper-Villarreal, M. Saunders, P. Maxwell, and S. Phinn. 2015, Rapid monitoring of seagrass biomass using a simple linear modelling approach, in the field and from space. *Marine Ecology Progress Series, 530*, 1-14. doi: 10.3354/meps11321

47. Collier, C.J., L. Langlois, R. Zemoi, K. Martin, and L.J. McKenzie, 2016, Developing and refining biological indicators for condition assessments in an integrated monitoring program. Report to the National Environmental Science Programme. Reef and Rainforest Research Centre Limited, Cairns.

48. Collier, C.J., L.A. Langlois, K.M. McMahon, J. Udy, M. Rasheed, E. Lawrence, A.B. Carter, M.W. Fraser, and L.J. McKenzie. 2021, What lies beneath: Predicting seagrass below-ground biomass from above-ground biomass, environmental conditions and seagrass community composition. *Ecological Indicators, 121*, 107156. doi: https://doi.org/10.1016/j.ecolind.2020.107156

49. Blue Ventures Timor-Leste. 2023, Data sharing showcases the potential power seagrass meadows hold for small-scale fishers in Timor-Leste. (1).

APPENDIX 1

Standardised Quadrat (0.25m^2)

Quadrats are a fixed unit area, usually square, of equal size to represent a small area within a larger area, when that larger area is unrealistic to sample. The recommended standardised unit area for assessing seagrass is fixed at 500 x 500 mm (0.25 m^2), internal dimensions (Fig Appx-2.1a). Quarter metre squared quadrats are easily transported and handled in the field, and the measures can be scaled to 1m^2 with minimal propagation of error.

Quadrats can be constructed using a variety of materials (e.g. PVC piping, wood), however, we recommend 4 mm or 6 mm diameter marine grade stainless steel (Fig Appx-2.1b)., for strength and durability (i.e. it is difficult to distort and lasts for many years). Stainless steel quadrats also have sufficient weight to stabilised on the seabed, have minimal profile on the seabed (preventing shadows from obscuring features when photographing), and the minimal stature (4-6mm) does not distract the observer when collecting measures.

If an alternative material (e.g. 20mm Class 12 PVC Pressure Pipe) is selected due to costs or accessibility to marine grade stainless steel and fabrication, the quadrat should be weighted or have holes in them so they sink.

Seagrass-Watch does not recommend the use of strings to partition quadrats, as this flattens the seagrass leaves to the seabed, resulting in inflated abundance measures, particularly if water depth is greater than leaf height/length. The use of strings also obscures features, making observations challenging, and renders quadrat photographs unusable for image analysis.

a. **b.**

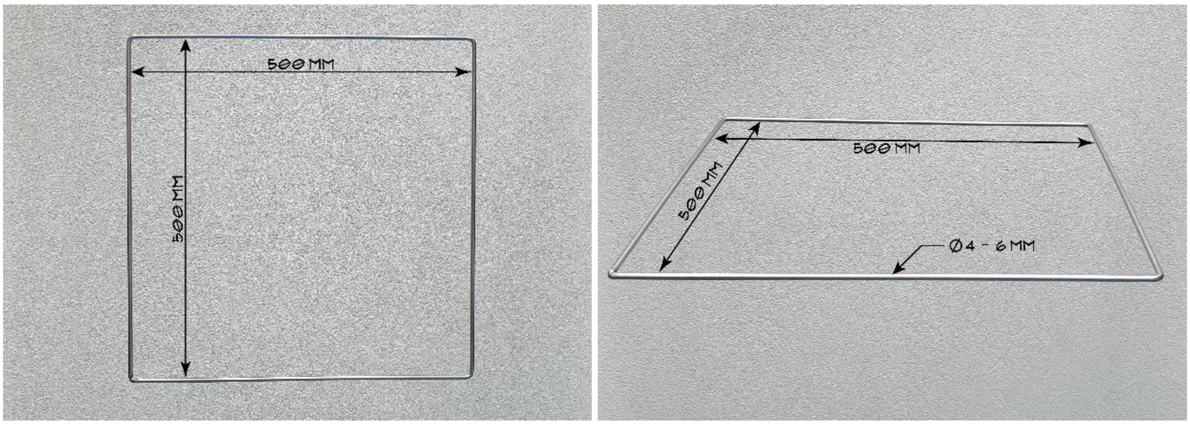


Figure Appx-2.1. Standardised quadrat constructed from marine grade stainless steel, shown in plan view (a) and oblique view (b).

Drop-camera assembly

Subtidal seagrass can be visually assessed using a real-time underwater closed circuit drop camera assembly which includes an action camera (e.g. GoPro® HERO®8 Black) mounted to a frame with a 0.25 m^2 quadrat in the field of view. The live image from the action camera is transmitted underwater via the camera's 2.4 GHz WiFi and Bluetooth signal using a high quality coaxial cable (WiFi Extension Cable) back to a surface SmartPhone/Tablet (mobile operating system) for live viewing and recording. The HERO®8 Black captures professional-quality 1080p240 video and the built-in Wi-Fi enables the use of the GoPro App which provides real time video monitoring via the SmartPhone/Tablet and complete control over the camera settings.

No direct connection is required to a camera, Apple or Android product, however the modules at each end (wet and dry) of the cable must be mounted in close proximity to surface and underwater devices to work. As the interface is wireless, the camera's underwater housing remains un-compromised and so the system can operate down to the specified operational depth of the housing.

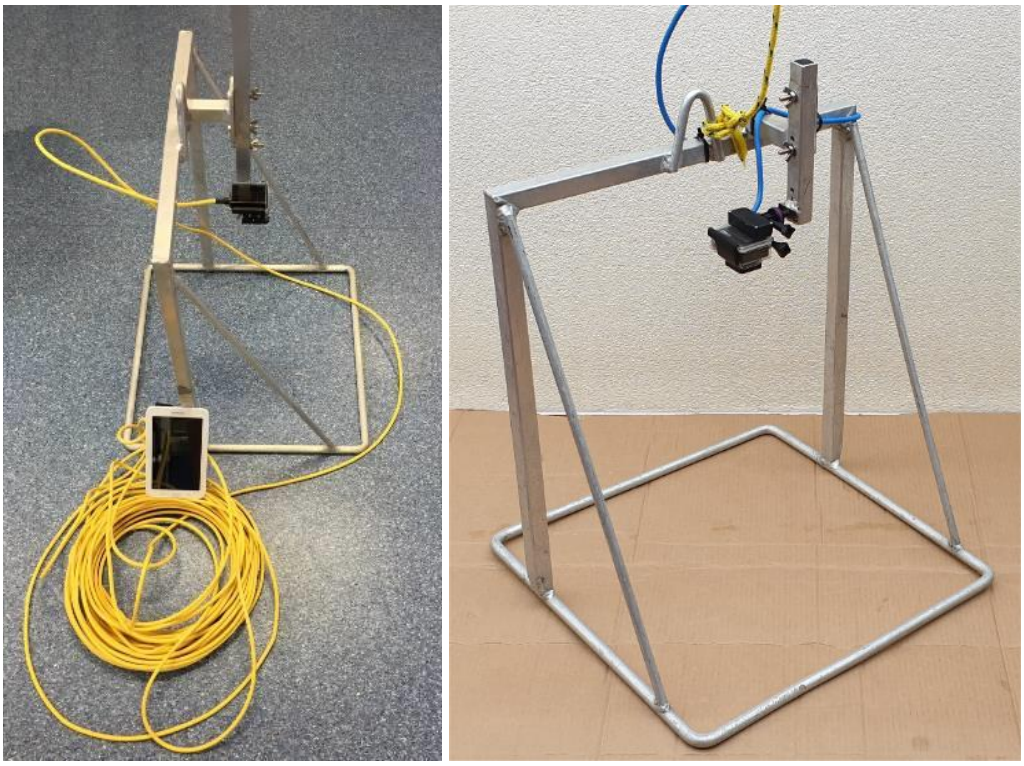


Figure Appx-2.2. Drop camera assembly. Note GoPro® fixed at correct height to ensure 0.25m2 quadrat is within field of view and focus, and Tablet with App to control GoPro, view and record image.

Prior to deployment, fix WiFi Extension cable along length of marine grade rope using cable ties, to ensure the weight of the frame is supported by the rope and not the WiFi Extension cable.

Figure Appx-2.3. Deployment of drop camera, with one operator controlling in-water frame assembly and the other operator checking images live from GoPro (note: screen operator requiring to shelter under towel to reduce screen glare).

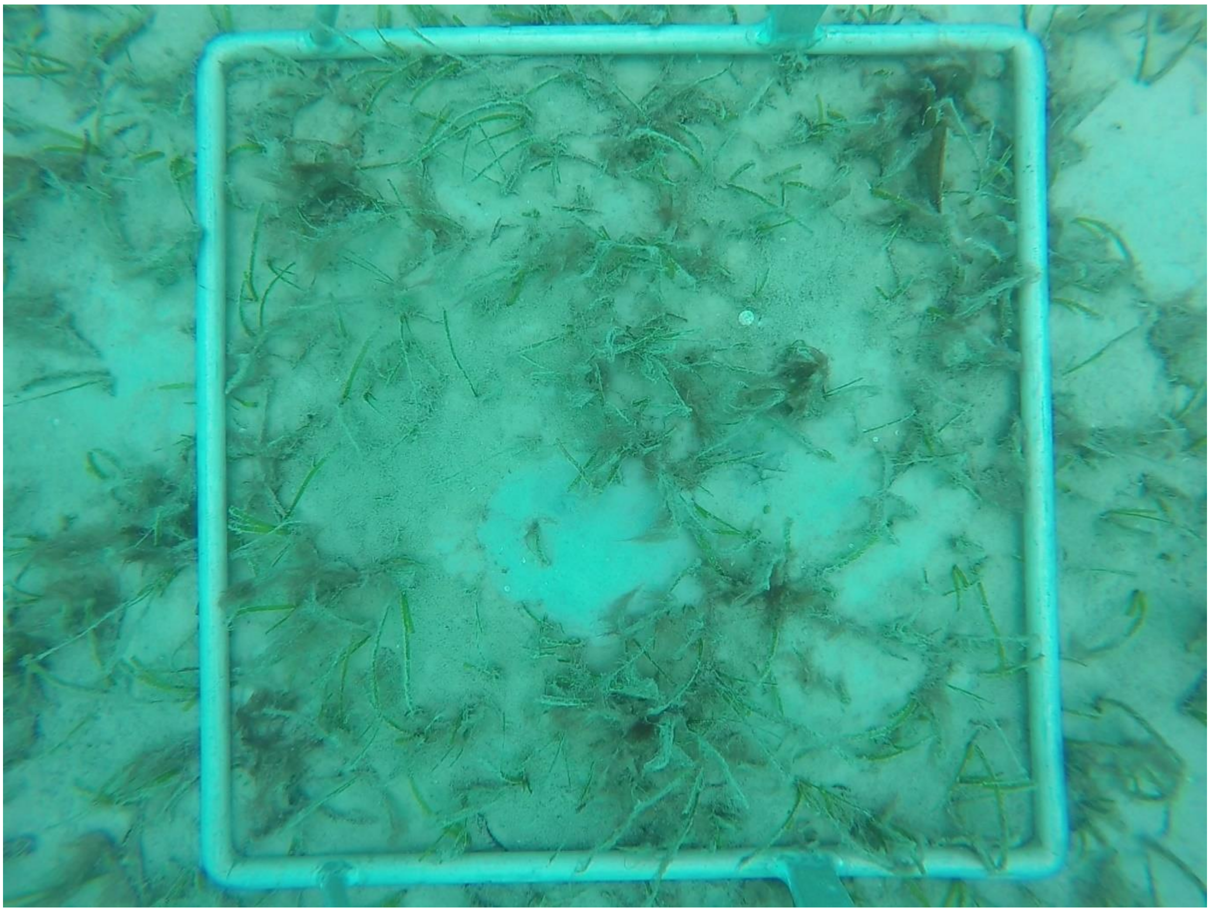
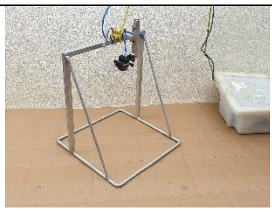


Figure Appx-2.4. Example of digital still image of benthos captured using drop-camera assembly, showing action cameras field of view filled with 0.25 m^2 quadrat at base of frame.

Item		**Specifications**
GoPro HERO 8 Black		Camera must have capability to simultaneously record and WiFi. *NB: This feature is only available up to GoPro HERO 8 Black. New versions no longer support this feature.* • Weight: <150g • Dimensions: 66.3W x 48.6H x 28.4D (mm) • Video: 4K60, 2.7K120, 1080P240 • Photo: 12MP • Max video bit rate: 100Mbps (4K) • Connectivity: Wi-Fi, Bluetooth • Digital lenses: SuperView, Wide, Linear, Narrow • Burst: 12MP 3-30fps with options of 1-10 seconds • Time Lapse: 0.5, 1, 2, 5, 10, 30-second intervals • Waterproofing: 10m (33ft) without a case • GPS: Yes • Battery: removable 1220mAh lithium-ion • Stabilisation: HyperSmooth • HDR: auto HDR processing • Live Streaming: Yes • Memory storage: microSD with at least class 10 or UHS-I rating
Underwater Housing for action camera		Housing must have a flat back and 2pin action camera pivot mount to enable optimal interface with Wet-end of WiFi Extension cable. *Please note:* GoPro genuine housing for GoPro HERO 8 Black has a slightly raised back, which does not provide optimal interface. 
WiFi Extension cable 15-30m	   	WiFi Extension Cable extends the use of WiFi and Bluetooth control of action cameras underwater. • At the wet end, the WiFi extension interfaces wirelessly with the action camera (in water proof housing), and attaches to the "2pin action camera pivot mount" of the waterproof camera housing. • At the dry end, the WiFi extension interfaces wirelessly with any Tablet or SmartPhone. The interface can be attached to the back of the SmartPhone/Tablet using velcro or 3M double sided removable mounting squares. *NB:* The cables are available in lengths of 7, 15, 38 and 90 metre lengths. You should note that signals will decay over distance and may require boosting. *High quality coaxial WiFi Extension cables can be purchased online: e.g.*

Item		Specifications
		https://seesense.eu/shop/camdo-underwater-wifi-extension-cables/
Tablet (or SmartPhone)	 	• is needed to view streamed video from the WiFi Extension cable. No requirement for large SSD storage, but option of expandable memory useful.
Waterproof pouch for Tablet (or SmartPhone)		• size to suit • minimum 2 metre waterproof
Drop-camera frame		Constructed of light-weight aluminium, with 0.25m^2 quadrat at base. *See next section on construction details.*
Rope (10-12mm diameter) 30-50m length		UV stable, 100% polyester
Plastic Scratch Tray - White		e.g. 445L x 315W x 58H mm
52L Plastic container with lid		For storage of ropes
Miscellaneous		• Cable ties

Van Veen grab sampler

The Van Veen grab sampler is used to sample sediment and benthos in water environments. Invented by Johan van Veen (a Dutch engineer) in 1933, the grab is usually a clamshell bucket made of stainless steel. A smaller grab is suitable for seagrass benthic assessments. Benthic samples up to 10 cm deep of roughly 250 cm^2 (0.025 m^2) can be extracted with this instrument. It can be light-weight (roughly 5 kg) and low-tech.

The Van Veen grab sampler consists of two buckets connected by a hinge. During the descent, the two buckets remain apart. When it hits the bottom, the locking mechanism releases, and when the main line is pulled to retrieve the grab, the buckets close allowing the collection of the sample.

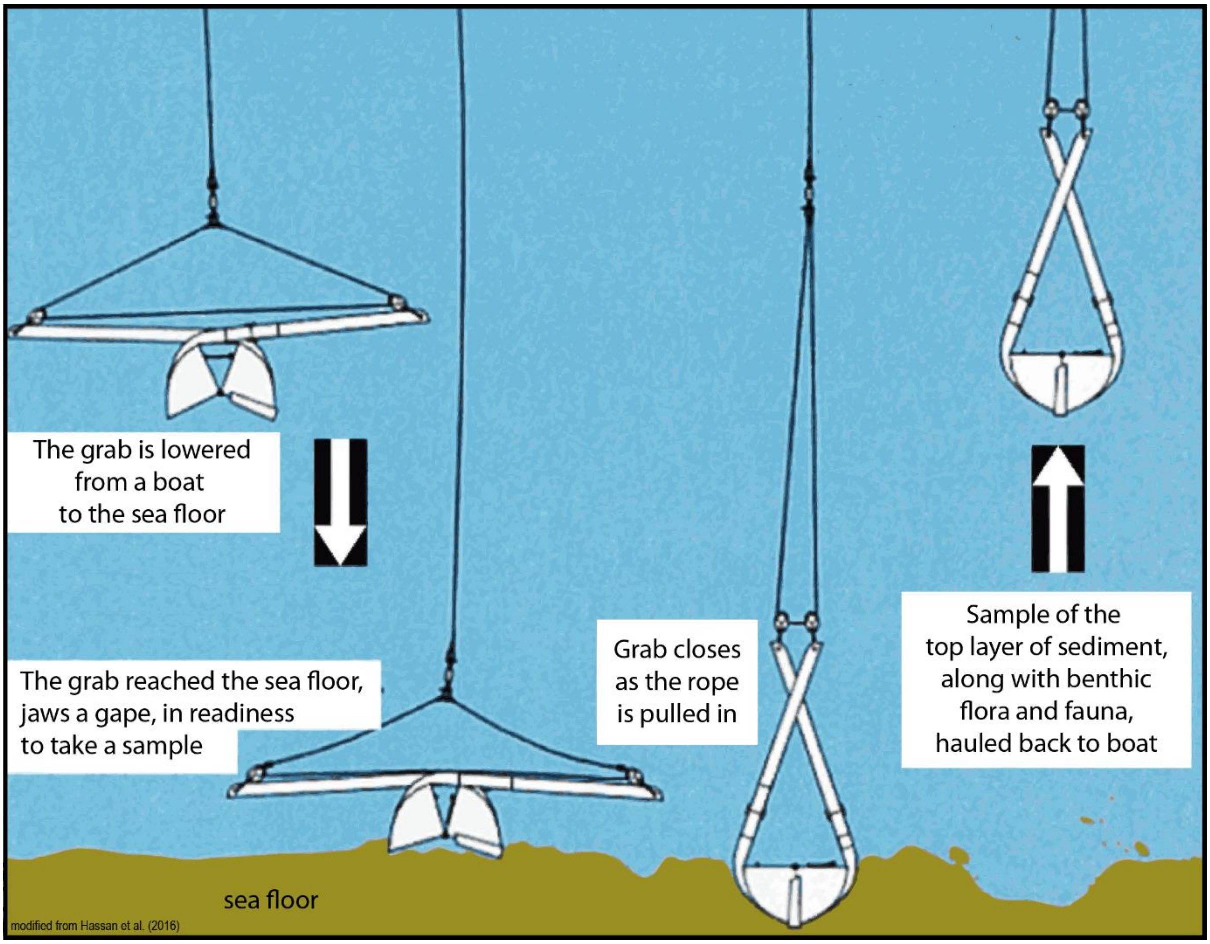


Figure Appx-2.4. Van Veen grab deployment for collection of benthic sample.

For details on how to collect a benthic sample, see the following section.

Van Veen grabs can be purchased from a number of scientific/laboratory supply providers, or they can be locally constructed by a metal fabricator.

For materials and specifications for fabrication of a Van Veen grab sampler, see below.

Collecting a benthic grab sample:

1. At the surface (on a vessel), the locking mechanism is first "triggered", by spreading the two bucket arms (with buckets at their ends) like an open scissor and securing the locking mechanism hook into the lock hook catch by. The mechanism is kept locked in position, by maintaining a tension on the main line (rope) which keeps the arms spread.

2. Lower the sampler down into the water, maintaining tension on the main line to ensure the bucket arms are spread and the sampler triggered.

3. Once the sampler is just below the water surface, release some tension from the rope, to allow the sampler to fall directly to the seabed. Keep minimal tension on the main line to ensure the sampler falls freely, but controlled.

4. When the sampler hits the seabed, release remaining tension on the main line and the samplers weight should allow the buckets to "bight" into the surface layer of the sediment. When this occurs, the bucket arms will also fall toward the seabed, releasing the trigger (i.e. lock hook fall free of catch).

5. When the rope is pulled upward again, the two buckets close and grab (scoop) a sample from the sea floor. The sampler is then retrieved (hauled) back to the surface.

6. At the surface (on the vessel), the sampler is placed in a plastic tray and the buckets opened to dispense the sample.

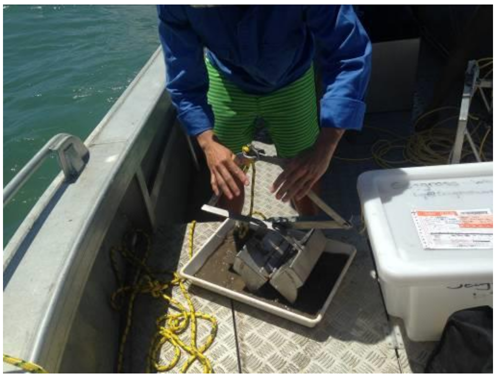


Figure Appx-2.5. Van Veen grab, required to check sediment grain size (left) and verify seagrass species (right).

Hints:

- To ensure the buckets dig into the sea floor, additional weights can be added. This can be important if the seabed is firm.

- If the buckets do not have lids, you may need to release any trapped air to ensure a maximum sample. You can release air from the bucket, before dropping to the seafloor, by lowering the open sampler into the water and gently swinging the sampler from side to side. You should see large air bubble be released.

You can also view examples of Van Veen grab sampler deployment and retrieval online at
https://www.youtube.com/watch?v=n96eNMozTrM
https://www.youtube.com/watch?v=nmfJRg6f2HQ

Contact

Seagrass-Watch Ltd
PO Box 4, Clifton Beach, QLD 4879
AUSTRALIA

www.seagrasswatch.org
admin@seagrasswatch.org