

# Seagrass-Watch

Proceedings of a workshop for assessment  
and monitoring of seagrass habitats in the  
Pacific Island nations of Melanesia

*Southern Cross Hotel, Suva  
10-16 July 2025*

Len McKenzie & Rudi Yoshida

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Front cover photos (left to right) by Len McKenzie: *Halodule uninervis* and *Syringodium isoetifolium* meadow, Natodola, Fiji (Aug11); *Enhalus acoroides* and *Thalassia hemprichii* meadow, Erakor Lagoon, Vanuatu (Aug17); and *Enhalus acoroides*, *Cymodocea rotundata* and *Halodule uninervis* meadow, Kaveing, Papua New Guinea (Aug04).

Enquires should be directed to:

Seagrass-Watch HQ  
Clifton Beach QLD 4879 AUSTRALIA  
[admin@seagrasswatch.org](mailto:admin@seagrasswatch.org)



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Southern Cross Hotel, 63 Gordon Street, Suva

This training event is organised by the Secretariat of the Pacific Regional Environment Programme (SPREP), with funding provided by the Management of Blue Carbon Ecosystems in Pacific Island Countries (MACBLUE) Project.

The MACBLUE project is being implemented in Fiji, Papua New Guinea, the Solomon Islands, and Vanuatu, and has the following five key overall outputs:

1. National mapping of mangroves and seagrass ecosystems
2. Ecosystem valuation with emphasis on carbon stock, emission factors and anthropogenic threats
3. Blue carbon policy and institutional strengthening
4. Implementation of local management approaches
5. Communication of proven concepts, project results and best practices.

The seagrass monitoring and mapping training workshop will provide the necessary skills and knowledge and enhance the technical capacity of the government partners. The training will enhance participants' skills in collecting data and information critical for the management and conservation of not only seagrass habitat but other important marine resources. Such information when analysed is useful to inform the policy and management measures for seagrass habitats. The training contributes directly to Outputs 1, 2 and 4 of the overall MACBLUE project.

# Overview

Seagrass-Watch is a global seagrass observing network, where scientists, coastal managers and local stakeholders from across the globe collaborate to assess the status of their seagrass meadows to provide an early warning of coastal ecological decline. The program started in 1998 in Australia, using standardised global monitoring protocols, and has so far expanded to include 445 sites and 33 countries. Anyone can participate in Seagrass-Watch, as it responds to local needs, and includes elements of citizen science. Seagrass-Watch is a monitoring program that brings people together for seagrass conservation.

Seagrass-Watch implements a globally standardised seagrass assessment and monitoring protocol, that has a rigorous quality assurance and quality control procedure to ensure data is of the highest quality and that time and resources are not wasted. The only condition is that on-ground data collection must be overseen by a qualified scientist or trained and competent participant (18 years or over). The program identifies areas important for seagrass species diversity and conservation. The information collected can be used to assist the management of coastal environments and to prevent significant areas and species being lost.

Monitoring seagrass resources is important for two reasons: it is a valuable tool for improving management practices; and it allows us to know whether resource status and condition is stable, improving or declining. Successful management of coastal environments (*including seagrass resources*) requires regular monitoring of the status and condition of natural resources. Early detection of change allows coastal management agencies to adjust their management practices and/or take remedial action sooner for more successful results. Monitoring is important in improving our understanding of seagrass resources and to coastal management agencies for:

- *exposing coastal environmental problems before they become intractable,*
- *developing benchmarks against which performance and effectiveness can be measured,*
- *identifying and prioritising future requirements and initiatives,*
- *determining the effectiveness of management practices being applied,*
- *maintaining consistent records so that comparisons can be made over time,*
- *developing within the community a better understanding of coastal issues,*
- *developing a better understanding of cause and effect in land/catchment management practices,*
- *assisting education and training, and helping to develop links between local communities, schools and government agencies, and*
- *assessing new management practices.*

Seagrass-Watch monitoring efforts are vital to assist with tracking global patterns in seagrass health, and assess the human impacts on seagrass meadows, which have the potential to destroy or degrade these coastal ecosystems and decrease their yield of natural resources. Responsive management based on adequate information will help to prevent any further significant areas and species being lost. To protect the valuable seagrass meadows along our coasts, everyone must work together.

The goals of the Seagrass-Watch program are:

- *to educate the wider community on the importance of seagrass resources*
- *to raise awareness of coastal management issues*
- *to build the capacity of local stakeholders in the use of standardised scientific methodologies*
- *to conduct long-term monitoring of seagrass & coastal habitat condition*
- *to provide an early warning system of coastal environment changes for management*
- *to support conservation measures which ensure the long-term resilience of seagrass ecosystems.*

This workshop is for experienced participants who may plan to participate and/or lead in seagrass monitoring events or conduct seagrass extension activities. Presentations are targeted at participants with a moderate proficiency in English and an education level of year 12 to first year university. As part of the Level 1 workshop we will:

- *study seagrass biology;*
- *learn seagrass taxonomy;*
- *discuss the present knowledge of seagrass ecology, including importance and threats;*
- *gain knowledge of monitoring;*
- *learn about the Seagrass-Watch program and techniques for monitoring seagrass resources; and*
- *become skilled at conducting a Seagrass-Watch field monitoring event.*

The following information is provided as a training guide and a reference for future Seagrass-Watch mapping and monitoring activities. For further information, please do not hesitate to contact us at

**Seagrass-Watch HQ**  
PO Box 4  
Clifton Beach QLD 4879  
AUSTRALIA  
E-mail [admin@seagrasswatch.org](mailto:admin@seagrasswatch.org)



Photo: Mikael Eriksson

# Workshop trainers



## Len McKenzie

Len is the Director of Seagrass-Watch and a Principal Researcher with James Cook University. He is a seagrass Technical Advisor for the CMS Dugong MoU, Project Manager of the Great Barrier Reef 2050 Plan Marine Monitoring Program – Inshore Seagrass Monitoring, a full member on the SCOR Working Group 158 for Coordinated Global Research Assessment of Seagrass System (C-GRASS), member of the IUCN Seagrass Specialist and Sirenian Specialist Groups, and principal investigator for a series of projects involving the assessment and sustainable use of coastal habitats. Len has over 25 years' experience as a researcher on seagrass ecology, assessment and fisheries habitats. This includes experience globally in seagrass research, resource mapping/ assessment, and biodiversity. He has provided information on seagrass ecosystems that has been vital in management of seagrass resources of the Great Barrier Reef, South East Asia and the Indo-Pacific. He has also advised on fisheries and coastal resource-use issues for managers, fishing organisations, conservation and community groups. Len is a qualified trainer and assessor (Cert IV TAE40110). Len is also the Secretary of the World Seagrass Association.

### **Current Projects**

- Seagrass-Watch
- Great Barrier Reef Marine Monitoring Program: inshore seagrass
- Status and mapping of seagrass resources in the Indo-Pacific
- Identification of indicators and thresholds of concern for water quality and ecosystem health on a bioregional scale for the Great Barrier Reef
- Seagrass resilience: seagrass connectivity, community composition and growth
- Restoration and enhancement of tropical seagrass meadows
- Investigations on the macrofauna associated with seagrass meadows.



## Rudi Yoshida

Rudi is the Seagrass-Watch Data Manager/Admin officer and a Researcher with James Cook University. Rudi has over 20 years' experience in seagrass related research and monitoring. He is also a core member of Seagrass-Watch HQ, and ensures data submitted is managed and QA/QC protocols applied. He is also responsible for maintenance of the Seagrass-Watch website and assists with training workshops.

### **Current Projects**

- Seagrass-Watch
- Great Barrier Reef Marine Monitoring Program: inshore seagrass
- Status and mapping of seagrass resources in the Indo-Pacific

# Agenda - Level 1

## Thursday 10<sup>th</sup> July 2025 (Southern Cross Hotel, Suva )

0830 - 0900 (30min)	Sign in (training will start at 900 sharp)
0900 - 0915 (15min)	Welcome & Introduction
0915 - 0945 (30min)	Seagrass Biology and Taxonomy
0945 - 1030 (45min)	Seagrass Identification
1030 - 1100 (30min)	<i>Break</i>
1100 - 1145 (45min)	Seagrass Identification <i>continued</i>
1145 - 1230 (45min)	Seagrass Biology 2 and Ecology
1230 - 1315 (45min)	<i>Lunch</i>
1315 - 1445 (90min)	Seagrass importance
1445 - 1515 (30min)	Seagrass monitoring
1515 - 1530 (15min)	<i>Wrap up for day</i>

## Friday 11<sup>th</sup> July 2025 (Southern Cross Hotel, Suva & Nasese)

0800 - 0815 (15min)	recap day 1
0815 - 0930 (75min)	Seagrass-Watch: how to sample
0930 - 0945 (15min)	<i>Break</i>
0945 - 1100 (75min)	Seagrass-Watch: how to sample + ID refresher
1100 - 1115 (15min)	Risk assessment
1115 - 1200 (45min)	<i>Lunch &amp; relocate to Nasese field site</i>
1200 - 1500 (3hrs)	<b>Field exercise:</b> Seagrass-Watch monitoring <i>Where:</i> Nasese (SV1) ( <i>low tide: 1307 0.50m</i> ) <i>What to bring:</i> <ul style="list-style-type: none"> <li>• <i>hat, sun protection</i></li> <li>• <i>dive booties or old shoes that can get wet</i></li> <li>• <i>drink/refreshments</i></li> </ul>
1500 - 1515 (15min)	<i>Wrap up for day 2</i>

## Monday 14<sup>th</sup> July 2025 (Southern Cross Hotel, Suva)

0900 - 0915 (15min)	recap day 2
0915 - 1030 (75min)	Seagrass threats
1030 - 1100 (30min)	<i>Break</i>
1100 - 1145 (45min)	Seagrass-Watch: QAQC
1145 - 1230 (45min)	Seagrass-Watch: how data is used
1230 - 1245 (15min)	Discussion and Intertidal monitoring close
1245 - 1330 (45min)	<i>Lunch</i>
1330 - 1415 (45min)	Mapping seagrass: background + mapping strategies
1415 - 1500 (45min)	Mapping seagrass: intertidal spot-checks
1500 - 1515 (15min)	<i>Wrap up for day 3</i>

## Tuesday 15<sup>th</sup> July 2025 (Southern Cross Hotel, Suva & Nasese)

0900 - 0915 (15min)	recap day 3
0915 - 0945 (30min)	Mapping seagrass: planning a mapping exercise
0945 - 1045 (60min)	Mapping seagrass: <i>GNSS background</i>
1045 - 1115 (30min)	<i>Break &amp; relocate to Nasese foreshore</i>
1115 - 1230 (75min)	<b>Field exercise:</b> <i>using a GNSS practical</i>
1230 - 1330 (60min)	<i>Lunch</i>
1330 - 1345 (15min)	Risk Assessment
1345 - 1615 (2.5hrs)	<b>Field exercise:</b> mapping Nasese fringing reef flat Intertidal Spot-checks ( <i>low tide: 1550 0.49m</i> )
1615 - 1630 (15min)	<i>Wrap up for day</i>

## Wednesday 16<sup>th</sup> July 2025 (Southern Cross Hotel, Suva)

0900 - 0915 (15min)	recap day 4
0915 - 1030 (75min)	Mapping seagrass: <i>downloading &amp; data entry</i>
1030 - 1100 (30min)	<i>Break</i>
1100 - 1200 (60min)	Mapping seagrass: <i>approaches to map creation &amp; visualisation</i>
1200 - 1300 (60min)	Workshop discussion, feedback & Close

### Notes:

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# Assessment requirements

To successfully attain a **Certificate of Achievement**, you will need to demonstrate you have the knowledge, skills, abilities and experience to competently conduct monitoring using Seagrass-Watch protocols.

Successful achievement must to be demonstrated across 9 core units, by completing:

- 1 a training workshop (classroom, laboratory and field), and
- 2 three post workshop monitoring events (within 12 months)

## **Training workshop (6 units)**

*Demonstrates you have the knowledge, skills and abilities to conduct monitoring*

**Classroom** (4 units): attendance + achieve 80% of formal assessment (multiple choice, open book)

**Laboratory** (1 unit): identify 3 local seagrass species correctly and demonstrate how to preserve seagrass samples for a herbarium

**Field** (1 unit): perform the following to the satisfaction of the trainer:

- layout a site and quadrat placement
- description of sediment & comments
- estimation of seagrass cover
- identification of seagrass species
- estimation of seagrass species composition
- measuring seagrass canopy height
- estimation of macro algae cover
- estimation of epiphyte cover
- taking a quadrat photo
- accurately record data

## **3 post workshop monitoring events (3 units)**

*Demonstrates you have the experience and competency to conduct monitoring on your own*

Must be completed within 12 months: starting no sooner than 1 month after the training workshop. Tentative monitoring events (dates) to be nominated within 1 month of a training workshop. Minimum of 1 site, maximum of 5 sites, per monitoring event assessed. Sites must be sampled within a 2-week period each sampling event. Each monitoring event/period must be separated by at least 1 month, regardless of number of sites monitored. Each participant must assess a minimum of 1 transect per site per sampling event (name must be clearly legible on field datasheet). *A Certified participant can oversee data collection, however, participant being assessed must collect the required data along transect and the name of Certified participant must be clearly legible on datasheet.*

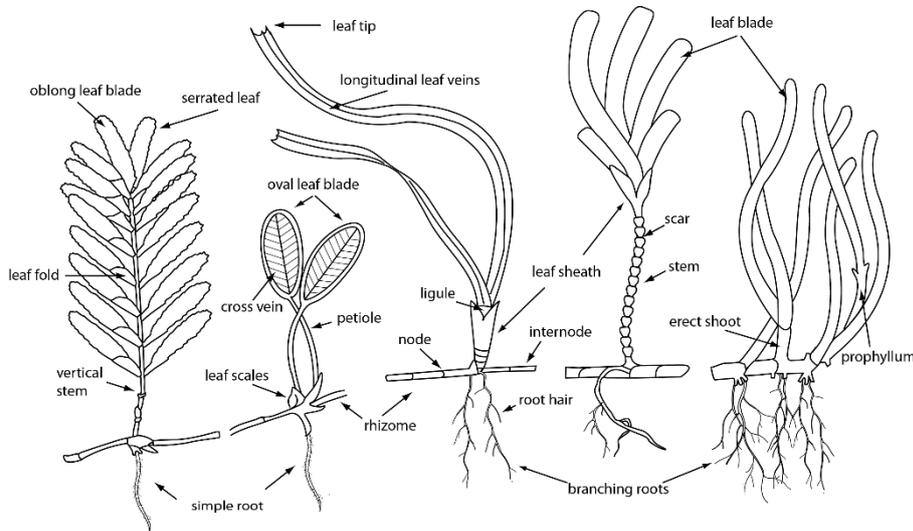
Original datasheets, photos, etc, must be submitted to Seagrass-Watch HQ within 2 weeks after each monitoring event. Data submitted must be compliant and must pass QAQC by achieving the following:

- correct description of sediment & comments
- seagrass cover estimates within acceptable limits
- correct seagrass species identification
- correct seagrass species compositions
- correct seagrass canopy height measures
- macro algae cover estimates within acceptable limits
- epiphyte cover estimates within acceptable limits
- compliant quadrat photos

Once all QAQC has been completed and the participant has demonstrated they have the skills, ability, experience and competency to conduct monitoring, a certificate will be issued by Seagrass-Watch HQ.

# Background

Seagrasses are unique flowering plants that have evolved to live in sea water. Seagrasses belong to a group of plants known as angiosperms (flowering plants).



Composite illustration demonstrating morphological features used to distinguish main taxonomic groups.

Various common names are applied to seagrass species, such as turtle grass, eelgrass, tape grass, spoon grass and shoal grass. These names are not consistently applied across countries.

Like terrestrial (land living) plants, a seagrass can be divided into its leaves (which contain veins), rhizome, roots (buried in the substrate), and reproductive parts such as flowers and fruits. Algae do not have veins in their leaves nor do they possess roots (anchoring to the surface of the substrate by a holdfast) or produce flowers or seeds.

These marine plants are called “seagrass” because most have ribbon-like, grassy leaves. There are many different kinds of seagrasses and some do not look like grass at all. Seagrass range from the size of your fingernail to plants with leaves as long as 7 metres. Some of the shapes and sizes of leaves of different species of seagrass include an oval (paddle or clover), a fern, a long spaghetti like leaf and a ribbon. Species that have a paddle or fern shaped leaf are called *Halophila*. Ones that have a ribbon shaped leaf are the *Cymodocea*, *Thalassia*, *Thalassodendron*, *Halodule* and *Enhalus*. Spaghetti-like seagrass is called *Syringodium*. At the base of a leaf is a sheath, which protects young leaves. At the other end of a leaf is the tip, which can be rounded or pointed. The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as scars.

Seagrass leaves lack stomata (microscopic pores on the underside of leaves) but have thin cuticle to allow gas and nutrient exchange. They also possess large thin-walled aerenchyma (air channels). Aerenchyma are specialised tissue having a regular arrangement of air spaces, called lacunae, that both provide buoyancy to the leaves and facilitate gas exchange throughout the plant. Leaves have a very thin cuticle, which allows gas and some nutrient diffusion into them from the surrounding water. Seagrass leaves also contain **veins** (lignified conducting tissue that transports water, nutrients and photosynthetic products around the plant) (i.e. an internal vascular system). Veins can be across the leaf blade or run parallel to the leaf edge.

Seagrass are marine flowering plants

Seagrasses have roots, stems and leaves

Seagrass is different to seaweed (algae) as seagrass have an internal vascular system, true roots and produce flowers, fruits and seeds

Leaves of different seagrass species can be shaped like a flattened ribbon, look like a fern, round like a clover, or even spaghetti shaped

Seagrass have veins and air channels in their leaves and rhizomes so they can carry water, food and absorb gases

Also within the leaves are chloroplasts, which use the sun's light to convert carbon dioxide and water into oxygen and sugar (photosynthesis).

The roots and horizontal stems (rhizomes) of seagrass are often buried in sand or mud. They anchor the plant, store carbohydrates and absorb nutrients. Roots can be simple or branching and all have fine hairs to help absorb nutrients. Rhizomes are formed in segments with leaves or vertical stems rising from the joints, called nodes. Sections between the nodes are called internodes. Seagrasses depend upon the growth of rhizomes to increase the area they occupy. This vegetative growth is the most common mode of growth for seagrasses. Although the rhizome mainly runs horizontally, some lateral branches are more or less erect and bear leaves (erect shoots). Sometimes the leaves are on a special type of stalk, called a petiole.

The roots and rhizomes of seagrasses are well endowed with aerenchyma and the lacunae are extensive and continuous with leaf tissues. Oxygen transport to the roots creates an oxic environment around the roots (in the sediment), facilitating nutrient uptake.

Seagrasses are flowering plants (angiosperms) which have flowers and pollination systems that are well adapted for pollination via water. Seagrass form tiny flowers, fruits and seeds. Most seagrasses have separate male and female plants. In most species, flowers are small, white and are borne at the base of the leaf clusters. The stamens (male parts) and pistils (female parts) extend above the petals to facilitate pollen release and pollination respectively.

Most seagrasses reproduce by pollination while submerged and complete their entire life cycle underwater. Pollination in seagrasses is hydrophilic (aided by water), and can occur by: (i) pollen transported above water surface (e.g., *Enhalus*); (ii) pollen transported on water surface (e.g., *Halodule*), or; (iii) pollen transported beneath water surface (e.g., *Thalassia*).

Seagrass pollen grains are elongated into a filamentous shape. The filamentous nature of pollen grains facilitates transport within the water medium, mainly by water currents. *Halophila* and *Thalassia* have spherical pollen grains, but they remain joined together in long chains, giving the same effect as having elongated, filamentous pollen grains.

After fertilization, the ovary of the female flower develops into a fruit. In seagrasses, fruit development and fruit structure are as diversified as their flowering patterns and floral structures. In general, the seeds, ranging in the size from 0.3 to 0.5mm in some *Halophila* species to more than 1–2 cm in *Enhalus*, are furnished with a nutrition reserve and sink rather than float. The number of seeds within a fruit also varies from 1 (e.g. *Halodule uninervis*) up to 25 (e.g. *Halophila ovalis*).

### Seagrass taxonomy

Taxonomy can be challenging for seagrasses due to their significantly reduced and variable morphologies. Since the mid-1800s, seagrasses have been classified within the angiosperms. A pivotal taxonomic study on seagrasses was published in 1970 by Cornelis den Hartog, titled "The Sea-Grasses of the World". Since that time, the number and composition of genera has remained largely unchanged. Taxonomy updates, including genera and species names and all the previous names used for each species, can be found at the International Plant Name Index ([www.ipni.org](http://www.ipni.org)).

Seagrasses rely on light to convert carbon dioxide and water into oxygen and sugars (photosynthesis)

Roots can be simple or branching and all have fine hairs to help absorb nutrients

Seagrass pump oxygen into the sediment via their roots

Seagrass are angiosperms. Seagrass have flowers, fruits and seeds

Pollination occurs in the water

Pollen from male seagrass flowers is mainly dispersed to female seagrass flowers by water currents

Seagrass-Watch primarily adheres to the classifications established by Cronquist (1981) and den Hartog (1970), while utilizing the family and genus names that are currently recognized by the Angiosperm Phylogeny Group (APG III).

Seagrasses are monocotyledons, which includes flowering plants whose seeds contain only one embryonic leaf, or cotyledon. Seagrasses are not true grasses (true grasses belong to the family Poaceae), but are rather more closely related to other aquatic plants such as duckweeds, pondweeds, peace lilies, the taro plant and world's largest inflorescence titan arum (aka corpse flower), in the order Alismatales. Note: waterlilies, family Nymphaeaceae, are basal angiosperms with the stem anatomy of dicots (an organized ring of vascular tissue) and therefore, not a monocot.

Seagrasses evolved approximately 100 million years ago from land plants that returned to the sea in at least four separate lineages. Thus, seagrasses are not a taxonomically unified group but a 'biological' or 'ecological' group. The evolutionary adaptations required for survival in the marine environment have led to convergence (similarity) in morphology.

Worldwide, there are about 12 major divisions, consisting of approximately 60 species (possibly up to 72) of seagrass. The highest concentration of species occurs in the Indo-West Pacific region.

#### Seagrass requirements for growth

Seagrasses require light, nutrients, carbon dioxide, substrate for anchoring, tolerable salinity, temperature and pH to survive. The requirements for a seagrass to be able to exist in the marine environment include:

1. adaptation to life in saline (salty) medium
2. growth when completely submerged
3. anchoring system able to withstand the forces of wave action and tidal currents
4. hydrophilous pollination (pollination aided by water).

The need for physiological adaptations to life in sea water is obvious when one considers that seagrasses evolved from land plants, and most land plants are unable to tolerate even small quantities of salt. In contrast to land plants, some seagrasses can tolerate a salinity range from 4 to 65 parts per thousand (2x seawater concentration). Typically, seagrasses grow best in salinities of 35 parts per thousand. Not all species tolerate all salinities equally well, and salinity tolerance may be a factor promoting different species distributions along salinity gradients, e.g., going up estuaries. Some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline (very salty). A limiting factor for many intertidal seagrasses is osmotic impacts resulting from hypersalinity due to evaporation

Seagrasses being plants need light for photosynthesis. Light availability is the most dominant overriding factor in seagrass growth. Seagrasses have high minimum light requirements (e.g. 10-20% of surface irradiance on average, 4.4% minimum and 29% maximum depending on species) because: (i) they have a high respiratory demand to support a large non-photosynthetic biomass (e.g. roots, rhizomes); (ii) they lack certain pigments and therefore can utilise only a restricted spectral range; and (iii) they must regularly oxygenate their root zone to compensate for anoxic sediment. However, light in the intertidal can be in excess of requirements and excess light can cause temporary photo damage. UV exposure can also have significant impacts on seagrasses.

Seagrasses are not true grasses

Seagrasses are closely related to peace lilies and the taro plant

Seagrass evolved 100 million years ago from land plants that returned to the sea

There are around 60 species of seagrass found in oceans throughout the world

Seagrasses need plenty of sun and clean water to grow.

Seagrasses are physiologically adapted to life in sea water

Seagrasses can tolerate a range of salinities. Some species are less tolerant than others

Light availability is the most important factor determining seagrass growth

Seagrasses require between 10-20% of surface light to grow

Temperature influences the rate of growth and the health of plants, particularly at the extremes. As tropical water temperatures increase (above 35°C) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given CO<sub>2</sub> concentration. The cause of thermal stress at higher temperatures (38°C to 42°C) is the disruption of electron transport activity via inactivation of the oxygen producing enzymes (proteins) of photosystem II. Above these temperatures many proteins are simply destroyed in most plants, resulting in plant death.

Temperature also controls the range of pH and dissolved carbon dioxide (CO<sub>2</sub>) concentrations in the water column; factors critical in plant survival in the marine environment.

Seagrasses require inorganic carbon for growth. They uptake inorganic carbon at the leaf surface via two pathways which are species-specific. Some species use bicarbonate (HCO<sub>3</sub><sup>-</sup>) as an inorganic carbon source (e.g. *Halophila ovalis*, *Cymodocea rotundata*, *Syringodium isoetifolium* and *Thalassia*), whereas others use enzymes to make CO<sub>2</sub> available as the inorganic carbon source (e.g. *Enhalus acoroides*, *Halodule*, *Cymodocea serrulata*).

Seagrasses require two key nutrients, nitrogen and phosphorous, for growth. In the coastal regions, seagrasses appear to be primarily limited by nitrogen and secondarily by phosphorus. The demand for nutrients by seagrasses appears seasonally dependent. During the growing season the demand for nutrients is high, however during the senescent season elevated nutrients may become toxic.

The availability of nutrients to seagrasses may also be dependent on sediment quality / geochemistry. Bioavailability of nutrients is dependent on particle size and type. For example, clay content influences sediment adsorptive capacity - the more clay the greater the adsorptive capacity - and, calcium carbonate binds phosphorus, limiting its bioavailability.

Sediment quality, depth and mobility are important factors for seagrass composition, growth and persistence. Most seagrasses live in sand or mud substrates where their roots and rhizomes anchor the plants to the sea floor. Some seagrasses, such as *Cymodocea* spp., prefer deeper sediments while others can tolerate a broad range of sediment depths. Colonising seagrasses such as *Halophila* spp. and *Halodule* spp. are better suited to mobile sediments than larger species. The biogeochemical characteristics of sediment that can affect the nutrient content/binding capacity, organic content and oxygen levels. Seagrasses are unable to grow in sediments of high organic content.

Currents and hydrodynamic processes affect almost all biological, geological and chemical processes in seagrass ecosystems at scales from the smallest (physiological and molecular) to the largest (meadow wide). The pollination of seagrass flowers and dispersal of vegetative material and seeds depends on currents. Without current flows, vegetative material and seeds will not be transported to new areas, and species will not be exchanged between meadows. Factors such as the photosynthetic rate of seagrasses depend on the thickness of the diffusive boundary layer that is determined by current flow, as is the sedimentation rate. Both influence growth rates of seagrass, survival of seagrass species and overall meadow morphology.

Water temperature influences the rate of growth and the health of seagrass

Seawater temperatures above 35°C will stress tropical seagrass. Death occurs at temperatures above 42°C

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

Seagrass require two key nutrients, nitrogen and phosphorous, for growth

Nutrient availability to seagrass is dependent on the type of sediment they grow in

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

Tidal currents are important for pollination, dispersal and exchange of gases from the water to the plant

### Where are seagrasses found?

Seagrasses are found in oceans throughout the world. They occur in tropical (hot), temperate (cool) and the edge of the arctic (freezing) regions.

Seagrass are mainly found in sheltered bays, estuaries and coastal waters from the mid-intertidal (shallow) region down to depths of 50 or 60 metres. Most species are found in clear shallow inshore areas between mean sea-level and 25 metres depth.

Seagrasses survive in the intertidal zone especially in locations sheltered from wave action or where there is pooling of water at low tide, (e.g., reef platforms and tide pools), which protects seagrass from elevated temperatures and drying.

Seagrasses inhabit all types of ground (substrates), from mud to rock. The most extensive seagrass meadows occur on soft substrates like sand and mud.

The depth range of seagrass is most likely to be controlled at its deepest edge by the availability of light for photosynthesis. Exposure at low tide, wave action and associated turbidity and low salinity from fresh water inflow determines seagrass species survival at the shallow edge.

Seagrass plants form small patches that develop into large continuous meadows. These meadows may consist of one or many species: sometimes up to 12 species present within one location.

### How are seagrasses important to the marine ecosystem?

Seagrass communities are one of the most productive and dynamic ecosystems globally. Seagrasses may significantly influence the physical, chemical and biological environments in which they grow by acting as 'ecological engineers'. They provide habitats and nursery grounds for many marine animals and act as substrate stabilisers.

Seagrass meadows are highly productive. They have been documented to create habitat complexity compared with unvegetated areas, providing up to 27 times more habitable substrate, as well as providing refuge and food for a range of animals. About 40 times more animals occur in seagrass meadows than on bare sand.

One of the most important roles of seagrasses is providing a nursery area, food and shelter for fish and prawns which are valuable to fisheries. Juveniles of some important species which depend on seagrass meadows include fish such as perch, mullet, whiting, tailor, bream, snappers, emperors and sweetlips. Commercial penaeid prawns such as red spot king, brown tiger, grooved tiger and endeavour also live in seagrass meadows as juveniles. Tropical rock lobsters also live in seagrass meadows as juveniles. Shellfish such as some oysters and pearl shell may be more likely to settle and survive where there is seagrass. Juvenile and adult sandcrabs and flathead are just two species which spend most of their lives in seagrass meadows, where there is not only food but also protection from strong tidal currents and predators. Larger predatory animals such as herons, cormorants, sharks, barramundi, salmon, crocodiles, etc, are also attracted to the seagrass meadows by the schools of forage fish which seek shelter there.

Seagrass are commonly found in estuaries, shallow coastal locations, and on reef-tops.

Seagrass are mainly found in clear shallow inshore areas between mean sea-level and 25 metres depth.

The depths that seagrass are found underwater depends on the light availability (water clarity)

Seagrass plants form small patches that develop into large meadows

Seagrasses are important habitat and feeding grounds for marine organisms.

About 40 times more animals occur in seagrass meadows than on bare sand.

Seagrasses are important nursery grounds for fish, and they support many human commercial activities.

Seagrass meadows are a major food source for a number of herbivores and are considered very productive pastures of the sea. The dugong (*Dugong dugon*) and the green turtle (*Chelonia mydas*) mainly feed on seagrass. An adult green turtle eats about two kilograms (wet weight) of seagrass a day while an adult dugong eats about 28 to 40 kilograms (wet weight) a day. Although dugongs and turtles will feed on any seagrass species within their range, if a range of species is available, they select seagrass species for food which are high nitrogen, high starch and low fibre. For example, the order of seagrass species preference for dugongs is *Halophila ovalis* ≥ *Halodule uninervis* > *Zostera muelleri*. In sub-tropical and temperate areas, water birds such as black swans also eat seagrass.

Decomposing seagrasses provide food for benthic (bottom-dwelling) aquatic life. The decaying leaves are broken down by fungi and bacteria which in turn provide food for other microorganisms such as flagellates and plankton. Microorganisms provide food for the juveniles of many species of marine animals such as fish, crabs, prawns and molluscs.

The rhizomes and roots of seagrasses bind sediments on the substrate, where nutrients are recycled by microorganisms back into the marine ecosystem. The leaves of the grasses slow water flow, allowing suspended material to settle on the bottom. This increases the amount of light reaching the seagrass meadow and creates a calm habitat for many species.

Seagrasses are nutrient sinks, buffering or filtering nutrient and chemical inputs to the marine environment. Seagrasses uptake nitrogen and phosphorus from coastal run-off that, in overabundance, can lead to algal blooms that can impair water quality.

Seagrasses play a vital role in mitigating climate change by sequestering (capturing and storing) carbon. They, along with other coastal and marine ecosystems like mangrove forests, tidal marshes, and macroalgae beds, contribute to what is known as blue carbon. Seagrasses are highly efficient at absorbing carbon dioxide from seawater during photosynthesis and incorporating the carbon into their biomass. A significant portion of this carbon is then stored in the seagrass meadows' sediments. Because seagrass sediments are saturated with water, maintaining an anaerobic state, and not allowing aerobic microbial carbon oxidation and release, which drives carbon accumulation over time and, therefore, creates long term carbon reservoirs through centuries to millennia. Seagrasses can sequester carbon up to 35 times faster than tropical rainforests. Coastal seagrass meadows are estimated to hold up to 83,000 metric tons of carbon km<sup>-1</sup>, with the median global soil C<sub>org</sub> stock estimated to be 24.2 (12.4 – 44.9) Mg C<sub>org</sub> ha<sup>-1</sup> in the top 30 cm of soil.

### Interactions with mangroves and coral reefs

Tropical seagrasses are important in their interactions with mangroves and coral reefs. All these systems exert a stabilizing effect on the environment, resulting in important physical and biological support for the other communities.

Barrier reefs protect coastlines, and the lagoon formed between the reef and the mainland is protected from waves, allowing mangrove and seagrass communities to develop. Seagrasses trap sediment and slow water movement, causing suspended sediment to fall out. This trapping of sediment benefits coral by reducing sediment loads in the water.

Dugongs can eat up to 40kg of seagrass per day.

Dugongs and turtles select seagrass species for food which are high nitrogen, high starch and low fibre

Seagrasses also contribute to the productivity of ecosystems via the detrital food pathway

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

The retention of carbon within seagrass meadow sediments contributes significantly to climate change mitigation

Seagrasses, mangroves and coral reef interact, providing physical and biological support for other communities

Mangroves trap sediment from the land, reducing the chance of seagrasses and corals being smothered. Sediment banks accumulated by seagrasses may eventually form substrate that can be colonized by mangroves. All three communities trap and hold nutrients from being dispersed and lost into the surrounding oceanic waters.

**The value of seagrasses**

The value of ecosystem goods and benefits (contributions) is a controversial topic in today's literature. Ecosystem services are the structures and processes by which the environment produces contributions to our quality of life, that we often take for granted. For seagrasses it is services such as clean water, preventing erosion, and habitat for fisheries. The economic values of seagrass meadows are very large, although not always easy to quantify. Seagrass meadows are rated the 3rd most valuable ecosystem globally (on a per hectare basis), only preceded by estuaries and wetlands. The average global value of seagrasses for their nutrient cycling services and the raw goods they provide has been estimated at US\$ 28,916 ha<sup>-1</sup> yr<sup>-1</sup> (in 2007 dollars).

In the last decade, seagrass carbon storage capacity (blue carbon) has emerged as a significant factor in valuation. The carbon stored in seagrasses is estimated to be valued at ~USD12,000 ha<sup>-1</sup>, on par with the annual value of other ecosystem services provided by seagrasses. A study focusing on Caribbean seagrasses estimated their total annual value at USD255 billion, with USD88.3 billion specifically attributed to carbon storage. Although all seagrass species contribute to blue carbon, the capacity for carbon storage varies significantly based on their growth form, biomass, and the specific environmental conditions they inhabit. Carbon storage in seagrass meadows is also strongly location-dependent, even within the same species.

**What causes seagrass areas to change?**

Tropical seagrass meadows vary seasonally and between years, and the potential for widespread seagrass loss has been well documented. Factors which affect the distribution of seagrass meadows are sunlight and nutrient levels, water depth, turbidity, salinity, temperature, current and wave action.

Seagrasses respond to natural variations in light availability, nutrient and trace element (iron) availability, grazing pressure, disease, weather patterns, and episodic floods and cyclones. The dynamic nature of seagrass meadows in response to natural environmental variation complicates the identification of changes caused by humans.

**What threatens seagrass?**

Seagrass meadows can be easily damaged. Approximately 58% of seagrass meadows globally, have lost part of their distribution. According to reports, the documented losses in seagrass meadows globally since 1980 are equivalent to two football fields per hour.

Some losses are natural due to storms and herbivores, however, most losses are the result of human activities. Human pollution has contributed most to seagrass declines around the world.

The most widespread and pervasive cause of seagrass decline is a reduction in available light. Processes that reduce light penetration to seagrasses include pulsed turbidity events during floods, enhanced suspended sediment loads and elevated nutrient concentrations. Poor farming practices can result in

Seagrass meadows are rated the 3rd most valuable ecosystem globally (more valuable than mangroves or coral reefs)

Seagrass ecosystems are increasingly recognised as valuable assets in the growing blue carbon market

Seagrasses can change due to both natural and human impacts

People can damage or destroy seagrass by pollution (sewage, oil spills, litter, and coastal runoff) and physical destruction (dredging, bait & clam digging, boat propellers and anchors/moorings).

excess sediments and fertilizers washing down creeks to the sea. Sewage discharge and stormwater runoff from urban development can elevate nutrients in coastal areas. Boating activity may also stir up sediment, reducing light levels. Phytoplankton and fast-growing macroalgae are also better competitors for light than benthic plants and their biomass can shade seagrasses during progressive eutrophication.

Oil and trace metal contamination can exert direct toxic effects on some seagrass species. Seagrasses are able to bioaccumulate the trace metals and this can have ramifications for grazers such as dugongs.

People can also physically damage or destroy seagrass. Coastal development for boat marinas, shipping ports and housing generally occurs on the coast in areas which are sheltered and seagrass like to grow. Seagrass meadows are either removed or buried by these activities. Coastal developments can also cause changes in water movement. Dredging boat channels to provide access to these developments not only physically removes plants, but can make the water muddy and dump sediment on seagrass. Litter and rubbish can also wash into the sea if not properly disposed. Rubbish can physically and chemically damage seagrass meadows and the animals that live within them.

Boating and fishing activities can physically impact or destroy seagrasses. Boat anchors and their chains can dig into seagrass. Propellers can cut into seagrass meadows and unbalance the rhizome mat. Storms can further exacerbate the damage by the physical force of waves and currents ripping up large sections of the rhizome mat. Uncontrolled digging for bait worm can also physically damage seagrasses and some introduced marine pests and pathogens also have the potential to damage seagrass meadows.

One of the other significant impacts to seagrass is climate change. The major vulnerability of seagrass to climate change is loss of seagrass in the coastal zone, particularly near river mouths and in shallow areas. The greatest impact is expected to result from elevated temperatures, particularly in shallower habitats where seagrasses grow (e.g., affecting distribution and reproduction). In addition, reduced light penetration from sediment deposition and resuspension are expected due to more intensive cyclones/hurricanes and elevated flooding frequency and amplitude. This will result in even greater seagrass losses, and changes in species composition are expected to occur particularly in relation to disturbance and recolonisation. Following such events, a shift to more ephemeral species and those with lower minimum light requirements is expected.

Poor farming practices can result in catchment runoff which can damage seagrass by elevating nutrients, reducing available light and releasing herbicides.

Coastal development can have a major impact on seagrass meadows

Climate change can threaten intertidal seagrass by increased seawater temperature and greater physical disturbance from storms

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# Seagrass ecosystems of the Pacific Island nations of Melanesia

modified from McKenzie *et al.* (2021a, b)

The Pacific Islands of Melanesia are located in the southwest Pacific and cover an area of approximately 5,500,000 km<sup>2</sup>. The region includes the key nations of Fiji, Papua New Guinea, Solomon Islands, and Vanuatu. Additionally, it encompasses the French overseas collectivity of New Caledonia. The region encompasses a diverse array of high and frequently volcanic islands, as well as low-lying atolls, each with a range of marine environments, some of which are suitable for seagrass colonisation and growth. It boasts a rich geological history coupled with intricate oceanographic processes. Typically, the region experiences a tropical climate, characterized by high humidity and significant rainfall, especially from November to April. Additionally, it is susceptible to cyclones and other severe weather phenomena.

Melanesia is the Pacific region with the highest seagrass species richness, followed by Micronesia and Polynesia, respectively <sup>[1]</sup>. Fifteen species of seagrass have been recorded from Melanesia, including: *Cymodocea rotundata* Ehrenberg and Hemprich ex Ascherson; *Cymodocea serrulata* (R. Brown) Ascherson & Magnus; *Enhalus acoroides* (L.f.) Royle; *Halodule pinifolia* (Miki) den Hartog; *Halodule uninervis* (Forsskål) Ascherson; *Halophila capricorni* Larkum; *Halophila decipiens* Ostenfeld; *Halophila minor* (Zoll.) den Hartog; *Halophila ovalis* (R. Brown) J.D. Hooker; *Halophila spinulosa* (R. Brown) Ascherson; *Ruppia maritima* Linnaeus var. *pacifica* H. St. John & Fosberg; *Syringodium isoetifolium* (Ascherson) Dandy; *Thalassia hemprichii* (Ehrenberg) Ascherson; *Thalassodendron ciliatum* (Forsskål) den Hartog; *Zostera muelleri* (Ascherson) (Table 1). The greatest diversity of seagrass is reported from Papua New Guinea (13 species), and attenuates eastward across the Pacific <sup>[1]</sup>.

**Table 1.** Seagrass species confirmed within each Pacific Island nation of Melanesia, and spatial extent of seagrass mapped with high confidence <sup>[1]</sup>, and estimated spatial extent from the Allen Coral Atlas <sup>[2,3]</sup>. P = 2000 to present (green fill), p = 1970 to 2000 (grey fill); \* = mapping incomplete.

Nation	# spp	<i>C. rotundata</i>	<i>C. serrulata</i>	<i>E. acoroides</i>	<i>H. pinifolia</i>	<i>H. uninervis</i>	<i>H. capricorni</i>	<i>H. decipiens</i>	<i>H. minor</i>	<i>H. ovalis</i>	<i>H. spinulosa</i>	<i>R. maritima</i>	<i>S. isoetifolium</i>	<i>T. hemprichii</i>	<i>T. ciliatum</i>	<i>Z. muelleri</i>	High confidence Extent (km <sup>2</sup> )	Allen Atlas extent (km <sup>2</sup> )
Fiji	6				P	P		P		P		p	P				59.19 <sup>[4]</sup> *	492.85
Papua New Guinea	13	P	P	P	P	P		p	p	P	p		P	P	p	p	117.2 <sup>[5]</sup> *	913.05
Solomon Islands	10	P	P	P		P		P	P	P			P	P	P		78.96 <sup>[6]</sup> *	351.26
Vanuatu	12	P	P	P	P	P	P	P	p	P		P	P	P			*	4.69

The most widely distributed species is *Halophila ovalis*, which is found in all Melanesian nations and extends from the intertidal to a depth of 20 m <sup>[1]</sup>. *Halophila ovalis* forms dense meadows in some locations, but is frequently encountered in small patches. It tolerates a wide variety of substrata from fine muddy sand to coarse sand, mixed sand/rubble or large boulders with sandy patches. The species of the most limited distributions in the Melanesian nations are *Halophila capricorni*, *Halophila spinulosa* and *Zostera muelleri* (Table 1). Both *Halophila spinulosa* and *Zostera muelleri* have not been reported from field collections this century (Table 1). All seagrass species in the Melanesian nations are listed as “least concern” on the IUCN Red List of threatened species <sup>[7]</sup>. Seagrass distribution throughout the region is most likely influenced by shelter, sediment characteristics, water turbidity and tidal exposure. Seagrass meadows are mostly found in the sheltered bays high islands and shallow lagoons.

The patterns of seagrass species diversity for the Pacific Island region are believed to stem from their biogeographic and dispersal history, with species richness diminishing as you move eastward<sup>[1]</sup>. It is widely accepted that seagrass spread east across the Pacific Islands through the Equatorial Counter Currents, originating from the Indo-Malayan biodiversity hotspot, where seagrasses first emerged in the Tethys Sea at equatorial latitudes<sup>[8]</sup>. The success of waterborne dispersal relies heavily on the buoyancy potential of viable propagules, which include vegetative fragments, fruits, and plant fragments that carry seeds<sup>[9, 10]</sup>. However, many tropical seagrass fruits have a short lifespan and typically feature negatively buoyant seeds, with primary dispersal movements generally limited to less than 100 km. This is primarily true, except during extreme weather events, where dispersal has been documented over distances of up to 400 km<sup>[11]</sup>. Nonetheless, in rare cases, vegetative fragments, along with attached fruits and seeds, can be transported over significantly larger distances. For instance, dispersal simulations along the tropical Great Barrier Reef suggest a maximum possible dispersal distance of 950 km<sup>[10]</sup>. Similarly, seagrass seeds can also be transported over large distances by biotic vectors, such as fish, birds, sea turtles, dugongs, and humans<sup>[12-14]</sup>. For example, *Ruppia maritima* has been documented to travel via attachment to bird feathers, as well as through ingestion and subsequent excretion by waterfowl. The strong phylogenetic connection of Vanuatu populations to those in China and India<sup>[15]</sup>, supports dispersal via the West Pacific Flyway. Consequently, seagrass distribution across the region is likely influenced by a complex interplay of factors, including the type of viable propagule, duration of dispersal, wind and water dynamics, coastal geography, and biological vectors.

Throughout the Pacific Island nations of Melanesia, seagrass ecosystems are recognised for their provision of food and a source of livelihoods for Pacific Islanders<sup>[16-19]</sup>. Seagrass meadows also support high biodiversity that includes megafauna such as the dugong (*Dugong dugon*) and green sea turtle (*Chelonia mydas*) which are seagrass specialists and culturally important to Pacific Islanders<sup>[20-22]</sup>. Seagrasses provide critical ecosystem services such as habitat, coastal protection, nutrient cycling, improving water quality, and mitigating pathogenic bacteria to the benefit of humans, fishes, and marine invertebrates such as coral<sup>[23-25]</sup>. In addition, the incorporation of carbon within seagrass tissues can affect local pH, thereby mitigating the effects of ocean acidification affecting coral reefs, and the retention of carbon within seagrass meadow sediments contributes significantly to climate change mitigation as well<sup>[26-29]</sup>. The ecosystem services provided by seagrasses across the Pacific Islands therefore make them a high conservation priority<sup>[30-33]</sup>.

Despite their significance, these crucial ecosystems are increasingly threatened by human activities, a situation exacerbated by the challenges of global climate change<sup>[16, 30, 34, 35]</sup>. In the Pacific Islands, Melanesia stands out as the oldest inhabited region, having been settled between 13,000 and 47,000 years ago<sup>[36]</sup>. The goods and benefits provided by seagrass ecosystems in this region surpass those in any other Pacific Island area, highlighting a stronger coupling between human society and these ecosystems<sup>[19]</sup>. Additionally, the deeper cultural ties have been found to motivate guardianship of seagrass ecosystems, helping to mitigate various pressures<sup>[1, 19]</sup>.

### **Papua New Guinea (Independent State of)**

The earliest seagrass record in Papua New Guinea (PNG) comes from New Hanover in 1875<sup>[37]</sup>. Thirteen seagrass species have been confirmed from PNG (Table 2), with species diversity highest in the southern part of the country (adjacent to Torres Strait) and declining eastward<sup>[1]</sup>. The highest number of species reported at a single location is 13, from Daru in the northern Torres Strait<sup>[38]</sup>. Eight species are widely distributed while five species are restricted to a few localities; the rarest are *Thalassodendron ciliatum* at Manus Island and *Zostera muelleri* at Daru<sup>[1]</sup>. *Zostera muelleri* just reaches PNG as a northern extension of its Australasian range, and although suggested to occur along the New Guinea coastline west of Daru, recent mapping efforts conducted this century have failed to locate any specimens<sup>[39]</sup>.

Seagrass communities occur in various habitats, including fringing reefs, protected bays, the sheltered side of barrier reefs, and the leeward side of islands. Significant seagrass meadows can be found along the north coast of Manus Island in Seadler Harbour, in the coastal bays surrounding Wewack and Port Moresby, on the island reef complexes of Milne Bay province and on the reef platforms surrounding the Tigak Islands and Kavieng<sup>[1]</sup>. Seagrass meadows are also a major feature at several other localities (e.g., Rabaul, Kimbe) and scattered areas of seagrasses line much of the mainland coast (e.g., Madang, Morobe and Western provinces) and the offshore islands (including Lihir and Mussau). The majority of seagrasses occur from nearshore intertidal to shallow subtidal (10 m depth), although *Halophila decipiens* has been reported down to 40 m near Laing Island, Hansa Bay on the north coast in Madang Province<sup>[40]</sup>. Extensive mixed species meadows are the dominant community type in the bays, harbours and sheltered capes along the coasts of the PNG mainland and the islands of New Britain and New Ireland<sup>[37, 41-43]</sup>. These extensive seagrass meadows are dominated by *Thalassia hemprichii* and/or *Enhalus acoroides*<sup>[1]</sup>. In the more protected bays and the shallow lagoons surrounding Kavieng, *Enhalus acoroides* borders the gentle sloping mangrove fringes. Smaller islands are generally characterised by relatively small fringing reef platforms, where seagrass are restricted to shallow fringing reef-flats with lagoons (0 - 2 m depth). In regions without large islands (e.g., Louisiades), low cover seagrass mainly occurs on the tops of the reefs and shoals with reef flats<sup>[5]</sup>.



*Enhalus acoroides*, *Cymodocea rotundata* and *Halodule uninervis* on the Sivasat fringing reef, Kavieng (left – August 2004). Right: *Enhalus acoroides* dominated meadow in Madang Lagoon, Madang (right – July 2003)  
Photos: Len McKenzie.

## Solomon Islands

Most seagrasses in the Solomon Islands occur in waters shallower than 10 m deep. These meadows can either be monospecific or contain a diverse range of species, with as many as six different species found in one location<sup>[44]</sup>. Ten species of seagrass are confirmed from the Solomon Islands (Table 2). The dominant species throughout the Solomon Islands are *Enhalus acoroides* and *Thalassia hemprichii*. Seagrass distribution is mainly determined by the intensity of wave action (exposure) and the availability of nutrients. It is estimated that just over half of all seagrass meadows, on a per hectare basis, are found in Malaita Province, while other provinces each account for less than 12% of the country's total extent. The seagrass habitats of the Solomon Islands can be broadly classified into four categories: estuaries (incl. large shallow lagoons), coastal (incl. fringing reef), deep-water and reef (e.g., barrier or isolated). In calm localities with relatively wide lagoons (30 – 100 m), like Tetel Island (Florida Islands) and Komimbo (north-west Guadalcanal), the sand-mud flats are generally dominated by *Thalassia hemprichii* shoreward and *Enhalus acoroides* seaward and often bordered by mangroves (*Avicennia*, *Rhizophora* and *Bruguiera*) particularly near rivers or streams<sup>[1]</sup>.



*Enhalus acoroides* and *Thalassia hemprichii* dominated meadows, Choisel (left) and Russell Islands (right), Solomon Islands – May-June 2004.  
Photos: Len McKenzie.

### Vanuatu (Republic of)

Twelve seagrass species have been confirmed from the waters of Vanuatu (Table 1), with the earliest record being of *Cymodocea rotundata* on the reef at Lamap (Port Sandwich, Malekula) in 1935-36 <sup>[45]</sup>. The most widespread species are *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule uninervis*, *Halophila ovalis* and *Thalassia hemprichii* <sup>[1]</sup>. Seagrass distribution is most likely influenced by shelter, sediment characteristics, water clarity and tidal exposure. Much of Vanuatu's seagrass meadows appear restricted to narrow fringing and inner reef areas or sheltered lagoons (e.g. Erakor, Éfaté), bays (e.g. Palikoulo Bay, Espiritu Santo), inlets (e.g. Mosso Islet, Éfaté), where they are generally reported to occur in scattered patches or form small meadows (e.g., <100m wide zones) <sup>[46, 47]</sup>. Extensive meadows, however, can occur on the comparatively wide intertidal areas around the Maskelyne Islands and along the east and southeast coast of Malakula (e.g. Crab Bay and Lamap) <sup>[48]</sup>. Denser meadows of predominately *Cymodocea rotundata*, *Enhalus acoroides*, *Halodule uninervis*, and *Thalassia hemprichii* occur in shallow lagoons, bays and intertidal areas, particularly where the major or only substrate is sand. Seagrass diversity and abundance is generally lower at reef habitats where sediments are coarser, the sediment depth is less and the physical disturbance from waves is greater <sup>[47]</sup>. Little is known of deepwater (>10 m) seagrasses, however, *Halophila decipiens* and *Halophila capricorni* have been reported from the channels and deep outer reef slopes of southern Espiritu Santo <sup>[46, 49]</sup>. The rarest species is *Ruppia maritima*, which occurs in the brackish waters of river mouths (e.g. Adisone River, Espiritu Santo) or coastal ponds (e.g. Port Resolution, Tanna).



*Enhalus acoroides* and *Thalassia hemprichii* dominated meadow (left) and *Halophila ovalis* (right), Erakor Lagoon, Efate, Vanuatu– August 2017). Photos: Len McKenzie.

### Fiji (Republic of)

Seagrasses are found in a range of habitats across the Fiji Islands, including: estuarine; barrier and patch reefs; island fringing reefs; bays and lagoons; and deepwater (>10m) <sup>[4]</sup>. Six seagrass species are confirmed, all of which are either opportunistic or colonising species <sup>[1, 50]</sup>. *Halodule pinifolia* occurs in the high intertidal to upper subtidal areas of sheltered bays and reef platforms.

*Halodule uninervis* can be found from intertidal to a depth of 6 m, growing in both sheltered or exposed coral reefs as well as shallow sand and mud banks, where it often forms dense meadows <sup>[1]</sup>. *Halophila ovalis*, the most widespread of all seagrasses in Fiji, ranges from the intertidal to depths of 10 - 12 m and can be found in various habitats due to its ability to tolerate a wide variety of substrates. *Syringodium isoetifolium* typically inhabits shallow subtidal reef areas (1 to 6 m deep), with some meadows occasionally exposed during extreme low tides on reef flats. Notably, *Syringodium isoetifolium* is also the only seagrass species reported from Rotuma <sup>[1]</sup>. *Ruppia maritima* is exclusively found in brackish water estuarine habitats on Viti Levu. Meanwhile, *Halophila decipiens* is located in waters exceeding 6 m in depth, particularly along the reef channels of Cakaulevu Reef (Great Sea Reef), northern Vanua Levu <sup>[1]</sup>.



*Halodule uninervis*, *Syringodium isoetifolium* and *Halophila ovalis* meadow, Natadola (left – August 2011) and *Halodule uninervis*, *Halodule pinifolia* and *Halophila ovalis* meadow, Nasese (right – March 2010). Photos: Len McKenzie.

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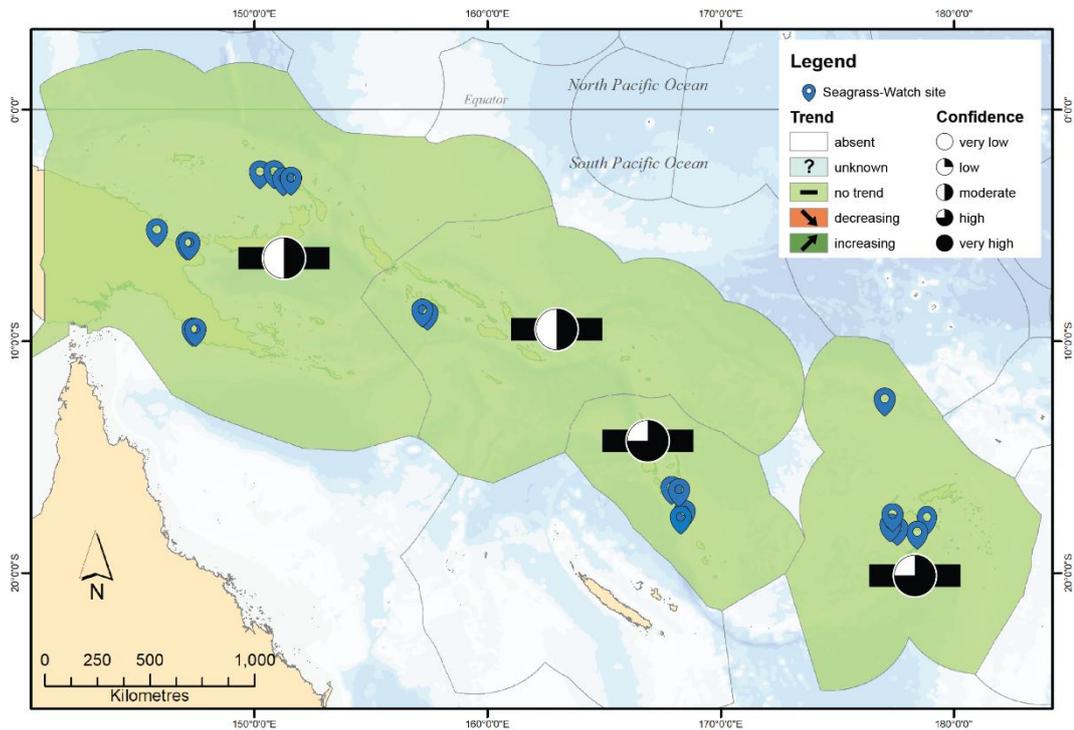
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## SEAGRASS-WATCH IN THE PACIFIC ISLAND NATIONS OF MELANESIA

To provide an early warning of change, long-term monitoring has been established at sixteen locations across the Pacific Island nations of Melanesia as part of the Global Seagrass Observing Network ([www.seagrasswatch.org](http://www.seagrasswatch.org)). Establishing a network of monitoring sites in the four nations provides valuable information on temporal trends in the health status of seagrass meadows in the region and provides a tool for decision-makers in adopting protective measures. Working with both scientists and local stakeholders, this approach is designed to draw attention to the many local anthropogenic impacts on seagrass meadows which degrade coastal ecosystems and decrease their yield of natural resources.

A qualitative assessment in 2021 of trends in seagrass ecosystem condition (e.g. extent, percentage cover, or biomass) in the Pacific Island nations of Melanesia, were relatively stable with more than 50 % of sites/locations showing no discernible trend <sup>[1]</sup>.



Trends in seagrass ecosystem state and location of Seagrass-Watch global seagrass observing sites across the Melanesian nations. Modified from <sup>[1]</sup>.

Status of seagrass at monitoring locations in the Pacific Island nations of Melanesia:

**Fiji** (ongoing, *ad hoc*)

<https://www.seagrasswatch.org/fiji/>

**Papua New Guinea** (ongoing, *ad hoc*)

<https://www.seagrasswatch.org/papua-new-guinea/>

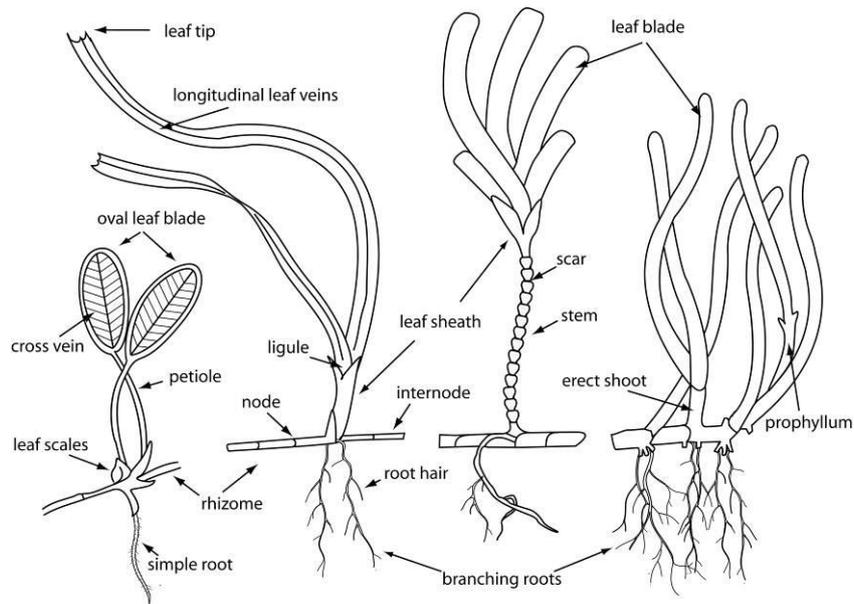
**Solomon Islands** (archived)

<https://www.seagrasswatch.org/solomon-islands/>

**Vanuatu** (ongoing, *ad hoc*)

<https://www.seagrasswatch.org/vanuatu/>

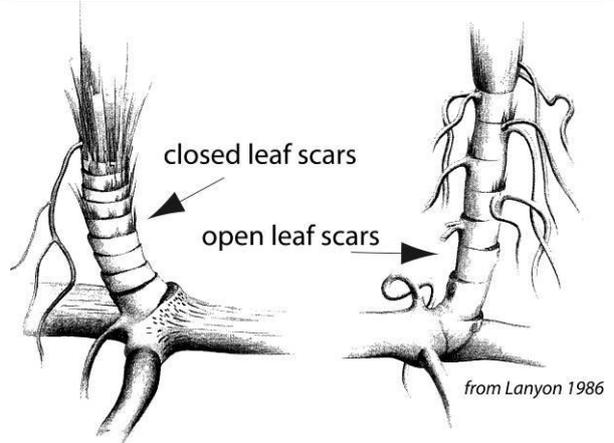
# Parts of a seagrass plant



Leaf		
Tip	<p>End of leaf with a variety of shapes and some may be dentate (having toothed-like projections).</p> <p>For identification use young leaves, as old leaves are easily damaged or cropped.</p>	<p>rounded notched concave pointed dentate flat</p>
Veins	<p>Used by the plant to transport water, nutrients and photosynthetic products. The pattern, direction and placement of veins in the leaf blade are used for identification.</p> <ul style="list-style-type: none"> <li>• cross-vein: perpendicular to length of leaf</li> <li>• parallel-vein: along the length of the leaf</li> <li>• mid-vein: prominent central vein</li> <li>• intramarginal-vein: around inside edge</li> <li>• split-vein: cross-veins that fork</li> </ul>	<p>cross parallel mid intramarginal cross + split</p>
Edges	<p>The edges of the leaf can be either serrated, smooth or inrolled</p>	<p>serrated smooth inrolled</p>
Ligule	<p>Membranous structure found at the junction of the blade and sheath. Clasps leaf sheaths, aiding protection of enclosed younger plant parts.</p>	<p>ligule</p>
Sheath	<p>A modification of the leaf base that protects the newly developing tissue. The sheath can entirely circle the vertical stem or rhizome (continuous) or not (non-continuous); fully or partly cover the developing leaves and be flattened or rounded.</p>	<p>clean &amp; flattened fibrous</p>
Attachment	<p>The leaf can attach directly to the rhizome, where the base of the leaf clasps the rhizome, or from a vertical stem or stalk (petiole) e.g. <i>Halophila ovalis</i>.</p>	<p>petiole rhizome scar stem</p>

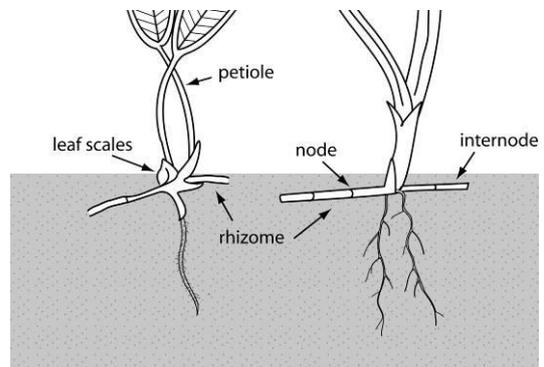
### Stem

The vertical stem, found in some species, is the upright axis of the plant from which leaves arise (attach). The remnants of leaf attachment are seen as scars. Scars can be closed (*entirely circle the vertical stem*) or open (*do not entirely circle the vertical stem*).



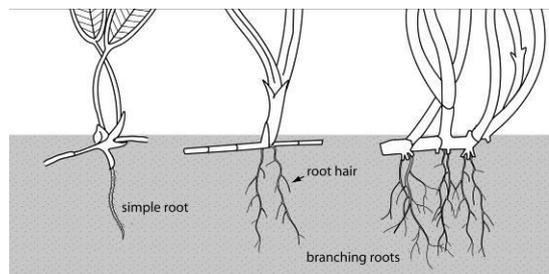
### Rhizome

The horizontal axis of the seagrass plant, usually in sediment. It is formed in segments, with leaves or vertical stem arising from the joints of the segments, the nodes. Sections between the nodes are called internodes. Rhizomes can be fragile, thick and starchy or feel almost woody and may have scars where leaves were attached.



### Root

Underground tissues that grow from the node, important for nutrient uptake and stabilisation of plants. The size and thickness of roots and presence of root hairs (very fine projections) are used for identification. Some roots are simple or cordlike, others may be branching, depending on seagrass species.



### Notes:

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# A guide to the identification of seagrasses in Melanesia

Adapted from <sup>[51]</sup>

## Leaves cylindrical



cylindrical

### *Syringodium isoetifolium*

- leaves noodle/spaghetti like and taper to a point
- leaves contain air cavities
- leaves 7-30cm long

### *Ruppia maritima*

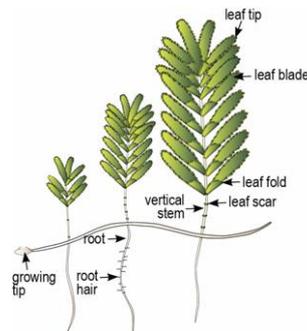
- leaves fine and thread-like,
- leaf tip pointed, sometimes serrated
- leaves up to 15cm long
- rhizome fragile
- inflorescence on a long stalk, sometimes spiralled

## Leaves oval to oblong



oval to oblong

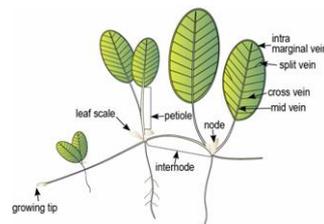
### obvious vertical stem with more than 2 leaves



### *Halophila spinulosa*

- leaves arranged opposite in pairs
- leaf margin serrated
- 10-20 pairs of leaves per shoot
- leaf 15-20mm long and 3-5mm wide

### leaves with petioles, in pairs



### *Halophila capricorni*

- fine hairs on one side of leaf blade
- leaf margins finely serrated
- leaf 15-30mm long and 5-9 mm wide
- 9-14 cross vein pairs, occasionally forked

### *Halophila decipiens*

- fine hairs on both sides of leaf blade
- leaf margins finely serrated
- leaf apex rounded to slightly pointed
- leaf 10-25mm long and 3-10mm wide
- 6-8 cross vein pairs

### *Halophila minor*

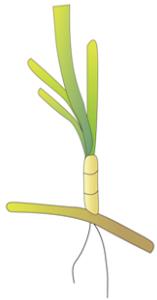
- less than 8 pairs of cross veins
- leaf 5-15mm long and 3.5-6mm wide
- leaf margins smooth
- no leaf hairs

### *Halophila ovalis*

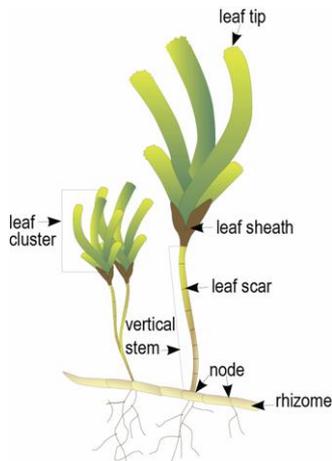
- 8 or more pairs of cross veins
- leaf 5-40mm long and 5-20mm wide
- leaf margins smooth
- no leaf hairs

## Leaves strap-like

### Leaves can arise from vertical stem



straplike



#### *Cymodocea rotundata*

- leaf tip rounded or slightly notched, with smooth edge
- leaf 2-4mm wide with 9-15 parallel veins
- leaf scars continuous around stem
- old sheaths forming a fibrous mass at the base of each shoot

#### *Cymodocea serrulata*

- leaf tip rounded with serrated edge
- leaf 4-9mm wide with 13-17 parallel veins
- leaf sheath broadly flat and triangular, not fibrous
- leaf scars not continuous around upright stem

#### *Halodule uninervis*

- leaf tip tri-dentate, not rounded
- leaf blades 0.5-5mm wide
- leaf with 3 distinct parallel veins, sheaths fibrous
- rhizome usually white with small black fibres at the nodes

#### *Halodule pinifolia*

- leaf tip rounded
- narrow leaf blades 0.25-1.2mm wide
- leaf with 3 distinct parallel veins, sheaths fibrous
- rhizome usually white with small black fibres at the nodes

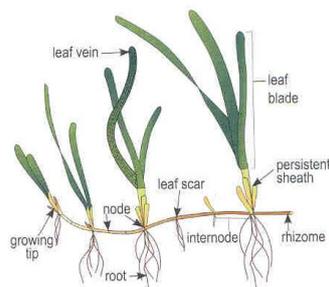
#### *Thalassia hemprichii*

- leaf tip rounded, may be slightly serrated
- leaf 4-12mm wide with 9-11 parallel veins
- leaf with small (1-2mm long) red flecks
- ligule absent
- leaf often distinctly curved
- rhizome thick with distinct nodes, usually triangular in shape
- one short root per rhizome node

#### *Thalassodendron ciliatum*

- distinct upright stem
- clusters of curved leaves (>5 mm wide), margins serrated
- stem and rhizome woody

### Leaves always arise directly from rhizome



#### *Enhalus acoroides*

- large plant, leaves >30 cm long, >1 cm wide
- in-rolled edges of leaves with rounded tip
- long, black bristles protruding from thick (1.5cm) rhizome
- roots cordlike and not branched/ramified, arising from the axillary buds of the ventral leaves
- often grows in a ring or patch

#### *Zostera muelleri*

- leaf with 3-5 parallel-veins
- cross-veins form mesh-like pattern across leaf blade
- leaf tip smooth and rounded, may be dark point at tip
- rhizome usually brown or yellow in younger parts
- prophyllum present, i.e. single leaf originating from rhizome instead of from vertical, leaf bearing shoot.

# Monitoring a seagrass meadow

Monitoring is the repeated observation of a system, usually to detect change. It is an integrated activity to evaluate the condition of the physical, chemical and biological character of the environment. Environment monitoring programs provide coastal managers with information and assist them to make decisions with greater confidence.

Environmental monitoring programs are ideally designed to: quantify the causes of change; examine and assess acceptable ranges of change for the particular site; and to measure levels of impacts.

Common drivers (reasons) for monitoring include: community interest; government policies such as Coastal Strategies and Plans, Oceans Policy, State of the Environment Reporting (SoE), Water Quality guidelines or Best Practice Guidelines; and Government Legislation (e.g., Fish Habitat Protection).

Users of the monitoring program information/results are diverse, including for example: the general public, environmental regulators - legislators, resource managers and scientists.

There are a number of issues to consider when implementing a monitoring program, including: ensure the protocols used have explicit objectives; clearly identified responsibilities of the partners (e.g. Gov agencies, consultants, First Nations and community groups); a clear and defensible rationale for using the parameters that are measures (e.g. physico/chemico, biological indicators); to have a baseline (first) assessment / measure against which subsequent changes can be measured/compared; knowledge of spatial and temporal variation prior to designing the program (i.e. pilot study); clearly defined field protocols; data management procedures, ensure the level of change and accuracy of the detection is appropriate (as will vary according to the methodology); selection of statistical tools; and a mechanism to reduce and manage errors (i.e. QA/QC program).

Appropriate Quality Assurance/Quality Control (QA/QC) procedures are an integral component of all aspects of sample collection and analysis in monitoring programs. This includes participation in relevant inter-laboratory studies, proficiency testing, and the use of standard reference materials. Monitoring programs often include the following guidelines for implementation by data collectors and reporters:

- appropriate methods must be in place to ensure consistency in field procedures to produce robust, repeatable and comparable results including consideration of sampling locations, replication and frequency;
- all methods used must be fit for purpose and suited to a range of conditions;
- appropriate accreditation of participating laboratories or provision of standard laboratory protocols to demonstrate that appropriate laboratory QA/QC procedures are in place for sample handling and analysis;
- participation in inter-laboratory performance testing trials and regular exchange of replicate samples between laboratories;
- rigorous procedures to ensure 'chain of custody' and tracking of samples;
- appropriate standards and procedures for data management and storage; and
- a process to ensure data collectors are aware of any errors and provide an opportunity to clarify or correct data.

## Monitoring seagrass

Seagrasses are often at the downstream end of catchments, receiving runoff from a range of agricultural, urban and industrial land-uses. Seagrass communities are generally susceptible to changes in water quality and environmental quality that make them a useful indicator of environmental health. Seagrass make good bioindicators of environmental health because they are:

- are widely distributed;
- are sessile plants which show measurable and timely responses to external stressors/impacts (rather than relocating to a less stressful environment) and;
- are integrative of environmental conditions.

Several factors are important for the persistence of healthy seagrass meadows, these include: sediment quality and depth; water quality (temperature, salinity, clarity); current and hydrodynamic processes; and species interactions (e.g., epiphytes and grazers). Seagrass generally respond in a typical manner that allows them to be measured and monitored. In reporting on the health of seagrasses it is important to consider the type of factors that can affect growth and survival. Factors include:

- increased turbidity reduces light penetration through the water, interfering with photosynthesis and limiting the depth range of seagrass;
- increased nutrient loads encourages algal blooms and epiphytic algae to grow to a point where it smothers or shade seagrasses, thereby reducing photosynthetic capacity;
- increased sedimentation can smother seagrass or interferes with photosynthesis;
- herbicides can kill seagrass and some chemicals (e.g., pesticides) can kill associated macrofauna;
- boating activity (propellers, mooring, anchors) can physically damage seagrass meadows, from shredding leaves to complete removal;
- storms, floods and wave action can rip out patches of seagrasses.

## Seagrass-Watch

A method for monitoring seagrass resources is used in the Seagrass-Watch: Global Seagrass Observing Network. This method uses globally standardised measurements taken from sites established within representative meadows to monitor seagrass condition. The number and position of sites can be used to investigate natural and anthropogenic impacts.

Seagrass-Watch is one of the largest seagrass monitoring programs in the world. Since its genesis in March 1998 in Australia, Seagrass-Watch has expanded internationally to more than 26 countries. Currently 445 sites have been established across 26 countries, with active monitoring at 298 sites (85 sites suspended and 62 archived). To learn more about the program, visit [www.seagrasswatch.org](http://www.seagrasswatch.org).

Seagrass-Watch aims to raise awareness on the condition and trend of nearshore seagrass ecosystems and provide an early warning of major coastal environment changes. Participants of Seagrass-Watch are scientists and volunteers from a wide variety of backgrounds who all share the common interest in marine conservation. Most participants are associated with universities & research institutions, government (local & state), non-government organisations or established local stakeholder groups.

Seagrass-Watch integrates with existing scientific programs to protect this important marine ecosystem for the benefit of the global community. The program has a strong scientific underpinning with an emphasis on consistent data collection, recording and reporting. Seagrass-Watch identifies areas important for seagrass species diversity and conservation and the

information collected is used to assist the management of coastal environments and to prevent significant areas and species being lost.

Seagrass-Watch methods were developed to be rigorous, yet relatively simple and easy to use. Each of the parameters used have been carefully chosen with a clear and defensible rationale. The protocols used have explicit objectives and the sampling strategy is prepared using baseline and knowledge of spatial and temporal variation. This ensures data is of the highest quality and that time and resources are not wasted. The only condition is that on ground data collection must be overseen by a qualified scientist or trained and competent participant (18 years or over). After comprehensive training, participants can produce reliable data. Training includes both formal and informal approaches. Formal training is conducted by Seagrass-Watch HQ for participants 18 years of age and over, and includes lectures and on-site assessments with a tiered level of certification for competency. Formally trained participants are certified to supervise on-site monitoring and demonstrate (i.e. informally train) monitoring methods. At least a professional scientist or a formally trained volunteer must be present at each monitoring event. Evidence of competency is securely filed at Seagrass-Watch HQ.

### **QUALITY ASSURANCE-QUALITY CONTROL**

Seagrass-Watch has an accepted Quality Assurance-Quality Control program in place to ensure that the program is producing data of high quality, and that time and resources are not wasted. Seagrass-Watch HQ has systems in place to manage the way Seagrass-Watch data is collected, organised, documented, evaluated and secured. The Seagrass-Watch program collects and collates all data in a standard format. By using simple and easy methods, Seagrass Watch ensures completeness (the comparison between the amounts of valid or useable data originally planned to collect, versus how much was collected). Standard seagrass cover calibration sheets are used to ensure precision (the degree of agreement among repeated measurements of the same characteristic at the same place and the same time) and consistency between observers and across sites at monitoring times to ensure percentage covers are close to a true or standardised value.

Other QAQC procedures include the selection of intertidal seagrass sites which are permanently marked with either plastic star pickets or an accurate ( $\pm 3\text{m}$ ) GPS waypoint. Labels identifying the sites and contact details for the program are attached to these pickets. This ensures that the same site is monitored each event and that data can be compared between periods of time.

Ongoing standardisation of observers is achieved by on-site refreshers of standard percentage covers by all observers prior to monitoring and through *ad hoc* comparisons of data returned from duplicate surveys (e.g. either a site or a transect will be repeated by Seagrass-Watch HQ scientists – preferably the next day and unknown to local observers). Any discrepancy in these duplicates is used to identify and subsequently mitigate bias. For the most part, uncertainties in percentage cover or species identification are mitigated in the field via direct communication (as at least one experienced/certified observer is always present), or the collection of voucher specimens (to be checked under microscope and pressed in herbarium) and the use of a digital camera to record images (protocol requires all quadrats are photographed) for later identification and discussion.

Seagrass-Watch HQ has implemented a quality assurance management system to ensure that data collected is organised and stored and able to be used easily. All data (datasheets and photographs) received are entered onto a relational database on a secure server. Receipt of all original data hardcopies is documented and filed within the Seagrass-Watch File Management System, a formally organised and secure system, and housed at James Cook University. Seagrass-Watch HQ operates as custodian of data collected from other participants and provides an evaluation and analysis of the data for reporting purposes. Access to the IT system

and databases is restricted to only authorised personnel. Provision of data to a third party is only on consent of the data owner/principal.

Seagrass-Watch HQ checks all data for completeness, consistency and accuracy. All data submitted to Seagrass-Watch HQ it is first checked for compliance:

- *legible original datasheets,*
- *good quality quadrat photographs (high resolution),*
- *voucher specimens (if required) and*
- *completed MS Excel spreadsheet.*

Validation is provided by checking observations against photographic records to ensure consistency of observers and by identification of voucher specimens submitted. In accordance with QA/QC protocols, Seagrass-Watch HQ advises observers via an official Data Notification of any errors encountered/identified and provides an opportunity for correction/clarification (this may include additional training).

Once Seagrass-Watch HQ has completed all checks, a field in the Master database identifies data as either passed, quarantined, non-compliant or not-passed. Non-compliant data is used for large-scale summary reporting only if the data quality is deemed acceptable, i.e. if it was collected by a scientist or formally trained participant, then the scans/copies of datasheets are sufficient (*only if originals are not available*), and/or that the quadrat images were acceptable to complete QAQC, etc. If data quality is unacceptable, the data is either not entered into the Master database or remains quarantined/not-passed (excluded from analysis & reporting). If predominantly non-compliant data is used for detailed analysis and reporting at a site or location/region, it is marked on the outputs with a notice of non-compliance (e.g., site graphs). If officially requested data is non-compliant, a note in the metadata advises of non-compliance and includes a caveat to "use with caution". Any data considered unsuitable (e.g. nil response to data notification within thirty days) is quarantined or removed from the database.

Seagrass-Watch employs a proactive approach to monitoring, involving ongoing training for observers and the continued development of new methods and refinement of existing methods, including location/habitat specific calibration sheets, operation & validation of autonomous temperature and light loggers, etc. Quality data reassures the data users (e.g., coastal management agencies) that they can use the data to make informed decisions with confidence.

## **DATA PROPERTY AND OWNERSHIP**

All raw data collected throughout the Seagrass-Watch program is the property of the individual/group/institution (*Principal*) who collected it, and Seagrass-Watch Ltd is custodian. When a Principal (*data collector*) submits data to Seagrass-Watch HQ, they do so under the proviso that Seagrass-Watch HQ can conduct a data quality assessment as part of the Seagrass-Watch program's QAQC protocols and that the validated data is available for condition and trend reporting at location, regional, state, national and global scales (e.g., State of the Environment). Copies of raw data are provided to third parties only when permission from the Principal is provided.

Ownership of data within the Seagrass-Watch program is determined by mutual agreement based on who is collecting the raw data, whether the data undergoes a quality assessment as part of Seagrass-Watch QAQC protocols and the funding sources that support the monitoring:

- **Raw Data** ownership (intellectual property rights) lies with the Principal (*data collector*). Seagrass-Watch Ltd is custodian of the Raw Data.
- **Validated Data** ownership (intellectual property rights) is shared between the Principal and Seagrass-Watch Ltd.

All data interpretation is conducted by Seagrass-Watch HQ. This ensures that the interpretation of data is consistent, unbiased and of scientific merit. Seagrass-Watch HQ also encourages peer review of published results.

Apart from the regional & state-wide report cards, the data has also been used for:

- understanding and responding to impacts from catchment runoff<sup>[52, 53]</sup>, coastal developments (e.g., marina constructions) and dredging proposals.
- Understanding natural levels of change<sup>[54-56]</sup> and supporting marine habitat conservation (e.g., GSS Ramsar Wetland, Cooloola World Heritage area, and Great Sandy Marine Park).

Seagrass-Watch monitoring efforts are vital to assist with tracking global patterns in seagrass health, and assessing human impacts on seagrass meadows, which have the potential to destroy or degrade these coastal ecosystems and decrease their value as a natural resource. Responsive management based on adequate information will help to prevent any further significant areas and species being lost. To protect the valuable seagrass meadows along our coasts, the community, government and researchers have to work together.

THE GOALS OF THE PROGRAM ARE:

- *To educate the wider community on the importance of seagrass resources*
- *To raise awareness of coastal management issues*
- *To build the capacity of local stakeholders in the use of standardised scientific methodologies*
- *To conduct long-term monitoring of seagrass & coastal habitat condition*
- *To provide an early warning system of coastal environment changes for management*
- *To support conservation measures which ensure the long-term resilience of seagrass ecosystems.*

Notes:

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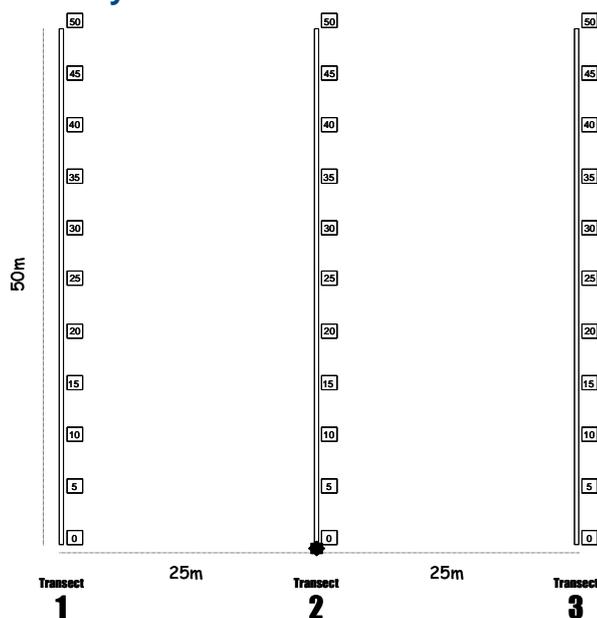
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# Permanent Transect Monitoring Protocols

Source: McKenzie et al. 2003<sup>[57]</sup> ([www.seagrasswatch.org/manuals/](http://www.seagrasswatch.org/manuals/))

## Site layout



**Quadrat code = site + transect+quadrat**

**e.g., C11225 = Chek Jawa, site 1, transect 2, 25m quadrat**

## Pre-monitoring preparation

### Make a Timetable

Create a timetable of times of departure and arrival back, and what the objective of the day is and what is to be achieved on the day. Give a copy of this to all participants involved in advance so they can make their arrangements to get to the site on time. List on this timetable what participants need to bring.

### Have a Contact Person

Arrange to have a reliable contact person to raise the alert if you and the team are not back at a specified or reasonable time.

## Safety

- Assess the risks before monitoring - check weather, tides, time of day, etc.
- Use your instincts - if you do not feel safe then abandon sampling.
- Do not put yourself or others at risk.
- Wear appropriate clothing and footwear.
- Be sun-smart.
- Be aware of dangerous marine animals.
- Have a first aid kit on site or nearby
- Take a mobile phone or marine radio

## Necessary equipment and materials

- 3x 50metre fibreglass measuring tapes
- 6x 50cm plastic tent pegs
- Compass
- 1x standard (50cm x 50cm) quadrat
- Magnifying glass
- 3x Monitoring datasheets
- Clipboard, pencils & 30 cm ruler
- Camera & film
- Quadrat photo labeller
- Percent cover standard sheets
- Seagrass identification sheet

## Each sampling event

Within the site, lay out the three 50 metre transects parallel to each other, 25 m apart and perpendicular to shore (see site layout). Within each of the quadrats placed for sampling, complete the following steps:

### Step 1. Take a Photograph of the quadrat

- Photographs are taken of every quadrat along each transect. Use a quadrat free of strings and place the photo quadrat labeller beside the quadrat and the tape measure, with the correct site code displayed.
- Take the photograph from an angle as **vertical** as possible, which includes the entire quadrat frame, quadrat labeller and tape measure. Avoid having any shadows or patches of reflection off any water in the field of view. Check the photo taken box on datasheet for quadrat.

### Step 2. Describe sediment composition

- Dig your fingers into the top centimetre of the substrate and feel the texture. Describe the sediment by noting the grain size in order of dominance (e.g., Sand, Fine sand, Fine sand/Mud).
- Note features such as ripples across the sediment surface (indicates the level of sediment movement from wave action)

### Step 3. Describe other features and ID/count of macrofauna

- Note and count (whole numbers - never use < or > symbols) any features which may be of interest (e.g. gastropods, hermit crabs, dugong excavating, turtle cropping, bioturbation, sediment ripples) within the comments column.
- If water covers half or more of the quadrat, measure depth in cm.

#### **Step 4. Estimate seagrass percent cover**

- Looking down on the quadrat from above, estimate the total percentage of the seabed (substrate) within the quadrat covered by seagrass leave. Estimate the footprint/shadow provided by the seagrass shoots.
- Always use the percent cover photo standards (calibration sheets) as your guide, estimating cover as accurate as possible, e.g. 27%, 61%. Remember, the lower the cover, the more accurate the measures.
- If cover is below 3%, you can count the seagrass shoots and calculate percent cover using the rule of approx 1 shoot = 0.1%. Please note: this will be greater for shoots of larger sized species.

#### **Step 5. Estimate seagrass species composition**

- Identify the species of seagrass within the quadrat and determine the percent contribution of each species (always start with least abundant species, total composition must equal 100%).
- Use seagrass species identification keys provided and use more than 1 feature to identify each species.

#### **Step 6. Measure seagrass canopy height**

- Measure canopy height (in centimetres) of the dominant strap-leaf species, ignoring the tallest 20%.
- Measure from the sediment to the leaf tip of 3 shoots, entering all 3 measures onto datasheet.

#### **Step 7. Estimate algae percent cover**

- Looking down on the quadrat from above, estimate the total percentage of the seabed (substrate) within the quadrat covered by macroalgae (independent of seagrass cover)
- Macroalgae is not attached to seagrass leaves and may be attached to rocks, shells or may be drifting.

#### **Step 8. Estimate epiphyte percent cover**

- Epiphytes are algae attached to seagrass blades and often give the blade a furry appearance.
- First estimate how much of an average seagrass leaf surface is covered, and then how many of the leaves in the quadrat are covered. For example, if 20% of the blades are 50% covered by epiphytes, then quadrat epiphyte cover is 10%. Use the epiphyte matrix to assist you.
- Do not include epifauna with epiphytes. Epifauna are sessile animals attached to seagrass blades – record % cover of epifauna in the comments or an unused/blank column – do not add to epiphyte cover.

#### **Step 9. Take a voucher seagrass specimen if required**

- Place seagrass samples in a labelled plastic bag with a little seawater and a waterproof label. Select a representative specimen of the species and ensure that you have all the plant parts including the rhizomes and roots. Collect plants with fruits and flowers structures if possible.

#### **Step 10. Move to next quadrat**

- Repeat steps 1 to 8 for the remaining 32 quadrats

#### **Step 11. Monitoring seed banks (an indicator of meadow resilience)**

- Using the seed corer, sample sediment to a depth of 10cm every 10m along five transects, 12.5m apart.
- Release each core into a sieve, wash away the sediment and count the number of seeds retained.

### **At completion of monitoring**

#### **Step 1. Before leaving the site**

- Check data sheets are filled in fully.
- Remove equipment from site (e.g. non-permanent pegs)

#### **Step 2. Wash & pack gear**

- Rinse all tapes, pegs and quadrats with freshwater and let them dry. Do every day of monitoring.
- Review supplies for next sampling and request new materials.
- Store gear in a safe and dry place for next sampling.

#### **Step 3. Press any voucher seagrass specimens if collected**

- The voucher specimen should be pressed as soon as possible after collection. Do not refrigerate >2 days.

#### **Step 3. Submit all data**

- Data can be entered into the MS-Excel file downloadable from [www.seagrasswatch.org](http://www.seagrasswatch.org).
- Upload full resolution quadrat photos, high resolution scans of datasheets and data files to a file hosting service or similar.
- If required, mail original datasheets and herbarium sheets

Seagrass-Watch HQ  
For postal or email address, see  
[seagrasswatch.org/contact/](http://seagrasswatch.org/contact/)

# SEAGRASS SPECIES CODES

**Ea**

*Enhalus acoroides*



- very long (>30cm) ribbon-like leaves with inrolled leaf margins
- thick rhizome with long black bristles and cord-like roots

**Th**

*Thalassia hemprichii*



- ribbon-like, curved leaves 10-40cm long
- leaf tip rounded, slightly serrated
- short black tannin cells, 1-2mm long, in leaf blade
- thick rhizome with scars between shoots

**Cr**

*Cymodocea rotundata*



- rounded leaf tip
- narrow leaf blade (2-4mm wide)
- leaves 7-15 cm long
- 9-15 longitudinal veins
- well developed leaf sheath

**Cs**

*Cymodocea serrulata*



- serrated leaf tip
- wide leaf blade (5-9mm wide)
- leaves 6-15cm long
- 13-17 longitudinal veins
- robust/strong rhizome

**Hd**

*Halophila decipiens*



- oval leaf, slightly pointed
- leaf hairs on both sides
- 6-8 cross veins
- leaf margins finely serrated

**Hm**

*Halophila minor*



- less than 8 cross veins
- small oval leaf blade less than 5mm wide
- leaf margins smooth
- no leaf hairs

**Si**

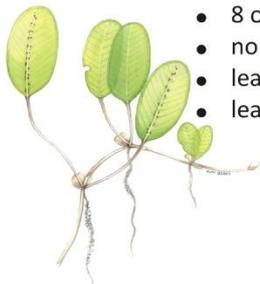
*Syringodium isoetifolium*



- narrow noodle-like leaves
- cylindrical in cross section, 1-2mm diameter
- leaves contain air cavities
- leaf tip tapers to a point
- leaves 7-30cm long

**Ho**

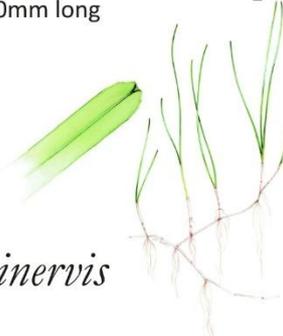
*Halophila ovalis*



- 8 or more cross veins
- no hairs on leaf surface
- leaf margins smooth
- leaf 5-20mm long

**Hp**

*Halodule pinifolia*



- rounded leaf tip
- 1 central vein
- pale rhizome, with clean black leaf scars

**Rm**

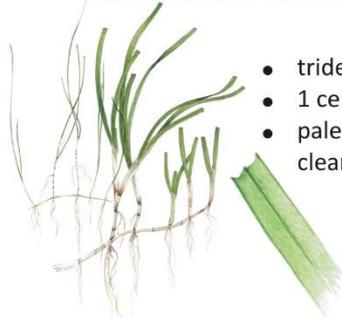
*Ruppia maritima*



- leaves fine and thread-like
- pointed tip on leaves, sometimes serrated
- inflorescence on a long stalk, sometimes spiralled
- rhizome fragile

**Hu**

*Halodule uninervis*



- trident leaf tip
- 1 central vein
- pale rhizome, with clean black leaf scars

**Tc**

*Thalassodendron ciliatum*



- erect stem to 65cm bearing leaf cluster
- rhizome tough and woody
- ribbon-like, sickle-shaped leaves with ligule
- round, serrated leaf tip
- often found attached to rock or coral substrate

# SEAGRASS-WATCH MONITORING



ONE OF THESE SHEETS IS TO BE FILLED OUT FOR EACH TRANSECT YOU SURVEY

START of transect (GPS reading)

Latitude: ..... Longitude: .....

OBSERVER: Beverly Citizen DATE: 17/2/21  
 LOCATION: Burren Heads  
 SITE code: BHT1 TRANSECT no.: 2  
 START TIME: 1304 END TIME: 1340

Quadrat (metres from transect origin)	Sediment (eg. mud/sand/shell)	Comments (eg 1lx gastropods, 4x crab holes, dugong, feeding trails, herbarium specimen taken)	Seagrass coverage (%)	% Seagrass species composition			Canopy height (cm)	% Algae cover	% Epi- cover
				HO	HU	ZC			
1 (0m)	Sand	SCx3 DFTx1 HCx1	40	30	70	0	5417	5	33
2 (5m)	Fs/S	GASx2 Ray pt x2	33	50	50	0	61616	10	18
3 (10m)	CS	Hcx3	0			0	-	0	-
4 (15m)	m/s	CHx10	0			1cm	-	17	-
5 (20m)	m/s	Turtle cropping GASx3	18	5	90	5	71516	12	57
6 (25m)	m/s/sh	SCx3 mwx2	36	90	90	10	81616	2	95
7 (30m)	Fine Sand	CHx9 GWSx1	48	100			-	0	10
8 (35m)	CS/S	Nothing	0.7		100		61515	0	36
9 (40m)	FS	HCx2	23	96	4		551516	5	38
10 (45m)	S/m	GWSx2	41	3	97		81817	3	90
11 (50m)	mud	CHx2 SCx1	16	3	7	90	71718	38	95

END of transect (GPS reading) Latitude: ..... Longitude: .....  
 FS = Fine Sand  
 CS = Coarse Sand  
 m = mud  
 S = Sand  
 SC = Sea Cucumber  
 HC = Hermit Crab  
 GAS = Gastropod  
 CH = Crab Hole  
 mw = mud worm  
 CW = Green worm  
 DFT = Dugong feeding trail

# Making a herbarium press specimen

Herbaria are repositories of preserved and labelled plant specimens, arranged to allow easy access and archival storage. The specimens are typically in the form of herbarium sheets: pressed and dried plants that have been attached to a sheet of heavy paper together with a data label. Herbarium specimens are simple in form and low-tech in preparation, yet it preserves a wealth of valuable information. If properly stored, a herbarium specimen will last for centuries without much deterioration. Specimens document the variation in form and geographical range of species. Herbaria also document valuable historical collections, such as "type specimens", the original specimens on which a plant's Latin name is based. Many herbarium specimens record the existence of plants in habitats now developed and lost.

## Collection

Before collecting any seagrass specimens, ensure you have the appropriate permits. For example, in Queensland, all marine plants, including seagrass, are protected under the Fisheries Act 1994.

In the field, collect a handful of representative seagrass shoots, including the leaves, rhizomes and roots. Keep in mind that it is not always possible to get a successful classification if you do not have particular parts such as flowers, fruits, seeds and roots, so try to select shoots which have these features. Ideally, collect plants with growing tips (apical meristems) as they contain higher concentrations of DNA which could aid genetic identification in the future.

Specimens should be pressed as soon as possible after collection. If it is more than 2 hours before you press the specimen, then you should refrigerate to prevent any decomposition. Do not refrigerate longer than 2 days, press the sample as soon as possible.

## Pressing

### Tools

First you will need some clean white cartridge-type paper (photocopy paper will suffice) and herbarium sheets (if available). You will also need forceps, scissors/scalpel, a dish of clean fresh water and a herbarium press. It is not difficult to build a home-made press, keeping in mind that what must be accomplished is to keep the specimens squeezed between layers of paper (newspapers or blotting paper) until they are totally devoid of the original content of water. The upper and lower parts of the press might be made of heavy cardboard or thick plywood or equivalent material. A more advanced kind of press might be built for an optimal drying of your plants. This press can be made with two wooden boards with screws and nuts placed at each corner: turning the nuts the two boards will come closer pushing together the paper with the plants. This kind of press can be built at home or bought in some art tools stores.

### Preparation

Wash the seagrass specimen in clean fresh water and carefully remove any debris, epiphytes or sediment particles.

### Arrangement

It is very important that the seagrass specimen be arranged so that you can immediately see all the main characters of that particular species; so do not focus only at the aesthetics of the mounted specimen. It is advisable to arrange specimens before being placed in the press as once dried, plant specimens can easily be broken if handled without care. The best manner to place the plants on the mounting sheets is to align them with the right side of the page (or

diagonally if space is required) and to have the heaviest parts and specimens at the bottom. Leaves can be folded in larger specimens if a larger press is not available. It is better to leave an empty space at the borders of the mounting sheets; but you can either arrange your specimens (along with the label) in a regular way from page to page, or stagger the specimens at different positions on each sheet, so that each group of sheets will have a more equally distributed pressure.

## Labels

Each specimen must have a label on its own sheet, which should include the taxonomic denomination (*at least family, genus and species*) along with information on the date and place of collection. The name of the collector and of the individual who did the determination should also be added. Use permanent and water resistant ink (black or blue) to write your labels; otherwise a pencil can be used (medium lead). Specimen labels should include:

- species name (*if known*)
- location & site code (*if applicable*)
- date collected
- latitude/longitude
- water depth
- % seagrass cover
- sediment type
- other seagrass species present
- name of collector and who identified the specimen
- comments -*such as presence of flowers/fruits or ecological notes*

Place the label on the lower right hand corner of the paper.

## Drying

Place another clean sheet of paper over the specimen and place within several sheets of newspaper. As circulating air is very important to get your specimens dried in a short time, the assemblage of specimen/paper should be placed within two sheets of corrugated cardboard and then into a herbarium press. Corrugated cardboard ensures air can penetrate and speed up the drying process. If no corrugated cardboard is available, keep the filled press size small.

Once in the herbarium press, wind down the screws until tight (*do not over tighten*). If you do not have a press, the specimens can be pressed by putting some heavy object on top, i.e. bricks or large books. It is important that the plants are put under sufficient pressure; otherwise more time will be required to achieve a good desiccation, besides they could be damaged by dampness and moulds.



The press should be exposed to a gentle heat source, avoiding excessive heat that will "cook" the specimens. Sometimes it is possible to use the heat from the sun. In this case the presses should be small. If fire is the heat source, keep the press at a safe distance to prevent fire starting on the press.

Changing the paper is a very important step. In the first three or four days a paper change should take place every day, then you can leave more time between changes. If you neglect the change of paper the plants will take more time to lose their water content, besides they could be

damaged if the paper stays wet for a few days. When changing the paper you must keep the specimens intact and ensure the label travels with the specimen. The minimum time required for complete drying ranges from two to four days or more. Once a specimen has become dry and stiff, it can be mounted and placed into the herbarium.

## Mounting

Once the specimen is completely dry, you will need to mount it to herbarium sheets if available or a new clean white cartridge-type paper.

There are different ways to mount the specimens to the herbarium sheets, such as strapping, gluing, or pinning. We recommend the strapping method using removable adhesive tape (e.g. Magic Tape). The tape pulls off easily, leaves behind no messy residue, and can be pulled up and moved around. To fix the specimen to the mounting paper, lay small strips of tape across a few sturdy parts of the plant (e.g. either end of rhizome or a stem) at a minimal number of points. This method will allow a certain degree of movement for further examinations, but the specimen will not fall from the mounting paper

## Herbaria

Once the specimen is mounted it can be stored in a dry place or lodged in Herbaria. If you do not have a Herbaria nearby (usually located at a University or Government agency), you can submit specimens to Seagrass-Watch HQ which maintains a Herbaria.

Alternatively, you can email a scanned image of the pressed specimen. Please ensure that the scanned image is no less than 600 dpi and includes the specimen and label. Scanned images can be sent to [hq@seagrasswatch.org](mailto:hq@seagrasswatch.org) and will be lodged in the Seagrass-Watch Virtual Herbarium <http://www.seagrasswatch.org/herbarium/>.

The Virtual Herbarium is an electronic gateway to the collections of the Seagrass-Watch HQ herbaria. The goals of the Virtual Herbarium are to make specimen data available electronically for use in biodiversity research projects; to reduce transport of actual specimens for projects where digital representations will suffice for study; and to provide a source of reference information for Seagrass-Watch participants.

## Notes:

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# Understanding sediment

Seagrasses, especially structurally large species, affect coastal and reef water quality by trapping sediments and acting as a buffer between catchment inputs and reef communities. Seagrass meadows have the ability to modify the energy regimes of their environments, and help stabilise sediment by trapping and binding the sediment. However, the trapping ability of seagrass is in reality an equilibrium established between deposition/sedimentation and erosion/resuspension.

Studies have shown that sediment characteristics are important in determining seagrass growth, germination, survival, and distribution. As part of Seagrass-Watch, field descriptions of sediment type collected 0-2 cm below the sediment/water interface are determined by visual and tactile inspection of (wet) samples and constituents (primary descriptors) differentiated according to the Udden – Wentworth grade scale.

## **Grain size classes used, based on the Udden – Wentworth grade scale <sup>[58]</sup>.**

<b>Mud</b>	Fine-medium Clay	0 – 0.002 mm
	Coarse Clay	0.0021 – 0.004 mm
	Very Fine Silt	0.0041– 0.008 mm
	Fine Silt	0.0081 – 0.016 mm
	Medium Silt	0.0161 – 0.031 mm
	Coarse Silt	0.0311 – 0.063 mm
<b>Sand</b>	Very Fine Sand	0.0631 – 0.125 mm
	Fine Sand	0.1251 – 0.250 mm
	Medium Sand	0.2501 – 0.500 mm
	Coarse Sand	0.5001 – 1.000 mm
	Very Coarse Sand	1.0001 – 2.000 mm
<b>Gravel</b>	Granules	2.0001 – 4.000 mm
	Pebbles and larger	>4.0001 mm

In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

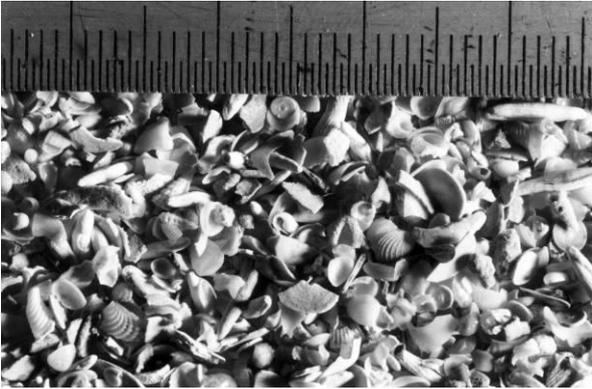
The sediment **Primary Descriptors** are written down from left to right in decreasing order of abundance: e.g. Mud/Sand is mud with sand, where mud is determined as the dominant constituent (by volume).

<b>mud</b>	<i>has a smooth and sticky texture.</i>
<b>fine sand</b>	<i>fairly smooth texture with some roughness just detectable. Not sticky in nature.</i>
<b>sand</b>	<i>rough grainy texture, particles clearly distinguishable.</i>
<b>coarse sand</b>	<i>coarse texture, particles loose.</i>
<b>gravel</b>	<i>very coarse texture, with some small stones.</i>

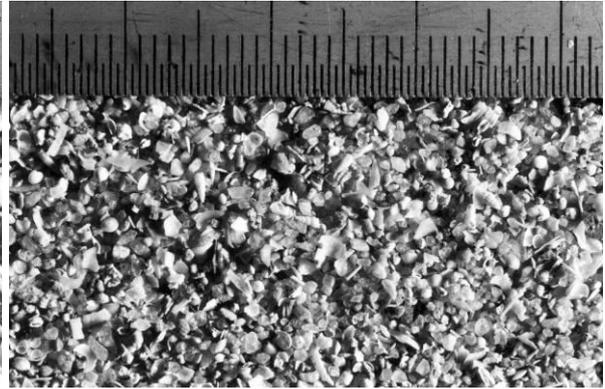
Sediment type **Modifiers** are also commonly used, however these are recorded in the comments section. Modifiers include: coral, shell grit, forams, diatoms, etc.

The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments <sup>[59]</sup>,

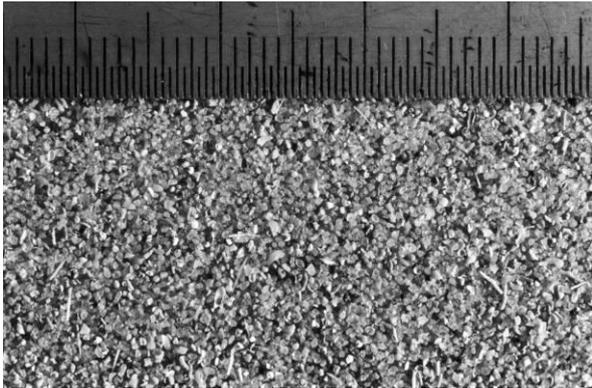
<https://bit.ly/3pTowW>.



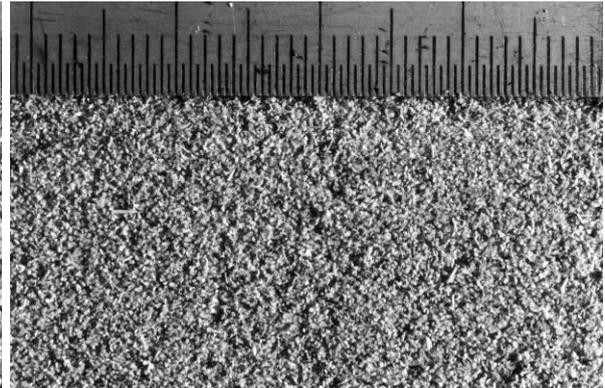
gravel (>2mm)



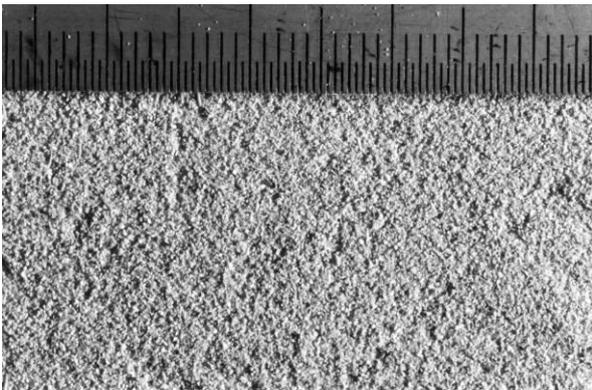
very coarse sand (1 - 2 mm)



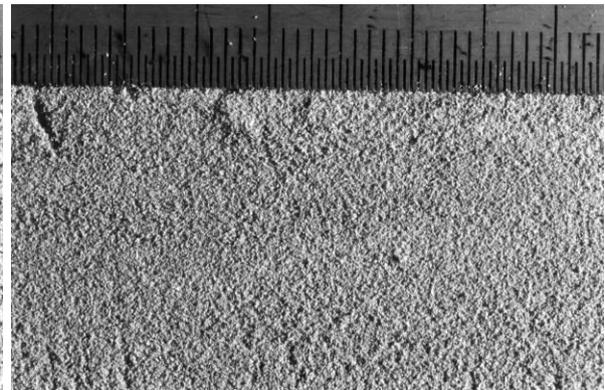
coarse sand (0.5 - 1 mm)



medium sand (0.25 - 0.5 mm)



fine sand (0.125 - 0.25 mm)



very fine sand (0.063 - 0.125mm)

**Notes:**

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# Mapping seagrass extent

To make informed management decisions, coastal managers require maps that detail the characteristics of seagrass resources. This includes information on where different species of seagrasses are found, their proportions and quantities, how they respond to human-induced changes, and whether damaged meadows can be repaired or rehabilitated. Additionally, understanding the extent of natural changes in seagrass meadows is crucial for distinguishing between human impacts and normal background variability. Changes may manifest in various aspects, such as the location, area, shape, or depth of a meadow. However, alterations in abundance, species composition, growth, productivity, and the associated flora and fauna can also occur, with or without a shift in distribution.

Seagrass-Watch activities include mapping the extent of seagrass meadows within a defined Area of Interest (AOI). This may be a site, locality (e.g., bay) or region. Mapping includes both the intertidal and subtidal seagrass meadows.

When developing a mapping task, there are a number of factors and several issues that need to be considered.

## **Scale**

The selection of a mapping scale represents a compromise between two components. One is the maximum amount of detail required to capture the necessary information about a resource. The other is the logistical resource available to capture that level of detail over an AOI. Mapping requires different approaches depending on whether the AOI is relative to a region (tens of kilometres), locality (tens of metres to kilometres) or to a specific site (metres to tens of metres). Scale includes aspects both of extent and resolution. In both broad and meso-scale approaches, the intensity of field validation/observation may be low (low resolution), with a statistical sampling design that allows the results to be extrapolated from a few observations to the extent of the AOI. For finer scale examinations of seagrass meadows, the sampling intensity required can be high with greater precision (high resolution). Scale also influences what is possible with a limited set of financial and human resources. The financial, technical, and human resources available to conduct the mapping is also a consideration.

## **Accuracy**

Determining the level of detail required when mapping an AOI also depends on the level of accuracy required for the final map product. Errors that can occur in the field directly influence the quality of the data. It is important to document these. Global Navigation Satellite System (GNSS) receivers are a quick method for position fixing during mapping and reduces point errors to <3m in most cases. It is important for the observer to be as close as possible to the GNSS aerial receiver to minimise position fix error.

## Choosing a Mapping strategy/approach

### ***Defining the Area of Interest (AOI)***

Identifying the Area of Interest (AOI) in which to conduct mapping activities is dependent upon the question being addressed, the human capacity and accessibility to suitable observing platforms. In most instances, the AOI may be restricted to waters shallower than 15m water depth. Once the extent of the AOI is identified (this also determines the scale of the mapping exercise), a mapping approach and sampling design for field data collection (i.e., plan) is prepared. In preparation for the approach and plan, all available seagrass spatial data should be first collated for the AOI via extensive literature and database searches. In some instances, it is



a good idea to conduct a reconnaissance survey. An initial visual (reconnaissance) survey of the region/area will give you an idea as to the amount of variation or patchiness there is within the meadows and benthic habitat types.

### Mapping approach

New and emerging technologies are changing the ways we assess seagrass meadows. Traditionally, seagrass mapping was conducted predominately by *in situ* observational approaches <sup>[60]</sup>, 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. GNSS, geotagging, Unoccupied Aerial Vehicles (UAVs)) have provided opportunities to revise/modify approaches to mapping seagrass meadows <sup>[61]</sup>. 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.

In the last few years, seagrass field mapping protocols have been 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, which are globally standardised <sup>[62]</sup>.

Globally standardised protocols were developed using design thinking <sup>[63]</sup>, where various scientific techniques were trialled and modifications fashioned on feedback from scientists and the broader community. To this end, Seagrass-Watch has developed a suite of booklets and field guides which detail the collection of quantitative data seagrass on seagrass condition using subtidal and Intertidal spot-checks ([seagrasswatch.org/iki-seagrass-resources](http://seagrasswatch.org/iki-seagrass-resources)). To encourage participation by a wider constituency of participants, the online app Seagrass Spotter ([seagrassspotter.org](http://seagrassspotter.org)) has also been developed by Project Seagrass (a Seagrass-Watch partner) to enable capture of seagrass spatial data by citizen scientists to supplement the quantitative mapping.

A mapping approach Seagrass-Watch recommends for mesoscale and broadscale mapping is Earth Observing from Space, coupled with on-site Near Earth and direct *in situ* Observing <sup>[61]</sup>. For finescale mapping, Near-field passive remotely sensed data collected from Unoccupied Aerial Vehicle (UAV), or helicopter is recommended. The near earth instrument of choice is a drop-camera (slaved to the surface via a WiFi extension cable) and the direct *in situ* observing which can be conducted on foot or snorkel. The near earth and *in situ* observing provides the field validation necessary for the classification/analysis of the satellite acquired imagery.

## Developing a mapping plan

The mapping plan details how the data is collected by field observations (i.e., field survey) or acquired from remote sensing imagery providers (e.g., Planet Labs, Sentinel (Copernicus), NASA's MODIS, Google Earth Engine, USGS EarthExplorer, and World Terrain).

A field survey plan is developed through an iterative process, where preliminary and subsequent plans are often refined and improved in consultation with the broader community to ensure the maximum coverage of the AOI within the resources available. Some mapping points may be removed as they may be positioned in locations where access is prohibited (e.g. military base and/or port), or provide a safety risk (e.g. deep waters, strong currents, distance from shore, etc).

Field *in situ* assessments within each AOI is best conducted at a number of predetermined mapping points, using a restricted random sampling design to position the mapping points. This ensures good dispersion of mapping points through the entire AOI while incorporating randomization in mapping point placement. A randomized tessellation stratified design can be used in which a grid of tessellated hexagons serves as the basis for locating the random mapping points. Depending on the strata, the tessellated hexagons can vary between 2,500 m<sup>2</sup> and 10 hectares each; which provides flexibility for different sampling intensities, e.g. higher in intertidal (points every 2,500 m<sup>2</sup>) and lower in subtidal (points every 10 ha) (**Error! Reference source not found.**). Within each tessellated hexagonal cell a single randomly positioned point (set of latitude and longitude coordinates) is located (minimum distance between randomized points generally set at 10m). The randomised points within some hexagons may be moved slightly to ensure they fall within historically reported seagrass meadows or predicted areas of seagrass (e.g. Allen Coral Atlas <sup>[2]</sup>).



Example of a seagrass field survey plan for mapping seagrass meadows, showing 2,500m<sup>2</sup>, 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. Example from Pulau Setindan (Mersing, Malaysia) <sup>[64]</sup>.

Alternatively, *in situ* reference data can be collected using a grid pattern or a mix of lines that run perpendicular to the shore, along with randomly placed points. When mapping a coastline that is relatively uniform and spans between 10 and 100 km, we suggest positioning lines no more than 500 to 1,000 m apart. For areas ranging from 1 to 10 km, lines could be set 100 to 500 m apart, and for locations less than 1 km, a spacing of 50 to 100 m is advisable. However, this may vary based on the complexity of the coastline; more intricate regions will require additional transects. Choosing exactly where to make an assessment of the benthos along a line can be done at regular intervals (e.g., 50 to 100m apart), but this may vary depending on the topography.

Once the survey plan is agreed, the optimal time to conduct the field assessment needs to be identified, as it may be dependent on environmental conditions (e.g. weather, tides) and the seagrass growing season (if known) at an AOI. For example, 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 <sup>[60]</sup>. 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.

## Field (in situ) reference data collection

Field surveys are ideally conducted over a period of a couple of weeks and follow the sampling plan tailored for the AOI. During field validation assessments, field teams navigated to each mapping point using a handheld GNSS receiver (with  $\leq 3$  m positional accuracy) and collect data based around photoquadrats or *in situ* observations from standardised quadrats ( $0.25 \text{ m}^2$ ) or grab sampling.

### Data types

#### Photoquadrats

The globally standard recommends the collection of georeferenced/geotagged photoquadrats, when conducting seagrass assessment and benthic characterisation. 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.  $0.25 \text{ m}^2$ ) or from a height above the substrate which results in a fixed field of view (e.g.  $0.25 \text{ m}^2$  or  $1 \text{ m}^2$ ) (**Error! Reference source not found.**). Photoquadrats can be collected on foot (benthos exposed or in clear water  $< 1 \text{ m}$  depth), by UAV (benthos exposed), by snorkelling (to a water depth of  $3 \text{ m}$ ), or by using a drop camera ( $1 \text{ m}$ - $25 \text{ m}$ ).

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 GNSS receiver/unit. When collecting photoquadrats subtidally by snorkelling, the position is recorded by a GNSS unit floating on the water surface directly above. In deeper waters, the position is recorded by a GNSS receiver 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.

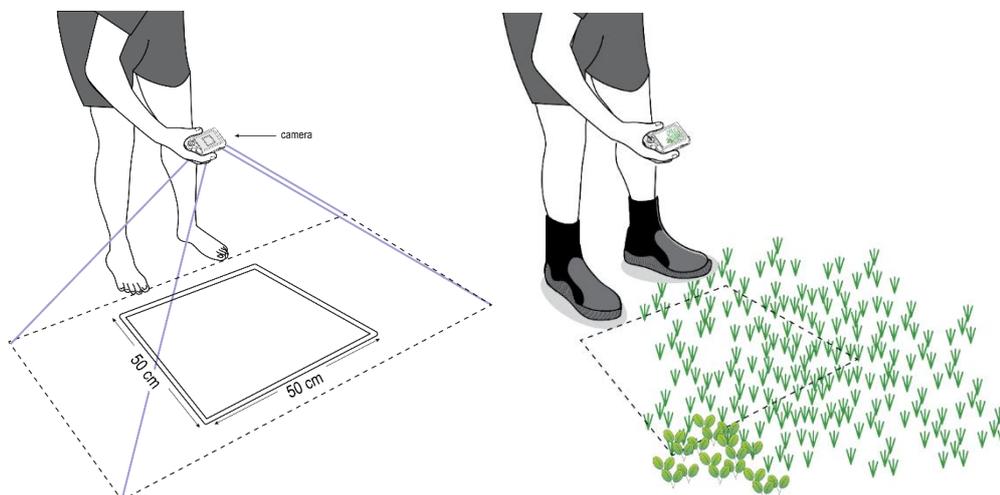


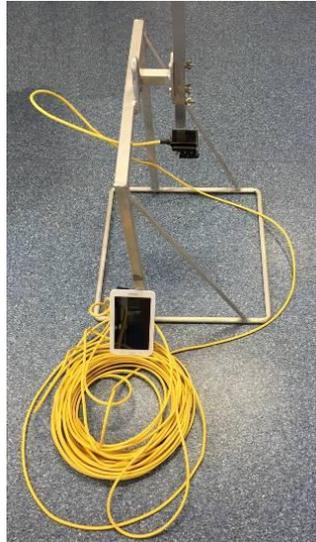
Illustration showing how to collect photoquadrats in the field using approximated height when  $0.25 \text{ m}^2$  quadrat absent.

#### *In situ* observations

*In situ* observations are taken/written in the field by observers and include visual estimates of above-ground seagrass percent cover, seagrass species and macroalgae percent cover, using globally standardised Seagrass-Watch protocols. Substrate type is assessed at each mapping point by hand using standardised visual/tactile protocols.

### **Drop-camera**

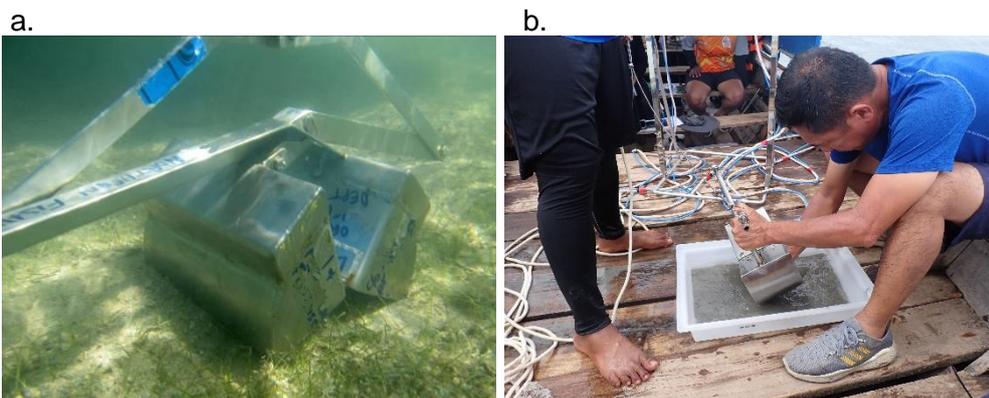
A drop-camera assembly includes an action camera (with simultaneous recording and Wi-Fi capability) mounted to a frame with a 0.25 m<sup>2</sup> quadrat in the field of view. The action camera captures professional-quality 4k video and the built-in Wi-Fi enables live image transmission via a high quality coaxial cable (Wi-Fi extender) back to a surface Tablet (mobile operating system, **Error! Reference source not found.**) providing real time video monitoring and control of the camera settings.



Drop-camera assembly. Note GoPro® fixed at correct height to ensure 0.25m<sup>2</sup> quadrat is within field of view and focus.

### **Grab samples**

In deeper waters, samples of the benthos are taken using a rake, sled, or benthic grab. These samples not only determine the occurrence of seagrass and characterise the benthos, but are used to verify seagrass species and describe sediment grain size composition or type (e.g., terrigenous or biogenous).



Van Veen grab, used to verify seagrass species and check sediment grain size: (a) Van Veen grab deployed (stock image); (b) releasing sample from grab; to assess sediment grain size and check seagrass species. Images courtesy of SAN and ZSL.

## **Mapping point data collection**

### **Spot-checks**

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.

### Intertidal

An intertidal spot-check mapping point is defined as a 1-3 m radius area around the GNSS waypoint. Observers walked to collect photoquadrats and/or *in situ* observations from three haphazardly placed quadrats (0.25 m<sup>2</sup>). All field point details and observations are recorded in the field on standardised waterproof datasheets or with the aid of open-source mobile data collection platforms such as ODK (getodk.org).

### Subtidal

For subtidal points, the validation mapping point is generally 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 is assessed using a drop-camera assembly and/or grab/rake. Observer's deploy the drop-camera assembly to the seabed, haphazardly raising and lowering the assembly at least three times while drifting 2-3 m to collect digital photoquadrat imagery (still and/or video) (**Error! Reference source not found.**). In conjunction with the visual assessment at each point, a Van Veen grab is used to verify the seagrass species and determine the sediment grain description inferred from the camera (**Error! Reference source not found.**). For subtidal assessments, the water depth and time is also recorded at each point (this can be later converted to depth below mean sea level)



Drop camera assembly field deployment (left) and Tablet (right) with App to control GoPro, view and record footage.).

### **Photo-transects**

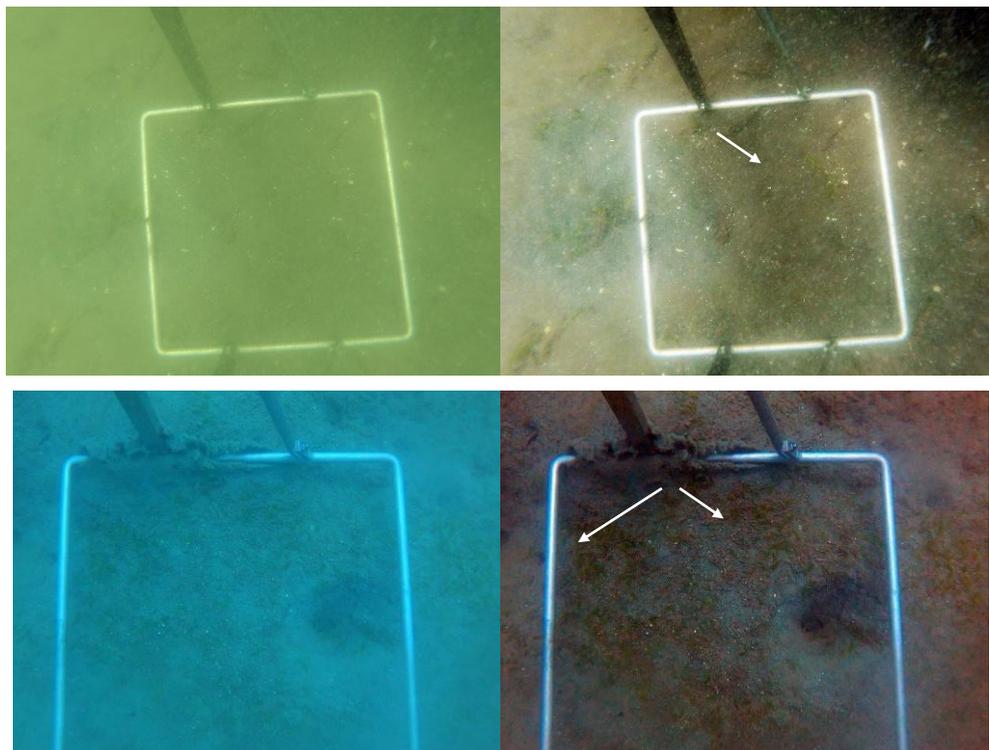
Photo-transects are where photoquadrats are collected sequentially along a path/distance of benthos using photoquadrats. These can be conducted by foot when the area to be surveyed is exposed during low spring tides, or the water is very shallow (<0.5m depth), sea state smooth and water clear. In clear 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. Alternatively, a sled with a mounted camera towed behind a vessel can be used. 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 <sup>[2]</sup>. Each photoquadrat captures a 0.25m<sup>2</sup> 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 optimal 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.

## 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) should be securely filed.

Data from field datasheets can then be entered into a relational database (MS Access) or MS Excel spreadsheets. All digital video footage and photoquadrats should be labelled with the code/ID of the mapping point where collected and then visually assessed by a trained and experienced scientist for seagrass percentage cover, species composition, sediment classification, macroalgae abundance and epiphyte abundance. Some post-processing may be necessary to enhance image features, particularly when captured in turbid/low light field conditions, to improve assessments.



Example of images captured from mapping points pre- and post-processing. Images from Ulugan Bay (Philippines) and Koh Libong (Trang, Thailand).

## Creating the map

The simplest way to map the distribution of seagrasses is to draw the meadows on a paper marine chart from the GNSS positions of the mapping points. The problem with this type of mapping is that the final map is in a format that does not allow manipulation and transformation. The layout of a paper map is permanent, which makes it difficult for future seagrass mapping studies to be compared, queried and analysed.

We recommend that the all seagrass map creation be conducted using a Geographic Information System (GIS). GIS are software systems of highly accurate digital maps that can be overlaid to reveal relationships that might not otherwise be detected on traditional paper maps. Digitally-stored cartographic databases can be altered much quicker than hard copies and shared data can be standardised. The key element of a GIS is the separation of differing data sets into thematic layers. GIS software provides the functions and tools needed to store, analyse, and display geographic information. The most common GIS packages are ArcGIS<sup>®</sup>, and QGIS. Mapping seagrass meadows with a GIS can help to identify emergent patterns or relationships in geographically referenced data.

A comprehensive guide on using and mapping with GIS is beyond the scope of this manual. We suggest reaching out to Seagrass-Watch HQ for guidance ([seagrasswatch.org/seagrass-services](https://seagrasswatch.org/seagrass-services)).

We recommend a package of four maps/shapefiles be created for each AOI, including: a point map of *in situ* reference data, a polygon boundary map of seagrass presence/absence, a “heat map” of interpolated seagrass abundance, and a polygon category map of dominant seagrass communities.

### **Point map**

Point shapefiles provide a visual representation of the location of *in situ* reference data (e.g., Spot-Check, Seagrass Spotter sightings) within the AOI. These points are generated using the positional data (geographic latitude and longitude) from each field mapping point, which is obtained from either the GNSS unit or geotagged photoquadrat.

At each point, seagrass and benthic attributes can be aggregated from the photoquadrats (ranging from 1 to 5) and additional environmental data collected within a radius of 10 meters for each subtidal point and 1 to 3 meters for intertidal points. The various attributes—including seagrass percentage cover, species composition, sediment classification, macroalgae abundance, and epiphyte abundance—are compiled for each mapping point by calculating the mean of the numerical fields and identifying the most frequently occurring value for the text fields.

### **Seagrass presence/absence map**

Utilising acquired imagery, spatially explicit maps of seagrass can be developed for the AOI. The classification process is most effectively carried out using a machine-learning model, such as Random Forest. Polygons/segments can be created based on *in situ* reference data and through expert interpretation of the imagery. A random split of 80-20% can be applied to the polygons for training and validating the model, respectively. The model should incorporate predictors, including the spectral bands from the imagery and the water depth recorded during field surveys. Ideally, the area of seagrass should be determined based on the model output probability thresholds of 60% to 100%.

### **Seagrass abundance maps**

To visualise seagrass abundance (% cover) within a designated AOI, a map can be created utilizing inverse distance weighted (IDW) point interpolation analysis based on the point data. Ideally, the area used for predicting percent cover should encompass the seagrass meadows identified by the presence model output at a probability threshold of 60%, along with any manually digitized meadows.

## Seagrass dominant species maps

To classify the mosaic of seagrass communities within a meadow, dominant species maps can be created using inverse distance weighted (IDW) point interpolation analysis based on species percentage composition data. Similar to the abundance maps, the area utilised for composition prediction encompasses the seagrass regions indicated by a model output probability threshold of 60% and the manually digitized seagrass areas. By estimating the species percentage composition for each grid cell in the model, it becomes possible to identify, group, and convert the cells containing dominant species into polygons.

## Visualising the maps

The final maps can be presented in hard copy or as layers within an interactive web mapping and data visualization application such as Map Viewer; the *map* making tool in ArcGIS™ Online (ESRI®'s web-based mapping software).

The completed maps should include a clear legend that outlines the highlighted features, the scale, and the source. It's also beneficial to accompany the maps with metadata. Metadata provides essential information about the data and should not be mistaken for a summary. It details the data source, reliability, usage conditions, interpretation limits, expiration date, and typically includes the proper citation format for acknowledging the source. Additionally, it contains information regarding the data's quality. Every project metadata for spatial data should include a statement regarding the accuracy of the map product.

We also recommend archiving your maps with a spatial data publisher such as the World Data Center PANGAEA® ([pangaea.de](http://pangaea.de)). PANGAEA® is free of charge and a member of the World Data System (WDS) of the International Council for Science (ICSU). Published data are open access and fully citable; can be cross-referenced with a digital object identifier (DOI) name for each data supplement. The Creative Commons Attribution license requires that author(s) are referenced if the data are reused and authorship for your data publications is automatically assigned in ORCID.

## Notes:

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# Seagrass conservation

## Threats to seagrass habitats

Destruction or loss of seagrasses have been reported from most parts of the world, often from natural causes, e.g., high energy storms. However, destruction commonly has resulted from human activities, e.g., as a consequence of eutrophication or land clamation and changes in land use. Increases in dredging and landfill, construction on the shoreline, commercial overexploitation of coastal resources, and recreational boating activities along with anthropogenic nutrient and sediment loading has dramatically reduced seagrass distribution in some parts of the world. Anthropogenic impacts on seagrass meadows continue to destroy or degrade coastal ecosystems and decrease the function and value of seagrass meadows including their contribution to fisheries. It is possible global climate change will have a major impact. Efforts are being made toward rehabilitation of seagrass habitat in some parts of the world: transplanted, improvement of water quality, restrictions on boating activity, fishing and aquaculture, and protection of existing habitat through law and environmental policy.

## Management

Seagrasses do not exist in nature as a separate ecological component from other marine plants and are often closely linked to other community types. In the tropics the associations are likely to be complex interactions with mangrove communities and coral reef systems. In temperate waters, algae beds, salt marshes, bivalve reefs, and epiphytic plant communities are closely associated with areas of seagrass. Many management actions to protect seagrasses have their genesis in the protection of wider ecological systems or are designed to protect the overall biodiversity of the marine environment.

Seagrasses are also food for several marine mammal species and turtles, some of which (such as the dugong *Dugong dugon* and green turtle *Chelonia mydas*) are listed as threatened or vulnerable to extinction in the IUCN Red List ([www.iucnredlist.org](http://www.iucnredlist.org)). Seagrasses are habitat for juvenile fish and crustaceans that in many parts of the world form the basis of economically valuable subsistence and/or commercial fisheries. The need to manage fisheries in a sustainable way has itself become a motivating factor for the protection of seagrasses.

Methods of direct protection range from legislative instruments and associated legal sanctions through to education <sup>[65]</sup>. These can be separated into three approaches: a proscriptive legal approach; a non-proscriptive broad based approach ranging from planning processes to education; and a reactive approach designed to respond to a specific issue such as a development proposal. These may overlap and be used simultaneously in many cases. It is these three approaches that Seagrass-Watch supports for the protection/conservation of seagrass.

### ***Reactive (on-ground)***

Reactive processes generally occur in response to a perceived operational threat such as a coastal development proposal <sup>[65]</sup>. Reactive processes can include port contingency planning, risk management plans and environmental impact assessments.

### ***Prescriptive (legal)***

Prescriptive management of seagrass issues can range from local laws to a Presidential Decree, or Executive Order. Laws can directly safeguard seagrasses or can protect them indirectly by protecting habitat types (all aquatic vegetation) or by influencing a process, e.g., prevention of pollution <sup>[65]</sup>.

In some locations, protection is often strongest at the village or community level. This may be by Government supported agreements or through local management marine area level. In these cases, successful enforcement is dependent on community support for the measure.

### ***Non-prescriptive (planning & education)***

Non-prescriptive methods of protecting seagrasses are usually part of planning processes and may have a strong extension/education focus <sup>[65]</sup>. Providing information is important as it enables individuals to voluntarily act in ways that reduce impacts to seagrasses. Non-prescriptive methods range from simple explanatory guides to complex industry codes of practice.

Coastal management decision making is complex, and much of the information on approaches and methods exists only in policy and legal documents that are not readily available. There may also be local or regional Government authorities having control over smaller jurisdictions with other regulations and policies that may apply. Many parts of South East Asia and the Pacific Island nations have complex issues of land ownership and coastal sea rights.

Approaches to protecting seagrass tend to be location specific or at least nation specific (there is no international legislation directly for seagrasses as such that we know of) and depend to a large extent on the tools available in law and in the cultural approach of the community. There is, however, a global acceptance through international conventions (RAMSAR Convention; the Convention on Migratory Species of Wild Animals; and the Convention on Biodiversity) of the need for a set of standardised data/information on the location and values of seagrasses on which to base arguments for universal and more consistent seagrass protection.

Indigenous concepts of management of the sea differ significantly from the introduced Western view of the sea as common domain, open to all and managed by governments <sup>[66]</sup>. Unlike contemporary European systems of management, indigenous systems do not include jurisdictional boundaries between land and sea. Indigenous systems have a form of customary ownership of maritime areas that has been operating in place for thousands of years to protect and manage places and species that are of importance to their societies.

Marine resource management these days should, therefore, attempt to achieve the following interrelated objectives: a) monitor the wellbeing (e.g. distribution, health and sustainability) of culturally significant species and environments (e.g. dugong, marine turtles, fish, molluscs, seagrass etc.); and b) monitor the cultural values associated with these culturally significant species and environments <sup>[67]</sup>.

To realize objective a) we believe the following also needs to be accomplished if the successful management of coastal seagrasses is to be achieved.

1. Important fish habitat is known and mapped
2. Habitat monitoring is occurring
3. Adjacent catchment/watershed impacts and other threats are managed
4. Some level of public goodwill/support is present
5. Legal powers exist that are robust to challenge
6. There is effective enforcement and punishment if damage occurs

The key element is a knowledge base of the seagrass resource that needs to be protected and how stable/variable that resource is. It is also important to know if possible any areas that are of special value to the ecosystems that support coastal fisheries and inshore productivity. It is important as well that this information is readily available to decision makers in Governments in a form that can be easily understood.



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## Useful web links

**Seagrass-Watch** Official Site [www.seagrasswatch.org](http://www.seagrasswatch.org)

**SeagrassSpotter** A conservation and education tool that could lead to new discoveries about one of the ocean's most under-appreciated habitats – seagrass. With SeagrassSpotter, ocean enthusiasts around the world can become citizen scientists who contribute to marine conservation with just a few taps of their phone. <https://seagrassspotter.org/>

**Project Seagrass** A marine conservation charity dedicated to ensuring that seagrass meadows are protected globally, for the biodiversity and people that depend on them. <https://www.projectseagrass.org/>

**Dugong & Seagrass Research Toolkit** Helps you refine your research questions and provide you with a list of recommended techniques and tools to answer them. Designed for use by marine natural resource managers and decision-makers and for dugong and seagrass researchers, the Toolkit will show you which techniques are the most effective and efficient for your team capacity, budget and timeline. <http://www.conservation.tools/>

**World Seagrass Association** A global network of scientists and coastal managers committed to research, protection and management of the world's seagrasses. <https://worldseagrass.org/>

**Seagrass forum** A global forum for the discussion of all aspects of seagrass biology and the ecology of seagrass ecosystems. Because of their complex nature, discussion on all aspects of seagrass ecosystems is encouraged, including: physiology, trophic ecology, taxonomy, pathology, geology and sedimentology, hydrodynamics, transplanting/restoration and human impacts. [lists.murdoch.edu.au/mailman/listinfo/seagrass\\_forum](http://lists.murdoch.edu.au/mailman/listinfo/seagrass_forum)

**Integration and Application Network (IAN)** A website by scientists to inspire, manage and produce timely syntheses and assessments on key environmental issues, with a special emphasis on Chesapeake Bay and its watershed. Includes lots of helpful communication products such as fact sheets, posters and a great image library. <https://ian.umces.edu/>

## Notes:

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