Seagrass-Watch

Proceedings of a workshop for monitoring seagrass habitats in Timor-Leste

Beach Garden Hotel, Dili
18-20 February 2019

Len McKenzie & Rudi Yoshida

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Front cover photos (left to right): *Thalassia hemprichii* and *Halodule uninervis* meadow, courtesy Conservation International; *Halodule uninervis* and *Halophila ovalis* meadow, Atuaro Is, by Paul Hilton, courtesy Conservation International; and *Enhalus acoroides*, Atauro Is, by Martine Perret, courtesy United Nations Photo (13Nov10).

Enquires should be directed to:
Seagrass-Watch HQ
PO Box 2242
Cairns QLD 4870 AUSTRALIA
hq@seagrasswatch.org

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Beach Garden Hotel

Avenida Portugal S/N Praia Coqueiros Dili, Timor-Leste

telephone: 006703315888

Overview

Seagrass-Watch is a scientific monitoring and education program, 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 355 sites across 19 countries. Anyone can participate in Seagrass-Watch, as it responds to local needs, and includes some 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 funded by the GEF Dugong and Seagrass Conservation Project, and supported by Seagrass-Watch HQ. The GEF Dugong and Seagrass Conservation Project "Enhancing the Conservation Effectiveness of Seagrass Ecosystems Supporting Globally Significant Populations of Dugongs across the Indian and Pacific Ocean Basins" is executed by the Mohamed bin Zayed Species Conservation Fund with financing from the GEF, implementation support by UNEP and technical support from the CMS Dugong MoU Secretariat

This workshop is for experienced participants who plan to lead a seagrass monitoring event 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 2242
Cairns QLD 4870
AUSTRALIA
E-mail hq@seagrasswatch.org

Photo: Fergus Kennedy

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 and Dugong and Seagrass Conservation Project, the Project Manager of the Great Barrier Reef 2050 Plan Marine Monitoring Program – Inshore Seagrass Monitoring and principal investigator for a series of projects involving the assessment and sustainable use of coastal habitats. Len has over 20 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 (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 Queensland
- 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
- Investigations on the macrofauna associated with seagrass meadows
- Dugong and Seagrass Conservation Project

Rudi Yoshida

Rudi is the Data Manager of Seagrass-Watch and a Research Officer with James Cook University. Rudi has over 15 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

Agenda - Level 1 (basic)

Monday 18th February 2019 (Beach Garden Hotel: Conference Room)

0815 - 0900	Registration
0900 - 0930 *(30min)*	Welcome & Introduction
0930 - 1030 *(60min)*	Seagrass Biology and Taxonomy*
1030 - 1100 *(30min)*	*Break*
1100 - 1230 *(90min)*	Seagrass Identification
1230 - 1330 *(60min)*	*Lunch*
1330 - 1500 *(90min)*	Seagrass Biology 2 and Ecology
1500 - 1515 *(15min)*	*Short break*
1515 - 1630 *(75min)*	Seagrass importance
1630	Wrap up for day

Tuesday 19th February 2019 (Beach Garden Hotel: Conference Room)

0900 - 0915 *(15min)*	recap day 1
0915 - 1030 *(75min)*	Seagrass threats*
1030 - 1100 *(30min)*	*Break*
1100 - 1145 *(30min)*	Seagrass monitoring*
1145 - 1230 *(45min)*	Seagrass-Watch: how to sample
1230 - 1330 *(60min)*	*Lunch*
1330 - 1415 *(45min)*	Seagrass-Watch: how to sample 2*
1415 - 1545 *(90min)*	Seagrass-Watch: QAQC
1545 - 1600 *(15min)*	Risk assessment
1600	Wrap up for day

Wednesday 20th February 2019 (Dili Bay & Beach Garden Hotel)

0700 - 0930 *(2.5hrs)*

Field exercise: Seagrass-Watch monitoring
Where: Dili Bay
- *meet at eastern end of park Largo de Lecidere*
- *be punctual*

What to bring:
- *hat, sunscreen, insect repellent*
- *dive booties or old shoes that can get wet*
- *drink/refreshments and energising snack*
- *enthusiasm*

You will be walking across a seagrass meadow exposed with the tide, through shallow water. It may be wet!

Tide: 0729, 0.2m

0930 - 1030 *(60min)*	Break *(relocate back to Beach Garden Hotel)*
1030 - 1200 *(90min)*	Seagrass-Watch: how data is used*
1200 - 1230 *(30min)*	Wrap up & workshop close

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:

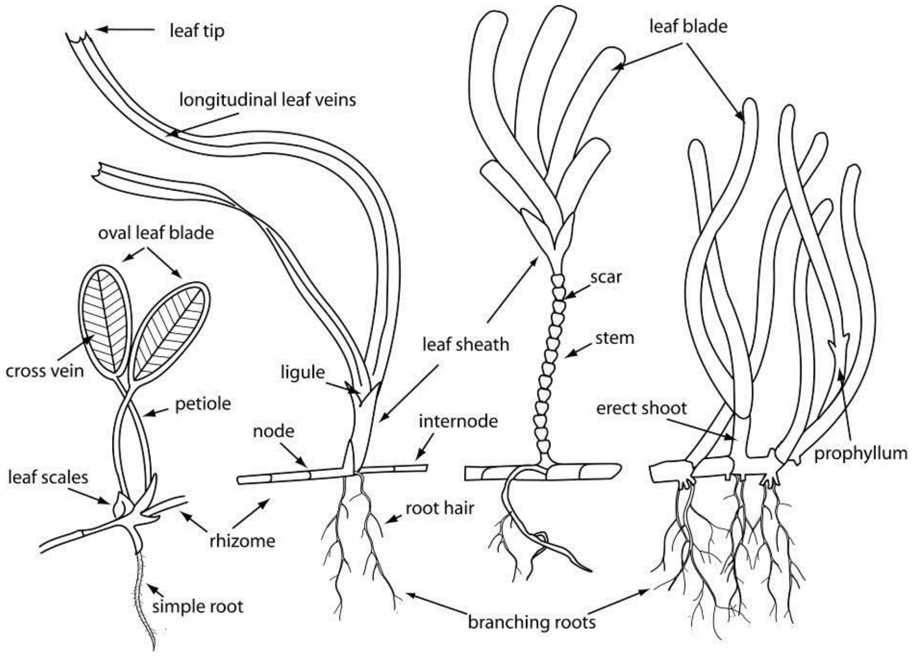
- correct description of sediment & comments
- seagrass cover estimates within acceptable limits
- correct seagrass species identification
- correct seagrass species compositions
- correct seagrass canopy height measures
- macro algae cover estimates within acceptable limits
- epiphyte cover estimates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

Seagrass are marine 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.

Seagrasses have roots, stems and leaves

Seagrass is different to seaweed (algae) as seagrass have internal veins, true roots and produce flowers, fruits and 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 *Zostera*. 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**.

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 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

Seagrass have veins and air channels in their leaves and rhizomes so they can carry water, food and absorb gases diffusion into them from the surrounding water. Seagrass leaves also contain **veins** (lignified conducting tissue that transports food, nutrients and water around the plant) (i.e. an internal vascular system). Veins can be across the leaf blade or run parallel to the leaf edge. Also within the leaves are chloroplasts, which use the suns light to convert carbon dioxide and water into oxygen and sugar (photosynthesis).

Seagrasses rely on 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 joins, called nodes or scars. 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.

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

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, facilitating nutrient uptake.

Seagrass pump oxygen into the sediment via their roots

Seagrasses have flowers and pollination systems that are well adapted for pollination by 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.

Seagrass have flowers, fruits and seeds

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*).

Pollination occurs in the water

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.

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

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

Seagrasses are monocotyledons that are not true grasses (true grasses belong to the family Poaceae), but are rather more closely related to the lily family.

Seagrasses are not true grasses

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.

Seagrasses are more closely related to lilies

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

Seagrass requirements for growth

Seagrasses require light, nutrients, carbon dioxide, substrate for anchoring, tolerable salinity, temperature and *p*H 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).

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

Seagrasses need plenty of sun and clean water to grow.

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 are physiologically adapted to life in sea water

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

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.

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 water temperatures increase (up to 38°C) the rate of photorespiration increases reducing the efficiency of photosynthesis at a given CO_2 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.

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

Temperature also controls the range of *p*H and dissolved carbon dioxide (CO_2) concentrations in the water column; factors critical in plant survival in the marine environment.

Seawater temperatures above 40ºC will stress tropical seagrass. Death occurs at temperatures above 43ºC

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_3^-) as an inorganic carbon source (e.g. *Halophila ovalis, Cymodocea rotundata, Syringodium isoetifolium* and *Thalassia*), whereas others use enzymes to make CO_2 available as the inorganic carbon source (e.g. *Enhalus acoroides, Halodule, Cymodocea serrulata*).

Seagrass require inorganic carbon for growth

Seagrass uptake carbon via two different pathways

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.

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

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.

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

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.

Most seagrass live in sand or mud sediments

Sediment movement can determine the presence of seagrass species

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.

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.

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.

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 food, a nursery and shelter area 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 meadows are a major food source for a number of grazing animals 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 > Syringodium isoetifolium*. 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

The depth 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.

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 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 the grasses 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.

Seagrass binds sediments and help prevent erosion

Seagrasses slow water flow and increase water clarity

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.

Seagrass help remove harmful nutrient and sediment pollution from coastal waters

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).

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

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 services is a very controversial topic in today's literature. Ecosystem Services are the processes by which the environment produces resources 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 product they provide has been estimated at US$ 28,916 ha^{-1} yr^{-1} (in 2007 dollars).

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

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 can change due to both natural and human impacts

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 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 unstabilise 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.

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

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

Coastal development can have a major impact on seagrass meadows

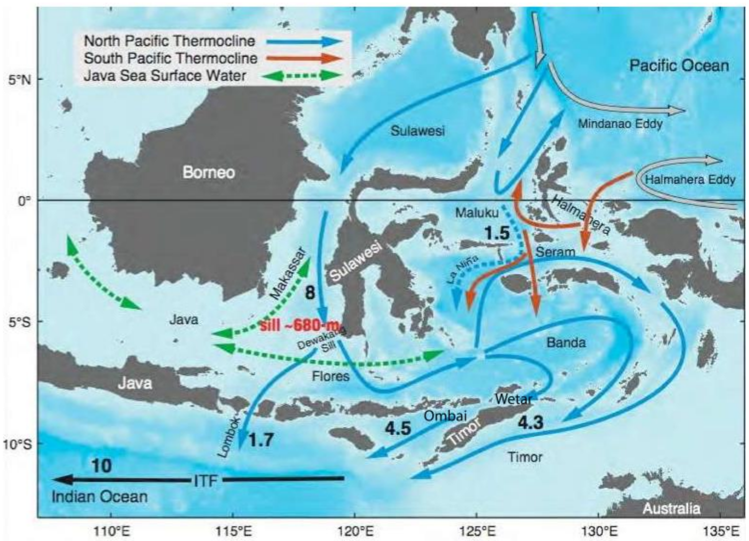
Climate change can threaten intertidal seagrass by increased seawater temperature and greater physical disturbance from storms

Seagrass in Timor-Leste

Timor-Leste, officially the Democratic Republic of Timor-Leste, is located in the Lesser Sunda Islands archipelago of Southeast Asia and comprises the eastern half of the island of Timor, the nearby islands of Atauro and Jaco, and Oecusse (an exclave on the north-western side of the island surrounded by Indonesian West Timor). The country lies mostly between latitudes 8° and 10°S, and longitudes 124° and 128°E. The Indonesian Province of East Nusa Tenggara (Nusa Tenggara Timur) lies to Timor-Leste's west and the Timor Sea separates the country from Australia to the south. To the north are the Wetar Strait and the greater Banda Sea.

Timor-Leste’s total land area covers 14,874 km^2 with a coastline of 706 km. The country’s north coast is rocky and steep, and arid woodlands tend to be the dominant vegetation type. Much of the country is mountainous, and coastal plains on the north tend to be very narrow; with the exceptions being the Dili and Manatuto Districts, where the coastal plains are slightly wider (Boggs *et al.*, 2009). White sandy beaches are spread along the north coast, interspersed by rocky outcrops. The waters on the north are deeper, calmer, and more transparent than those off the south coast. The nearshore littoral zone of the north coast is very narrow, and the sea floor drops off sharply to the deep sea (Boggs *et al.*, 2009). For example, bathymetry on the north coast declines steeply into a three km deep marine trench at approximately 20 km from shore. The shelf on Timor-Leste’s southern coast is wider and relatively shallower, with gentler slopes than the northern coast. The southern coastal plains are also wider, and as a result, this area is home to many deltas, floodplains, lagoons, and swamps (Asian Development Bank, 2014). Long stretches of sandy beach with heavy waves and surf episodically exceeding 3m height are common on the southern coast (Turak and DeVantier, 2013b). As a result, the nearshore waters there are turbid most of the time (Sandlund *et al.*, 2001).

Positioned on the north-western edge of the Australian tectonic plate, the island of Timor drifted northward during the Miocene and Pliocene, attaining its present position relatively recently (Hall, 2001; Audley-Charles, 2004), and transporting a different biota to that of islands to its west. It has, over the past few million years, always been surrounded by deep waters during the episodic Pleistocene glaciations. The waters surrounding Timor-Leste include complex bathymetry, with deep basins, and currents driven by the Indonesian ThroughFlow (ITF), a major conduit of Pacific waters to the Indian Ocean. The main path of the ITF consists of water entering from the North Pacific between the Philippines and New Guinea into the Sulawesi Sea and continuing through Makassar Strait. From there, the water exits either via the Lombok Strait or circulates through the Flores and Banda Seas and to enter the Indian Ocean via Wetar/Ombai Strait or Timor Passage on either side of Timor (Tillinger, 2011).



Indonesian Throughflow (Source: David Picel, 2013)

Timor-Leste's climate is tropical with two distinct dry and wet seasons annually, driven by the annual movement of the inter-tropical convergence zone - the South-east and North-west monsoons. The northwest monsoon during the wet season typically extends from October-November to February-March and the southeast monsoon during the dry season from May to October, with a transition period of 1–2 months between seasons characterized by variable and lower winds. Timor-Leste is only occasionally affected by major tropical storms. Timor-Leste has a distinct mountainous spine running from west to east which causes the rainfall patterns and climates on the northern and southern coasts to differ considerably. The highest rainfall occurs in the central and western parts of the country and the eastern tip tends to be drier, particularly along the northern coast. The mountainous areas receive the greatest amount of rainfall, which on average exceeds 1,600 mm annually. Apart from some drier areas on the northern coast that receive only about 1,000 mm, the remainder of the country receives a minimum of 1,500 mm annually (Asian Development Bank, 2014).

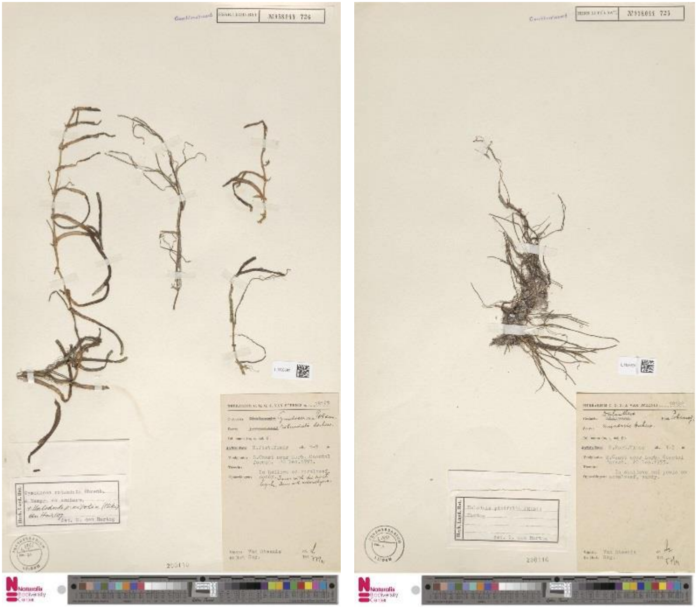
Water temperatures around Timor-Leste range from 26.1°C in the cooler months (July/August) to 31.9°C in the summer (December – February). Along the north coast of Timor-Leste, water temperatures are one to several degrees cooler than surrounding areas unaffected by the ITF or localized upwelling. Inter-annual variability in air and sea temperature is caused by the influence of large-scale climate phenomena, notably the El Niño–Southern Oscillation and the Indian Ocean Dipole (Asian Development Bank, 2014). Timor-Leste has mixed tides with prevailing semidiurnal tides and a maximum tidal range of 2.47m on the north coast.

Timor-Leste is situated in the south-eastern boundary of the important biogeographical region known as Wallacea. This region between Australia and Asia is marked by the Wallace Line to the west and the Weber/Lydekker Line to the east. Wallacea is a biodiversity hotspot where species from Asia and Australia converge. Not only is Timor-Leste located in Wallacea, it is also within the global centre of marine diversity known as the Coral Triangle.

Timor-Leste's population is 1,183,643 (2015 census), with an average annual growth rate of 2.1% (~25,000 people per year). Most of population lives on the northern half of the country, with significant clustering around Dili. Timor Leste also faces major human development challenges - with some of the highest levels of population growth, infant mortality, malnutrition, unemployment, illiteracy and food insecurity in South East Asia (Boggs *et al.*, 2012). The coral reefs, seagrass meadows, mangroves, beaches and intertidal habitats support a high diversity of marine plants and animals that provide critical resources for coastal communities and also species of conservation concern, including dugongs and marine turtles.

Coral reefs (including coastal fringing and large elongate patch reefs) cover 146 km^2 of the Timor-Leste's nearshore area (Asian Development Bank, 2014). In Timor-Leste, most of the reefs appear to be found on the north coast, which is characterized by karst geology and uplifted ancient coral reefs (Audley-Charles, 2004; Boggs *et al.*, 2009), which results in reefs with a narrow reef flat (20-100 m) and a steep drop-off (40-60 m depth). Limited information is available on the seagrass habitats in Timor-Leste. The lack of knowledge makes it difficult for stakeholders to effectively integrate seagrass protections into local, regional or national initiatives.

The earliest record of seagrass from Timor-Leste is 20 December 1953; *Cymodocea rotundata* and *Halodule pinifolia* herbaria specimens were collected from the sandy coral reef near Lore on the south coast (den Hartog, 1970; National Herbarium of the Netherlands, Leiden). Over the following decades, the majority of records have been *ad hoc* collections/observations as very few nearshore habitat surveys have been conducted. To date, no comprehensive survey has mapped the entire seagrass resources of Timor-Leste (Fortes *et al.*, 2018). The best estimates available are from broad-scale, predominately remote assessments, conducted over the last twelve or so years.



Earliest known herbaria specimens from Timor Leste: *Cymodocea rotundata* Ehrenb. & Hempr. ex Aschers. [L.1196592] (left) and *Halodule pinifolia* (Kiki) Hartog [L.1196691] (right) (courtesy National Herbarium of the Netherlands).

The first broad-scale mapping of Timor Leste nearshore habitats was undertaken in 2007 along the northern coast, using Landsat TM/ETM+ imagery (imagery captured between 2003 and 2006) and field work (19-30 November 2007) (see Boggs *et al.*, 2012). Field ground-truthing of the Landsat TM imagery was undertaken in 6 locations – Metinaro, Manatuto, Baucau, Com, Jaco and Lore. From this, a broad scale (1:100k) map of the north and east coast of Timor-Leste was produced (smallest mapped element was 0.1ha). Nearshore marine habitats were delineated from the remote imagery using object based image analysis, and classified using the field ground-truthing. The marine nearshore zone was characterised by a narrow reef flat (often <60m wide, but up to almost 1km), dominated by seagrass in shallower water (approximately 2,200ha) and corals in deeper water and on the escarpment (approximately 2,000ha) (Boggs *et al.*, 2012). A mixed-cover class, which included coral-seagrass and open reef flat, occupied 1,266 ha.

Seagrass meadows on fringing reef flat (left) and high density *Halodule/Cymodocea* meadow (right) on the north coast of Timor-Leste. Photos from Boggs *et al.*, 2009

As part of the 2007 broadscale mapping (Boggs *et al.*, 2012), a survey of Nino Konis Santana National Park confirmed the presence of *Syringodium isoetifolium, Cymodocea rotundata, Halophila ovalis*, and *Halodule uninervis* (Edyvane *et al.*, 2012). Within the park, areas of seagrass habitat included: sparse patches of *Thalassia hemprichii* meadow (5-8% seagrass cover) on the inner reef flat on the north and east coast of Jaco Island; dense but narrow seagrass meadow on the inner reef flat at the North Coast (east of Com) where there was a 30 m wide band dominated by *Halodule uninervis* with some *Thalassia* and *Syringodium isoetifolium*; and a wide dense seagrass meadow with all the above species as well as *Halophila ovalis* on the inner reef flat at Com on the western boundary of the Marine Park (Edyvane *et al.*, 2012).

Thalassia hemprichii on the Jaco Island north reef flat (left) and gleaning in seagrass meadow (right), Nino Konis Santana Marine Park. Photos courtesy Tony Ayling and from Edyvane et al., 2012.

In 2012, a marine rapid assessment (MRAP) of coral reefs conducted between 14-23 August examined twenty-two sites, including 14 sites within Nino Konis Santana National Park (both mainland coast and Pulau Jako), as well as 4 sites on the northern mainland coast east of Dili and 4 sites on Pulau Atauro (Erdmann and Mohan, 2013). As shallow seagrass dominated habitats were not surveyed specifically, only seagrass presence is mentioned with no detail on species or abundance available (Allen and Erdmann, 2013; Turak and Devantier, 2013a). The authors also commented that some of the MRAP sites on the north coast suffered from sedimentation caused by erosion of watersheds and that it was highly likely that nearshore seagrass habitats present at those sites are also affected by sedimentation (Erdmann and Mohan, 2013). It was noteworthy that some areas on Atauro Island had an extremely high cover of hard corals (and likely seagrass), compared to the mainland which was likely due to the absence of major rivers on Atauro Island.

Also in 2012, broad-scale mapping of the marine and coastal habitats of Timor-Leste was completed using Landsat satellite imagery, covering the districts of Oecussi, Bobonaro, Liquicia, Dili (Atauro Island), Kova Lima, Ainaro, Manatuto (south coast), Manufahi, and Vikeke, that were not mapped by Boggs *et al.* (2012) (Joyce, 2013). Five Landsat 5 TM scenes (acquired in 2008) coupled with geo-referenced aerial photographs (captured in 2002) and photographs taken during an aerial survey in November 2012 were used to guide the supervised classification. Field surveys were also undertaken to collect calibration and validation data, centred on four sites that contained a wide range of habitat-types: Beacou (Bobonaro district), Suai (Kova Lima district), Tibar (Liquicia district), and the northern coast of Atauro Island (Dili district). Beacou, Suai and Tibar were surveyed in June 2012; Atauro Island was surveyed in November 2012. Due to logistical limitations, habitats along the south coast were only assessed by aerial survey in November 2012. The total area of seagrass identified from the final classified images were 500ha of dense seagrass (30-100% cover) and 300ha of sparse seagrass (5-30% cover) (Joyce, 2013). If seagrass cover was less than 5%, the area was classified as bare area. Seagrass field validation points were classified correctly 67% of the time, with misclassifications occurring between classes with similar spectral reflectance signatures (e.g. coral and sparse seagrass). When combined with the 2007 mapping, this estimates the overall area of seagrass habitat in Timor Leste to be approximately 4,266 ha.

Seagrass distribution throughout Timor-Leste is most likely influenced by shelter, sediment characteristics, water clarity and tidal exposure. **Eight** seagrass species, with an additional two species under review for synonymy, have been confirmed from the waters of Timor-Leste: *Cymodocea rotundata* Ehrenb. et Hempr. ex Aschers.; *Cymodocea serrulata* (R. Br.) Aschers. et Magnus; *Enhalus acoroides* (L.f.) Royle; *Halodule uninervis* (Forsk.) Aschers. in Bossier; *Halophila ovalis* (R.Br.) Hook. f.; *Syringodium isoetifolium* (Ascherson) Dandy; *Thalassodendron ciliatum* (Forsk.) den Hartog; and,*Thalassia hemprichii* (Ehrenberg) Asherson. Two additional species *(Halodule pinifolia* and *Halophila minor*) are reported from Timor-Leste, but are under review for synonymy. Waycott et al. (2004) suggested that *Halodule pinifolia* and *Halodule uninervis* were conspecific, recognising that the plasticity of the leaf blade size can be attributed to local conditions. However, recent rbcL gene sequencing has suggested that the species may be separate (Wagey and Calumpong, 2013). Similarly, *Halophila minor* is considered synonymous with *Halophila ovalis* (Waycott *et al.*, 2004), as it is difficult to distinguish the species visually in the field and phylogenetic studies indicate either none or some potential divergence (Waycott *et al.*, 2002; Uchimura *et al.*, 2008; Xu *et al.*, 2010).

Seagrasses on the nearshore reefs of Atauro Island: *Thalassodendron ciliatum* (left - courtesy Do Berco, Instagram-07Aug18), *Thalassia hemprichii* (centre), and *Halodule uninervis* (right) (courtesy The Blue Martin, Instagram - 14Dec17)

Seagrasses on the nearshore reefs of Atauro Island: *Enhalus acoroides* dominated meadow (left, courtesy Blue Ventures) and *Enhalus acoroides /Thalassia hemprichii/Syringodium isoetifolium* mixed meadow (right, courtesy chrisandsarah, instagram-Feb14).

Enhalus acoroides at Tibar Bay (left, courtesy divetimor.com - Apr13) and *Halodule uninervis/Thalassia hemprichii* meadow, Dili waterfront (right, Seagrass-Watch HQ, 29Jun15).

Unconfirmed occurrences of other species (e.g. *Ruppia maritima* L.) appear in the literature, however no specimens confirm their presence. The occurrence of species in adjacent Indonesian waters implies presence in Timor-Leste waters, however oceanic currents may be a determining factor. For example, both *Ruppia maritima* and *Halophila spinulosa* occur in Indonesian waters, however their presence is limited; they have not been reported east of Lombok. This constrained western distribution may be a consequence of the Lombok Strait corridor of the Indonesian ThroughFlow, which could be restricting eastern dispersal. The absence of other species (e.g. *Halophila decipiens*) from Timor-Leste waters, may however be a consequence of limited surveys, particularly of subtidal waters deeper than 10m where some species dominate. Anecdotal reports of rarer species in Timor-Leste such as *Halophila beccarii* and *Zostera capensis* are erroneous, as these species is not reported from any adjacent areas (i.e. does not occur in

Indonesia, Papua New Guinea or Australia) and the reports were from habitats where this species is not known to occur.

The seagrass species reported from Timor-Leste are not unique from those found along the coast of adjacent countries in the Arafura, Timor, Flores, Savu and Banda Seas, including: northern Australia, Papua New Guinea, and the Indonesian provinces of East Nusa Tenggara, Maluku, and Papua (Coles *et al.*, 2003; Kuriandewa *et al.*, 2003; McKenzie, 2006; McKenzie *et al.*, 2007).

Seagrass meadows are important economic assets in Timor-Leste on both regional and local scales. Seagrass meadows represent important nursery and feeding grounds for many fish of subsistence and artisanal important in Timor-Leste, in particular Lutjanidae, Lethrinidae, and Serranidae (CTI-TLS, 2012; Nordlund *et al.*, 2017; Unsworth *et al.*, 2018). Seagrasses are valuable at local levels as they contribute to the provision of protein and cash income to the different human populations. In some regions, local communities engage in reef gleaning (*meti fai, tono fai*) of nearshore seagrass meadows during low tide targeting juvenile fishes, crabs, molluscs, and sea urchins (McWilliam, 2011; Unsworth *et al.*, 2018). Apart from fisheries production, seagrasses provide a range of goods and services from attenuating wave energy and reducing coastal erosion / sedimentation to cultural importance (Nordlund *et al.*, 2018).

A woman gleans for clams at Hera beach (left, by Martine Perret, courtesy UN Photo, 01Jul08) and gill netting at Akrema Beach (right, Instagram-12Nov18).

The seagrass meadows of Timor-Leste also provide food and critical habitat for green sea turtle (*Chelonia mydas*) and dugong (*Dugong dugon*) which are listed as threatened or vulnerable to extinction in the IUCN Red List (www.iucnredlist.org). Considered sacred animals, dugongs are not actively hunted in Timor-Leste; however, incidentally trapped individuals are often killed and consumed. Dugong mortality has not been formally reported in Timor-Leste although the use of gillnets in nearshore waters by coastal fishers is increasing.

The distribution of dugongs in the coastal waters of Timor-Leste is largely unknown with sightings of individuals recorded on the north coast of the country and from Atauro Island. A marine megafauna survey conducted in 2008 for the whole coastline reported dugongs are rare with one individual sighted in the northwest and five individuals in the north-east (Dethmers *et al.*, 2009). Anecdotal sightings of dugongs feeding on seagrass meadows have also been reported on the north coast by recreational divers at popular dive sites west of Dili including: Dan´s Sandy Bottom, Secret Garden, K41 and Piertamina. The most frequent sightings are of “Douglas” the resident dugong at Roda Reef, Tasi Tolu and Dili Rock East. In mid 2017 it was reported that a small juvenile dugong was accompanying “Douglas”. Dugong have also been reported from east of Dili, e.g. Dollar Beach.

In Timor-Leste, dugongs are protected under the Marine Protected Species Act, the Ministerial Diploma and Decree law, and reference to their endangered status is made in the National Biodiversity Strategy and Action Plan (NBSAP). The NBSAP describes the importance of seagrass ecosystems not only as the primary habitat for dugongs and many fish and shellfish species, but also as a protective barrier for coral reefs against sedimentation. In recognition of the significant importance of dugong to the country, Timor-Leste became the 27th Signatory to the CMS Dugong MOU on 10 September 2018, confirming its support towards the protection of dugongs and their vital seagrass habitats (http://timor-leste.gov.tl/?p=20427&lang=en&n=1).

Dugong mother and offspring at K41 dive site (left, by Nick Hobgood, 15May05) and "Douglas" the resident dugong (right, courtesy Dive Timor Lorasae).

As a partner in the GEF Dugong and Seagrass Project, a number of country projects focus on the north and north-east coast of Timor-Leste, including Atuaro Island. One project (TL1) is training national-level partners in seagrass and dugong research techniques to overcome existing knowledge barriers regarding the distribution, status and ecology of seagrass ecosystems and dugong populations, and to identify priority sites for dugong and seagrass conservation efforts. Another project (TL4) is designing a "Tool Box" of materials and media to illustrate the importance of dugong and seagrass habitats, explain their benefits to local people, outline options for their protection, and communicate dugong and seagrass related laws and regulations to target groups. A model for marine conservation ecotourism is also being developed to incentivise local engagement in dugong and seagrass conservation (TL2). This project is pioneering a model to diversify livelihoods among target coastal communities, generating a sustained source of income for the target population to encourage community-based natural resource management (CBNRM) activities for priority seagrass ecosystems and small-scale fisheries. A further project (TL3) is strengthening and operationalising inter-ministerial mechanisms to ensure a coordinated approach to national-level coastal zone planning and decision-making to effectively address dugong and seagrass conservation. Finally, to assist national capacity-building and mobilise decision-maker support for dugong and seagrass conservation, a National Facilitating Committee has been established (TL5), to work with Project partners, to share data, lessons learned and experience of dugong and seagrass ecosystem conservation.

Seagrass and shallow marine habitats in Timor-Leste are susceptible to degradation through a number of anthropogenic impacts, including sedimentation, destructive aquaculture practises (e.g. intensive sea weed farming), overfishing, coastal mining (e.g. sand extraction from beaches), coastal development and land-based pollution. Unsustainable agricultural practices (e.g. traditional slash and burn) and poor land management (e.g. deforestation, forest degradation, domestic livestock grazing) combined with sloping terrain and short, intense rainfall patterns results in high levels of soil erosion which can have negative impacts on marine habitats and biodiversity. Sedimentation and elevated turbidity can cause the degradation of seagrass meadows in shallow waters. Population growth (increasing urbanisation), coastal development and inadequate wastewater disposal all contribute to an increase in nutrients and other pollutants entering the coastal environment around Timor-Leste. Impacts are currently at a relatively small scale and confined mostly to urban areas (Wirasantosa *et al.*, 2011).

Flood waters, Dili (left, by Ian Stehbens) and construction of a rubble mound breakwater and floating small boat pier (right, by Petty Officer 2nd Class Matt Dawson, 21Oct13).

Research also indicates that climate change will likely affect seagrass ecosystems in Timor-Leste, through increases in sea surface temperature (expected to rise 0.5–1.1°C by 2030, and up to 4.2°C by 2090) and sea level (9 - 18cm predicted by 2030, and up to 88cm by 2090), and changes in storms/cyclone patterns, frequency and intensity (Australian Bureau of Meteorology and CSIRO, 2014). Thus, promoting and enabling an adaptive approach to seagrass management will not only maintain seagrass diversity, ecological functions and ecosystem services, but also enhance the resilience and adaptive capacity of seagrass ecosystems to cope with climate change impacts.

Notes:

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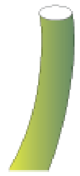
Matadalan atu halo indentifikasaun ba du'ut tasi iha Timor-Leste

Adaptadu husi Waycott *et al.*, 2014. *Translation by Venancio Lopes Carvalho*

Tahan silíndriku



cylindrical

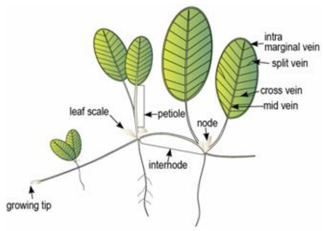
Syringodium isoetifolium

- Tahan hanesan supermie/espageti no sai ki'ik iha nia tutun
- Tahan kontén kavidade ár
- Tahan nia naruk entre 5-50cm, diametru 1-3mm
- Rizoma mihis, mutin no kabeer
- Abut kór mutin ka kór de roza, abut sanak barak

Tahan ovál to'o kuadradu

oval to oblong

Tahan ho petiole (tangkai daun), iha pár



*Halophila decipiens**

- Tahan ninin hanesan kadó nia nehan
- Tahan nia uat pár 6-8
- Iha fulun ki'ikoan loos iha tahan nia sorin-sorin
- Tahan naruk, naruk liu tahan nia luan

**currently unreported husi Timor-Leste*

Halophila minor

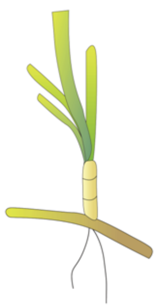
- Tahan nia uat menus husi pár 8
- Tahan nia naruk 5-15mm, no luan 3.5-6mm.
- Tahan ninin kabeer.
- Tahan laiha fulun

Halophila ovalis

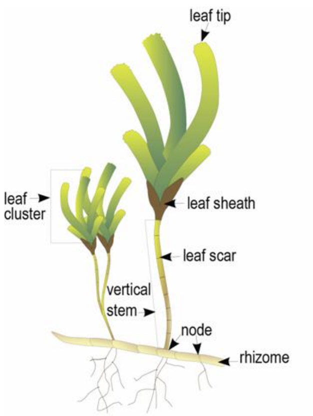
- Tahan nia uat pár 8 ka liu
- Tahan nia naruk 5-40mm, no luan 5-20mm
- Tahan nia ninin kabeer.
- Tahan laiha fulun

Tahan foma hanesan fita

Tahan bele mosu husi kain ne'ebé vertikál



straplike

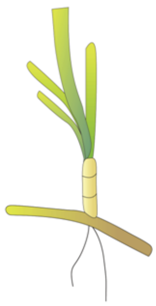


Cymodocea rotundata

- Tahan nia tutun hanesan kabuar ho nia rohan kabeer
- Tahan nia luan 2-4mm ho nia uat (veia da folha) paralelu 9-15
- Tahan nia kós nia fatin (fitar) metin nafatin iha kain
- Kós ne'ebé tuan forma fibrozu barak iha kada dikin

Cymodocea serrulata

- Tahan nia tutun hanesan kabuar ho rohan hanesan kadó nia nehan
- Tahan nia luan 4-9mm ho nia uat (veia da folha) paralelu 13-17
- Tahan nia kós jeralmente belar no triángulu, la'ós fibroza.
- Tahan nia kós nia fatin (fitar) la mosu iha kain



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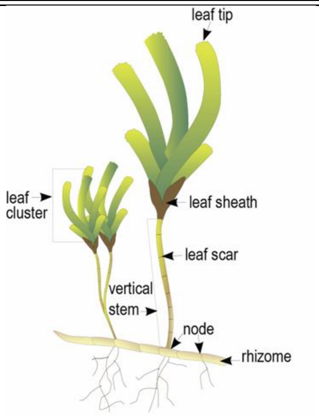


Halodule uninervis

- Tahan nia tutun meik, la'ós kabuar
- Tahan ho luan 0.5-5mm
- Tahan ho uat paralelu 3 ne'ebé bele haree moos, nia kós fibroza
- Rizoma baibain kór mutin ho fibroza ki'ikoan kór metan iha kain nia junta

Halodule pinifolia

- Tahan nia tutun hanesan kabuar
- Tarak lateral dezenvolve ladún moos ka laiha
- Tahan ho uat paralelu 3 ne'ebé moos, nia kós fibroza
- Rizoma baibain kór mutin ho fibroza ki'ikoan kór metan iha kain nia junta

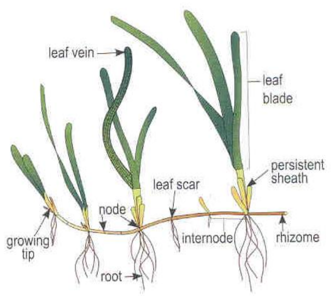
Thalassia hemprichii

- Tahan nia luan 4-12mm ho nia uat (veia da folha) paralelu 9-11
- Tahan baibain forma kurva
- Tahan nia tutun kabuar, karik hanesan uitoan ho kadó nia nehan
- Tahan iha sinál kór mean, naruk 1-2mm
- Kain bele badak no dalaruma labele nota
- Rizoma mahar ho fitar ne'ebé haree moos, baibain ho forma triángulu
- Abut badak iha kada rizoma nia junta

Thalassodendron ciliatum

- Kain hamriik loos no forsa
- Tahan forma kurva no tuur ho grupu (luan >5 mm), nia ninin hanesan kadó nehan
- Kain no rizoma hanesan ai

Tahan sempre mosu diretamentu husi rizoma

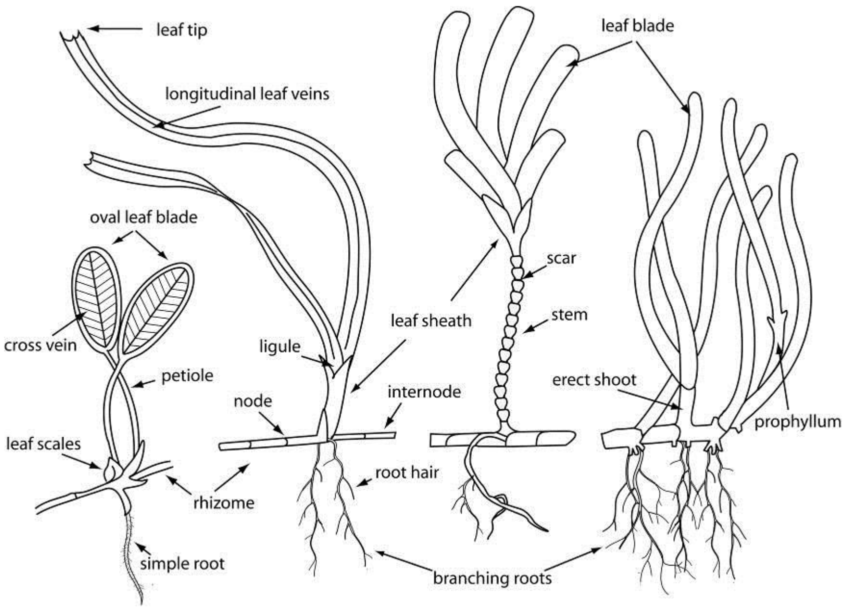


Enhalus acoroides

- Moris boot, tahan nia naruk >30 cm, luan >1 cm
- Nia tutun/ninin lulun an tama
- Tarak/fulun naruk, kór mean moris sai husi rizoma ne'ebé mahar

Notes:

Parts of a seagrass plant



Leaf

Tip

Can be rounded or pointed. Tips are easily damaged or cropped, so young leaves are best to observe.

rounded *pointed*

Veins

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.

- cross-vein: perpendicular to the length of the leaf
- parallel-vein: along the length of the leaf
- mid-vein: prominent central vein
- intramarginal-vein: around inside edge of leaf

cross *parallel*

mid *intramarginal*

Edges

The edges of the leaf can be either serrated, smooth or inrolled

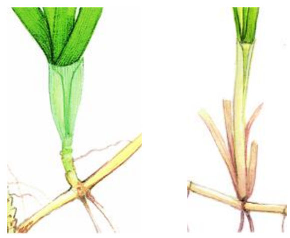
serrated *smooth* *inrolled*

Ligule

short membranous flap on the upper, inner side of a leaf at the junction of the leaf blade and the sheath

Sheath

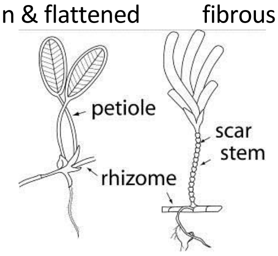
A modification of the leaf base that protects the newly developing tissue. The sheath can entirely circle the vertical stem or rhizome (continuous) or not (non-continuous); fully or partly cover the developing leaves and be flattened or rounded. Once the leaf has died, persistent sheaths may remain as fibres or bristles.



clean & flattened fibrous

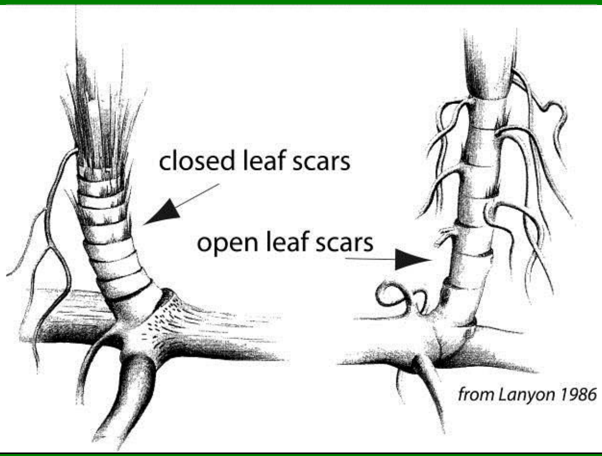
Attachment

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. *Halophila ovalis*.



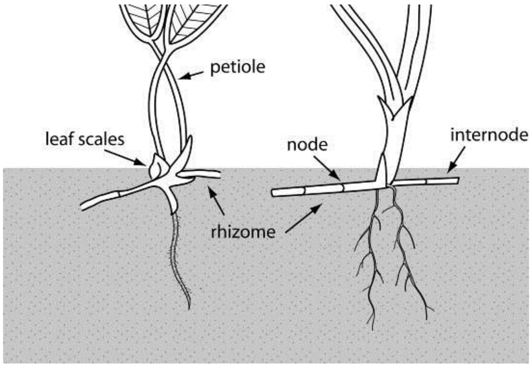
Stem

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*).



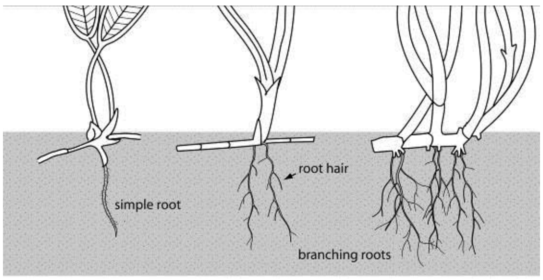
Rhizome

The horizontal axis of the seagrass plant, usually in sediment. It is formed in segments, with leaves or vertical stem arising from the joins 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.



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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, 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;
- have an important ecological role;
- 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 program. 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. Monitoring is currently occurring at over 355 sites. To learn more about the program, visit 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 raise awareness and protect this important marine habitat for the benefit of the 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 6–9 hours of 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 formal lectures and on-site assessments with a tired 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 (±3m) GPS waypoint. Labels identifying the sites and contact details for the program are attached to these pickets. Positions of 0 m and 50 m points for all three transects at a site are also noted using GPS. 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 compliancy:

- *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, that the scans/copies of datasheets are OK (*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-compliancy (e.g., site graphs). If officially requested data is non-compliant, a note in the metadata advises of non-compliancy 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 (Campbell and McKenzie, 2004; Petus *et al.*, 2016), coastal developments (e.g., marina constructions) and dredging proposals.
- Understanding natural levels of change (e.g.,Macreadie *et al.*, 2014; Yaakub *et al.*, 2014; McKenzie *et al.*, 2016) 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.*

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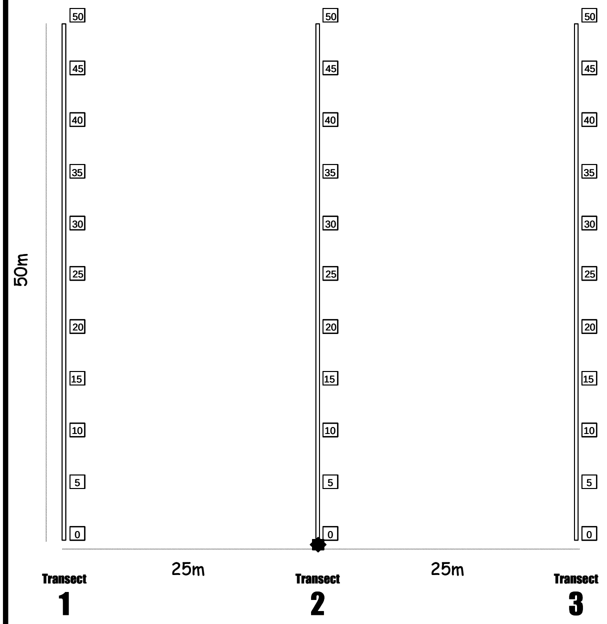
Seagrass-Watch Protocols

Source: McKenzie et al., 2003 (www.seagrasswatch.org/manuals.html)

Modelu Sítiu



Kuadrat kódigu = sítiu + transek + kuadrat

Ez., DL1225 = Dili sítiu 1, transek 2, 25m kuadrat

Preparasaun molok halo monitorizasaun

Halo oráriu

Halo oráriu kona-ba tempu atu sai no tempu atu filafali, no saida mak sai objetivu iha loron ne'e no saida mak tenke atinje. Fó kopia kona-ba oráriu ne'e antes ba partisipante hotu-hotu ne'ebé involve atu nune'e sira bele regula sira-nia tempu atu to'o iha fatin tuir oras. Alista mós iha oráriu ne'e kona-ba saida mak voluntáriu sira tenke lori.

Ema ne'ebé tenke kontaktu

Tau ema ruma ne'ebé ita fiar atu fó alerta bainhira ita-boot no ekipa la fila tuir tempu ne'ebé determina ona.

Seguransa

- Avalia risku sira molok halo monitorizasaun - haree tempu, laloran,nst
- Uza ita-boot nia instink - se ita-boot sente la seguru tenke husik lalais sampling
- Labele tau ita-boot nia an no ema seluk iha risku
- Hatais roupa ne'ebé apropriadu no taka ain
- Proteje an husi raius loro-matan
- Kuidadu ho animál tasi sira-ne'ebé perigu
- Lori Primeiru Sokoru ho ita-boot
- Lori ita-nia telemóvel ka rádio ne'ebé uza atu kontaktu

Ekipamentu no matriál sira-ne'ebé presiza

- ❑ *3x50m fita metru*
- ❑ *6x50cm kabidu plástiku*
- ❑ *kompas*
- ❑ *1x kuadrat padraun (50cmx50cm)*
- ❑ *3x fixa-dadus ba monitorizasaun*
- ❑ *clipboard, lapis no régua 30cm*
- ❑ *kamera*
- ❑ *labeller ba kuadrat foto*
- ❑ *fixa padraun ba kobertura persentajen*
- ❑ *fixa ba identifikasaun du'ut tasi*

Sampel ida-idak

Iha sítiu ho medida 50x50 nia laran tau transek 3 medida 50 paralelu, distánsia 25m husi id aba seluk, no perpendikula (tau loos husi tasi ba tasi-ibun ho angulu 900). Iha kada kuadrat tau sampling, kompleta etapa sira tuirmai ne':

Etapa 1. Hasai foto kuadrat t

- Hasai kada kuadrat nia foto (ka iha 5m, 25m no 45m se limitadu) iha kada transek. Uza kuadrat ne'ebé laiha tali no tau labeller foto kuadrat iha kuadrat nia sorin no fita metru no tau kódigu ne'ebé loos
- Hasai foto husi angulu vertikál, ne'ebé inklui kuadrat tomak, fó label ba kuadrat no fita metru. Koko atu labele iha lalatak ka reflesaun iha bee ne'ebé ita hasai nia foto. Haree filafali foto ne'ebé hasai no tau iha fixa-dadus ba kuadrat

Etapa 2. Deskreve sedimentasaun nia kompozisun

- Uza liman-fuan hatama ba sedimentasaun nia parte leten to'o sentímetru balu no sente nia testura. Deskreve sedimentasaun liuhosi sente partíkula sira iha orden ne'ebé dominante (ez. Rai-henek, rai-henek mamar, rai-henek mamar/tahu

Etapa3. Deskreve karakterístika seluk no ID/konta makro fauna

- Konta no hakerek (númeru – labele uza símbolu < ka >) ba buat ruma ne'ebé ita interese ba (Ez. Gastropoda, kadiuk, iha evidénsia kona-ba dugong ka lenuk han. Bioturbasaun, sedimentasaun nia forma hanesan laloran) iha koluna komentáriu
- Se bee kobre hotu kuadrat nia sorin ka tomak, entaun sukat bee nia naruk iha cm

Etapa 4. Halo estimasaun kona-ba pursentu du'ut tasi ne'ebé moris kobre área

- Haree tama ba kuadrat husi leten, halo estimasaun ba totál persentajen husi tasi-okos(substratu) iha kuadrat laran ne'ebé du'ut tasi taka. Halo estimasaun ba lalatak ne'ebé hamosu husi du'ut tasi.
- Sempre uza padraun foto ba kobertura persentajen (Fixa-kalibrasi) nu'udar matadalan bai ta-boot, atu halo estimasaun kobertura ho loloos, Ez. 27%, 61%
- Se du'ut tasi nia kobertura menus husi 3% ita-boot bele konta du'ut tasi nia dikin (pucuk) no kalkula kobertura nia persentajen uza formula dikin(pucuk) 1=0.1%. Nota: Ida ne'e sei boot liu ba dikin(pucuk) husi espésie ho medida boot

Etapa 5. Halo estimasaun ba kompozisaun espésie du'ut tasi

- Identifka espésie du'ut tasi iha kuadrat laran no determina persentajen kona-ba distribuisaun kada espésie ((hahú husi ladún barak, kompozisun totál tenke iguál ho 100%)
- Uza matadalan atu halo indentifikasaun ba espésie du'ut tasi, no uza karakterístika barak (liu husi karakterístika 1) atu identifika kada espésie

Etapa 6. Skat kanopi du'ut tasi nia aas

- Sukat kanopi nia aas (iha unidade sentímetru) husi espésie ne'ebé moris domina ho tahan rabat malu, ignora sira-ne'ebé aas liu 20%.
- Sukat husi sedimentasaun to'o iha tahan 3 iha dikin nia tutun. Hatama hotu tahan 3 ne'ebé sukat bai ha fixa-dadus

Etapa 7. Halo estimasaun ba persentajen kobertura alja sira

- Haree tama ba kuadrat husi leten, halo estimasaun ba total persentajen husi tasi-okos(substratu) iha kuadrat laran ne'ebé taka husi makro alja sira (du'ut tasi ne'ebé kobre independente)
- Makro alja sira la belit iha du'ut tasi nia tahan sira, maibé karik belit iha fatuk, eskeletu sira ka karik namlele

Etapa 8. Halo estimasaun ba persentajen kobertura epifit

- Epifit nu'udar alja sira-ne'ebé belit iha du'ut tasi nia tahan no halo sai aat.
- Dahuluk, halo estimasaun ba médiu husi du'ut tasi nia tahan superfísie ne'ebé kobre ona, no hafoin tahan hira iha kuadrat laran ne'ebé kobre. Ezemplu: se 20% husi tahan mak kobre husi epifit 50%, entaun kuadrat epifit kobre mak 10%. Uza matriks epifit atu tulun ita-boot.
- Labele inklui epifauna iha epifit. Epifauna mak animál sira ne'ebé moris metin iha du'ut tasi nia tahan- Rejista % epifauna nia kobertura iha iha koluna komentáriu / iha koluna mamuk – Labele aumenta ka kahur ba kobertura epifit nian

Etapa 9. Foti espésiemen du'ut tasi bainhira presiza

- Tau amonstra du'ut tasi iha saku plástuku ne'ebé tau ona kódigu no ho tasi-been uitoan. Hili espésimen du'ut tasi ne'ebé reprezentativu atu asegura katak ita-boot lori du'ut tasi nia parte sira hotu inklui rizoma no abut sira. Koleta du'ut tasi ho nia estrutura fuan no funan se posível

Etapa 10. La'o ba kuadrat tuirmai

- Repete etapa 1 to'o 8 hodi kobre kuadrat 32 ne'ebé sei iha

Etapa 11. Monitorizasaun remata

- Haree fali fixa-dadus no konfirma katak prienxe hotu ona
- Hasai sasán sira (Ez. Kabidu sira ne'ebé la'ós permanente

Monitorizasaun remata ona

Etapa 1. Fase no aruma sasán

- Fase sasán sira hanesan metru, kabidu no kuadrat, ho bee-moos no husik maran.
- Haree fali sasán atu halo sampel tuirmai no husu materiál foun ne'ebé presiza
- Tau sasán atu halo sampel tuirmai

Etapa 2. Falun no hanehan espésimen du'ut tasi bainhira koleta cted

- Espésimen tenke falun no hanehan lalais hafoin koleta. Labele tau iha jaleira liu husi loron 2
- Tau espésimen iha fatin maran/manas nato'on/ nakukun mínimu durante semana rua. Atu hetan rezultadu di'ak, troka surat-tahan (koran) depois loron 2-3

Etapa 3. Entrega dadus hotu-hotu

- Dadus bele hatama ba iha Ms-Excel ne'ebé bele download husi www.seagrasswatch.org. Envia dadus complete ba Email hq@seagrasswatch.org
- Envia fixa-dadus orijinál, foto sira no fixa herbariu

Seagrass-Watch HQ
Ba enderesu kódigu postál, haree
http://www.seagrasswatch.org/contact.html

KÓDIGU ESPÉSIE DU'UT TASI

Ea *Enhalus acoroides*

- naruk loos (>30cm) tahan hanesan fita ho ninia ninin lulun an tama.
- rizoma mahar ho nia tarak/fulun kór metan naruk no nia abut hanesan tali

Thalassia hemprichii Th

- tahan hanesan fita, forma kurva ho naruk 10-40cm
- tahan nia tutun kabuar, hanesan kadó nia nehan uitoan
- sélula tannin badak, naruk 1-2mm iha nia tahan
- rizoma mahar ho kuak (fitar) entre dikin (pucuk) sira

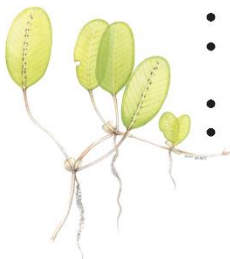
Cr *Cymodocea rotundata*

- tahan nia tutun kabuar
- tahan kloot (luan 2-4mm)
- tahan nia naruk 7-15cm
- tahan nia uat 9-15 longitudinál
- tahan nia kós dezenvolve ho di'ak

Cs *Cymodocea serrulata*

- tahan nia tutun hanesan kadó nia nehan
- tahan nia luan (5-9mm)
- tahan nia naruk 6-15cm
- iha uat 13-17 longitudinál
- iha rizoma ne'ebé forte

Ho *Halophila ovalis*



- tahan nia uat 8 ka liu
- laiha fulun iha tahan nia superfísie
- tahan nia ninin kabeer
- tahan nia naruk 5-20mm

Hd *Halophila decipiens*

- tahan ho forma ovál, tutun meik uitoan
- tahan nia fulun iha parte rua hotu
- iha uat 6-8
- tahan nia ninin hanesan kadó nia nehan uitoan

Hm *Halophila minor*

- tahan nia uat menus husi 8
- tahan ovál ki'ikoan, nia luan menus husi 5mm
- tahan nia ninin kabeer
- laiha fulun iha nia tahan

Hu *Halodule uninervis*

- tahan nia tutun hanesan kabuar
- iha uat sentrál 1
- rizoma mamar, iha tahan nia fitar ho kór metan moos

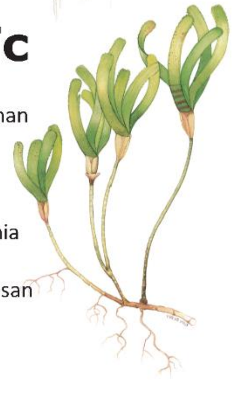
Si *Syringodium isoetifolium*

- tahan hanesan supermie ne'ebé ki'ik.
- silíndriku ho diamentru 1-2mm
- tahan kontén kavidade ár
- tahan nia tutun sai ki'ik iha nia rohan
- tahan nia naruk 7-30cm

Hp *Halodule pinifolia*

- tahan nia tutun kabuar
- iha uat sentrál 1
- rizoma mamar, iha tahan nia fitar ho kór metan moos

Thalassodendron ciliatum Tc



- nia kain hamrik naruk to'o 65cm no iha tahan ne'ebé moris hamutuk (iha grupu)
- rizoma forsa no hanesan ai
- tahan hanesan fita, forma hanesan tara
- tahan nia tutun kabuar no hanesan kadó nia nehan
- baibain hetan belit iha substratu sira hanesan fatuk ka korál

Ilustrasaun sira labele fó eskala

SEAGRASS-WATCH MONITORING

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

OBSERVER: Bev Citizen **DATE:** 17 / 2 / 09
LOCATION: Burrum Heads
SITE code: BH1 **TRANSECT no.:** 2
START TIME: 1304 **END TIME:** 1340

START of transect (GPS reading)
Latitude: .... ° .... ' ...... **Longitude:** .... ° .... ' ......

Quadrat (metres from transect origin)	Sediment (eg, mud/sand/shell)	Comments (eg 10x 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		Water			
1 (0m)	Sand	SC x 3 HC x 1	√	40	30	70			0	5,4,7	5	33
2 (5m)	S	GAS x 3	√	33	50	50			0	10,7,8	10	18
3 (10m)	mud/sand	worm x 1	√	18	70	20	10		0	6,8,5	0	48
4 (15m)	m/s	DFT x 1	√	0					0	0	17	0
5 (20m)	m/s/shell	HC x 3	√	36	5	90	5		1cm	9,7,5	12	57
6 (25m)	m/s/sh	—	√	48	100				1cm	NA.	2	96
7 (30m)	Fine Sand	Turtle cropping	√	0					1.5cm	0	23	0
8 (35m)	FS	SC x 2	√	0.7		100			2cm	7,7,7	18	31
9 (40m)	s/m	CH x 3	√	23	96	4			2cm	2,4,6	6	17
10 (45m)	m	Mud whelk x 2 HC x 1	√	41	2	95	3		2cm	5.5,6 9	3	21
11 (50m)	m/s		√	16	3	7	90		2cm	7,6,7	38	6

END of transect (GPS reading)
Latitude: .... ° .... ' ...... **Longitude:** .... ° .... ' ......

SC = Sea Cucumber
GAS = Gastropod.
DFT = Dugong feeding trail.
HC = Hermit Crab.
CH = Crab Hole.

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. A herbarium specimen is 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.

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 in 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 dying 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 as part of the Australian Tropical Herbarium.

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 and will be lodged in the Seagrass-Watch Virtual Herbarium http://www.seagrasswatch.org/herbarium.html.

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 Wentworth, 1922.

Mud	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
Sand	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
Gravel	Granules	2.0001 – 4.000 mm
	Pebbles and larger	>4.0001 mm

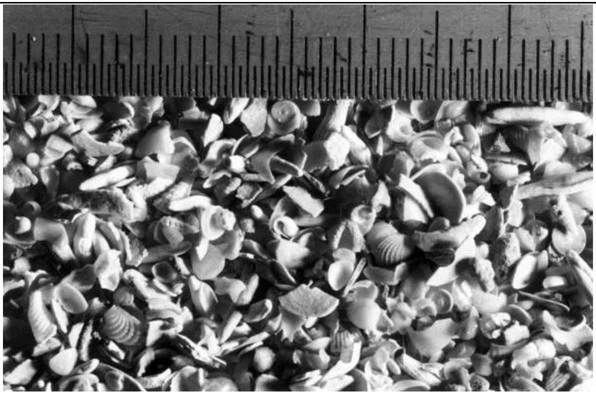
In Seagrass-Watch, the primary descriptors relate to the size of the sediment grains: gravel (>2000µm); coarse sand (>500 µm); sand (>250 µm); fine sand (>63 µm); and mud (<63 µm).

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).

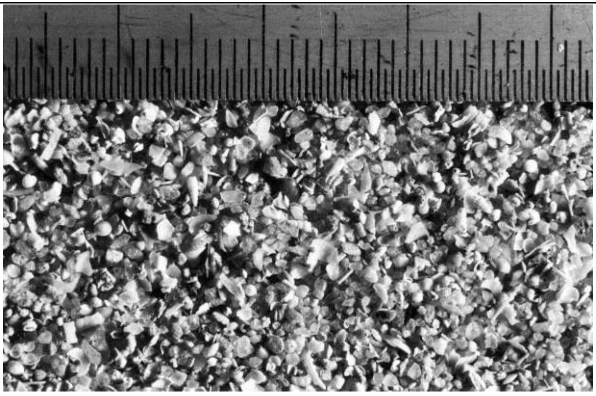
mud *has a smooth and sticky texture.*
fine sand *fairly smooth texture with some roughness just detectable. Not sticky in nature.*
sand *rough grainy texture, particles clearly distinguishable.*
coarse sand *coarse texture, particles loose.*
gravel *very coarse texture, with some small stones.*

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

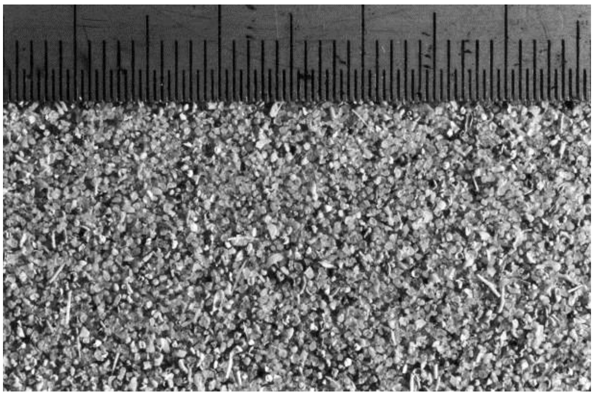
The visual/tactile estimation method used in Seagrass-Watch is a simple yet relatively accurate measure of the sediment grain size which can be used for quantitative assessments McKenzie, 2007, http://www.seagrasswatch.org/Info_centre/Publications/pdf/371_DPIF_McKenzie.pdf.



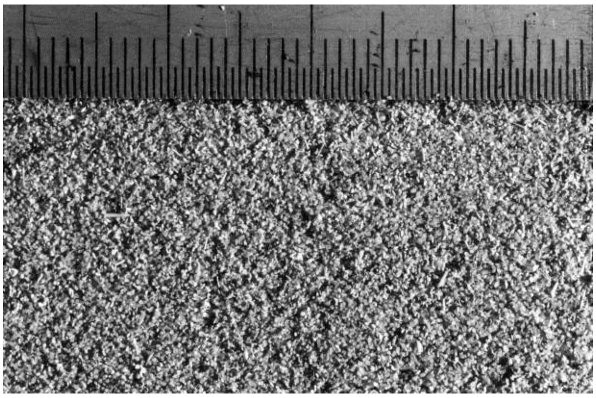
gravel (>2mm)



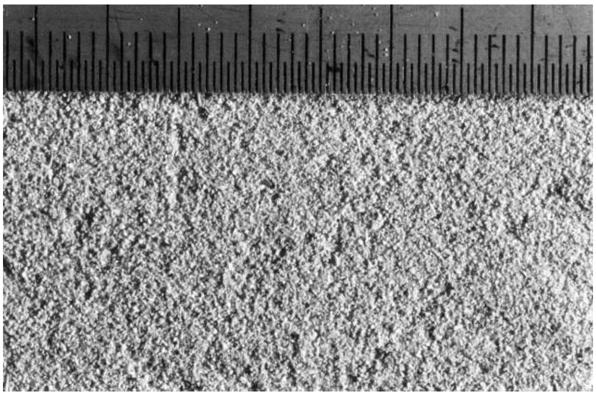
very coarse sand (1 – 2 mm)



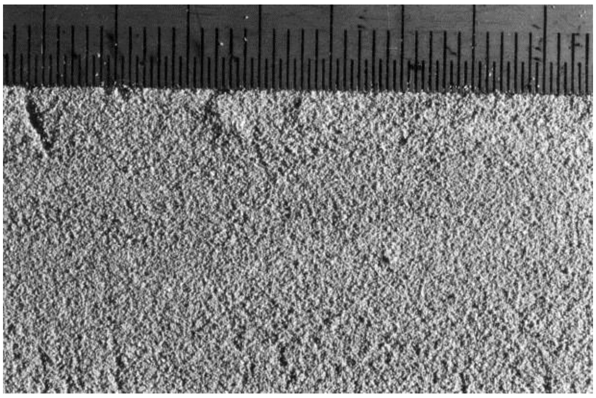
coarse sand (0.5 – 1 mm)



medium sand (0.25 – 0.5 mm)



fine sand (0.125 – 0.25 mm)



very fine sand (0.063 – 0.125mm)

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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., "wasting disease" or 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: transplantation, 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). 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 (Coles and Fortes, 2001). 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 (Coles and Fortes, 2001). 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 (Coles and Fortes, 2001).

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 (Coles and Fortes, 2001). 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 (Hardin, 1968). 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 (Smyth *et al.*, 2006).

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 hat 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.

Consequently a combination of modern “western” science and indigenous knowledge should be brought together within a co-management framework for the successful management of these resources (Johannes, 2002; Gaskell, 2003; Aswani and Weiant, 2004; George *et al.*, 2004; Turnbull, 2004; Middlebrook and Williamson, 2006). This can only occur if the resource owners actively involve themselves in the management of their resources. Western science also needs to recognise that resource owners have practical and spiritual connections with the resources found within their environment. Once this is recognized then this approach will have the added benefit of empowering communities who own the knowledge to be the primary managers and leaders in decisions about their land and sea country.

Notes:

References

Allen, G.R., Erdmann, M.V., 2013, Coral Reef Fishes of Timor-Leste. *In*: Erdmann, M., Mohan, C. (Eds.), A Rapid Marine Biological Assessment of Timor-Leste, RAP Bulletin of BiologicalAssessment 66. Conservation International, Coral Triangle Support Partnership, Dili, Timor Leste, pp. 32-82.

Asian Development Bank, 2014, State of the Coral Triangle: Timor-Leste. Asian Development Bank, Mandaluyong City, Philippines.

Aswani, S., Weiant, P., 2004. Scientific evaluation in women's participatory management: monitoring marine invertebrate refugia in the Solomon Islands. *Human Organisation* **63** (3): 301-319.

Audley-Charles, M.G., 2004. Ocean trench blocked and obliterated by Banda forearc collision with Australian proximal continental slope. *Tectonophysics* **389** (1): 65-79.

Australian Bureau of Meteorology, CSIRO, 2014, East Timor (Timor-Leste). Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report. Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia, pp. 49-63.

Boggs, G., Edyvane, K., de Carvalho, N., Penny, S., Rouwenhorst, J., Brocklehurst, P., Cowie, I., Barreto, C., Amaral, A., Monteiro, J., Pinto, P., Mau, R., Smit, N., Amaral, J., Fernandes, L., 2012, Marine and Coastal Habitat Mapping in Timor Leste (North Coast) – Final Report. Project 1 of the Timor Leste Coastal-Marine Habitat Mapping, Tourism and Fisheries Development Project. Ministry of Agriculture & Fisheries, Government of Timor Leste, Dili, Timor Leste.

Boggs, G., Edyvane, K., de Carvalho, N., Penny, S., Rouwenhorst, J., Brocklehurst, P., Cowie, I., Barreto, C., Amaral, A., Smit, N., Monteiro, J., Pinto, P., Mau, R., Amaral, J., Fernandes, L., 2009, Marine and Coastal Habitat Mapping in Timor Leste (North Coast) – Final Report. Ministry of Agriculture & Fisheries, Government of Timor Leste, Dili, Timor Leste.

Campbell, S.J., McKenzie, L.J., 2004. Flood related loss and recovery of intertidal seagrass meadows in southern Queensland, Australia. *Estuarine, Coastal and Shelf Science* **60** (3): 477-490.

Coles, R., McKenzie, L.J., Campbell, S., 2003, The seagrasses of Eastern Australia. *In*: Green, E.P., Short, F.T. (Eds.), The World Atlas of Seagrasses: present status and future conservation. University of California Press, Los Angeles, USA, pp. 119-133.

Coles, R.G., Fortes, M.D., 2001, Protecting seagrass—approaches and methods. *In*: Short, F.T., Coles, R.G. (Eds.), Global seagrass research methods. Elsevier, Amsterdam, pp. 445–463.

CTI-TLS, 2012, State of the Coral Reefs Of Timor Leste. Coral Triangle Marine Resources: their Status, Economies and Management. National CTI Coordinating Committee of Timor-Leste, Dili, Timor Leste.

den Hartog, C., 1970, The sea-grasses of the world. North-Holland Publishing Company, Amsterdam.

Dethmers, K., Chatto, R., Meekan, M., Amaral, A., de Cuhna, C., de Carvalho, N., Edyvane, K., 2009, Marine megafauna surveys in Timor-Leste: identifying opportunities for potential ecotourism – Final Report. Ministry of Agriculture and Fisheries, Government of Timor Leste, Dili, Timor-Leste.

Edyvane, K., de Carvalho, N., Penny S, F., A, de Cunha, C., Amaral, A., Mendes, M., Pinto, P., 2012, Conservation Values, Issues and Planning in the Nino Konis Santana Marine Park, Timor Leste – Final Report. Project 4 of the Timor Leste Coastal-Marine Habitat Mapping, Tourism and Fisheries Development Project. Ministry of Agriculture & Fisheries, Government of Timor Leste, Dili.

Erdmann, M., Mohan, C. (Eds.), 2013, A Rapid Marine Biological Assessment of Timor-Leste, RAP Bulletin of BiologicalAssessment 66. Conservation International, Coral Triangle Support Partnership, Dili, Timor Leste.

Fortes, M.D., Ooi, J.L.S., Tan, Y.M., Prathep, A., Bujang, J.S., Yaakub, S.M., 2018. Seagrass in Southeast Asia: a review of status and knowledge gaps, and a road map for conservation. *Botanica Marina* **61** (3): 269.

Gaskell, J., 2003. Engaging science education within diverse cultures. *Curriculum Inquiry* **33** 235-249.

George, M., Innes, J., Ross, H., 2004, Managing sea country together: key issues for developing co-operative management for the Great Barrier Reef World Heritage Area. CRC Reef Research Centre Technical Report No 50. CRC Reef Research Centre Ltd, Townsville.

Hall, R., 2001. Extension during late Neogene collision in east Indonesia and New Guinea. *Journal of The Virtual Explorer* **04** (4): 17-24.

Hardin, G., 1968. The tragedy of the commons. *Science, New Series* **162** (3859): 1243-1248.

Johannes, R.E., 2002. The renaissance of community-based marine resource management in Oceania. *Annu. Rev. Ecol. Syst* **33** 317-340.

Joyce, K., 2013, Mapping and assessment of the coastal-marine habitats of Timor- Leste: South and northwest coasts. Charles Darwin University, Darwin, NT.

Kuriandewa, T.E., Kiswara, W., Hutomo, M., Soemodihardjo, S., 2003, The Seagrasses of Indonesia. *In*: Green, E.P., Short, F.T. (Eds.), World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre, University of California Press, Berkeley U.S.A., pp. 171-182.

Macreadie, P.I., York, P.H., Sherman, C.D.H., 2014. Resilience of *Zostera muelleri* seagrass to small-scale disturbances: the relative importance of asexual versus sexual recovery. *Ecology and Evolution* **4** (4): 450-461.

McKenzie, L.J., 2006, Seagrasses. WCS and CFMDP Marine Training Program: Course notes. Motupore Island Research Centre, Papua New Guinea, January 29 - February 23 2006. WCS, Port Moresby, pp. 128-147.

McKenzie, L.J., 2007, Relationships between seagrass communities and sediment properties along the Queensland coast. Progress report to the Marine and Tropical Sciences Research Facility. Reef and Rainforest Research Centre Ltd, Cairns

McKenzie, L.J., Campbell, S.J., Roder, C.A., 2003, Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources. QFS, NFC, Cairns.

McKenzie, L.J., Coles, R., Erftemeijer, P., 2007, Seagrass Ecosystems of Papua. *In*: Marshall, A.J., Beehler, B.M. (Eds.), The Ecology of Papua. The Ecology of Indonesia Series, Vol VI, pp. 800-823.

McKenzie, L.J., Yaakub, S.M., Tan, R., Seymour, J., Yoshida, R.L., 2016. Seagrass habitats in Singapore: Environmental drivers and key processes. *Raffles Bulletin of Zoology* **Supplement 34** 60-77.

McWilliam, A., 2011, Fataluku Living Landscapes. *In*: McWilliam, A., Traube, E.G. (Eds.), Land and Life in Timor-Leste Ethnographic Essays. ANU E Press, The Australian National University Canberra ACT, Australia pp. 61-86.

Middlebrook, R., Williamson, J.E., 2006. Social attitudes towards marine resource management in two Fijian villages. *Ecological Management & Restoration* **7** (2): 144-147.

Nordlund, L.M., Jackson, E.L., Nakaoka, M., Samper-Villarreal, J., Beca-Carretero, P., Creed, J.C., 2018. Seagrass ecosystem services – What's next? *Marine Pollution Bulletin* **134** 145-151.

Nordlund, L.M., Unsworth, R.K.F., Gullström, M., Cullen-Unsworth, L.C., 2017. Global significance of seagrass fishery activity. *Fish and Fisheries*n/a-n/a.

Petus, C., Devlin, M., Thompson, A., McKenzie, L., Teixeira da Silva, E., Collier, C., Tracey, D., Martin, K., 2016. Estimating the Exposure of Coral Reefs and Seagrass Meadows to Land-Sourced Contaminants in River Flood Plumes of the Great Barrier Reef: Validating a Simple Satellite Risk Framework with Environmental Data. *Remote Sensing* **8** (3): 210.

Sandlund, O.T., Bryceson, I., de Carvalho, D., Rio, N., Silva, J.d., Silva, M.I., 2001, Assessing Environmental Needs and Priorities in East Timor: Issue and Priorities. United Nations Development Programme (UNDP) & Norwegian Institute for Nature Research (NINA-NIKU), Dili & Trondheim.

Smyth, D., Fitzpatrick, J., Kwan, D., 2006, Towards the development of cultural indicators for marine resource management in Torres Strait. CRC Torres Strait, Townsville.

Tillinger, D., 2011. Physical oceanography of the present day Indonesian Throughflow. *Geological Society Special Publication* **355** 267-281.

Turak, E., Devantier, L., 2013a, Reef-building Corals in Timor-Leste. *In*: Erdmann, M., Mohan, C. (Eds.), A Rapid Marine Biological Assessment of Timor-Leste, RAP Bulletin of BiologicalAssessment 66. Conservation International, Coral Triangle Support Partnership, Dili, Timor Leste, pp. 84-149.

Turak, E., DeVantier, L. (Eds.), 2013b, Reef-building corals in Timor-Leste. Conservation International, Washington D. C.

Turnbull, J., 2004. Explaining complexities of environmental management in developing countries: lessons from the Fiji Islands. *The Geographical Journal* **170** (1): 64-77.

Uchimura, M., Faye, E.J., Shimada, S., Inoue , T., Nakamura, Y., 2008. A reassessment of *Halophila* species (Hydrocharitaceae) diversity with special reference to Japanese representatives. *Botanica Marina* **51** 258-268.

Unsworth, R.K.F., Nordlund, L.M., Cullen-Unsworth, L.C., 2018. Seagrass meadows support global fisheries production. *Conservation Letters*.

Wagey, B., Calumpong, H.P., 2013. Genetic Analysis of the Seagrass Halodule in Central Visayas, Philippines. *Asian Journal of Biodiversity* **4** 223-237.

Waycott, M., Freshwater, D.W., York, R.A., Calladine, A., Kenworthy, W.J., 2002. Evolutionary trends in the seagrass genus *Halophila* (thouars): Insights from molecular phylogeny. *Bulletin of Marine Science* **71** (3): 1299-1308.

Waycott, M., McMahon, K., Lavery, P., 2014, A Guide to Southern Temperate Seagrasses. CSIRO PUBLISHING.

Waycott, M., McMahon, K.M., Mellors, J.E., Calladine, A., Kleine, D., 2004, A guide to tropical seagrasses of the Indo-West Pacific. James Cook University, Townsville.

Wentworth, C.K., 1922. A scale of grade and class terms for clastic sediments. *Journal of Geology* **30** 377-392.

Wirasantosa, S., Nurhakim, S., Adrianto, L., Nugroho, D., dos Santos Silva, C., 2011, ATSEA Thematic Reports on the Arafura and Timor Seas Region. Arafura and Timor Seas Ecosystem Action (ATSEA) Program, Jakarta, Indonesia.

Xu, N.-N., Yu, S., Zhang, J.-g., Tsang, P.K.E., Chen, X.-Y., 2010. Microsatellite primers for *Halophila ovalis* and cross-amplification in *H. minor* (Hydrocharitaceae). *American Journal of Botany* **97** (6): 56-57.

Yaakub, S.M., McKenzie, L.J., Erftemeijer, P.L.A., Bouma, T., Todd, P.A., 2014. Courage under fire: Seagrass persistence adjacent to a highly urbanised city–state. *Marine Pollution Bulletin* **83** (2): 417-424.

Further reading:

Hemminga M and Duate CM. (2000). Seagrass ecology. United Kingdom: Cambridge University Press.

Larkum AWD, Orth RJ and Duarte CM (2006). Seagrasses: biology, ecology and conservation. Springer, The Netherlands. 691 pp.

Phillips, R.C, E.G Menez. (1988). Seagrasses. Smithsonian Institution Press, Washington, D.C. 104 pp.

Short, FT and Coles, RG. (Eds.) Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam. 473pp.

Useful web links

Seagrass-Watch Official Site www.seagrasswatch.org

Project Seagrass An environmental charity devoted to the conservation of seagrass ecosystems through education, influence, research and action. www.projectseagrass.org

Dugong and Seagrass Conservation Project The first coordinated global effort to conserve dugongs and their seagrass habitats. www.dugongconservation.org

World Seagrass Association A global network of scientists and coastal managers committed to research, protection and management of the world's seagrasses. wsa.seagrassonline.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

for more links, visit **www.seagrasswatch.org/links.htm**