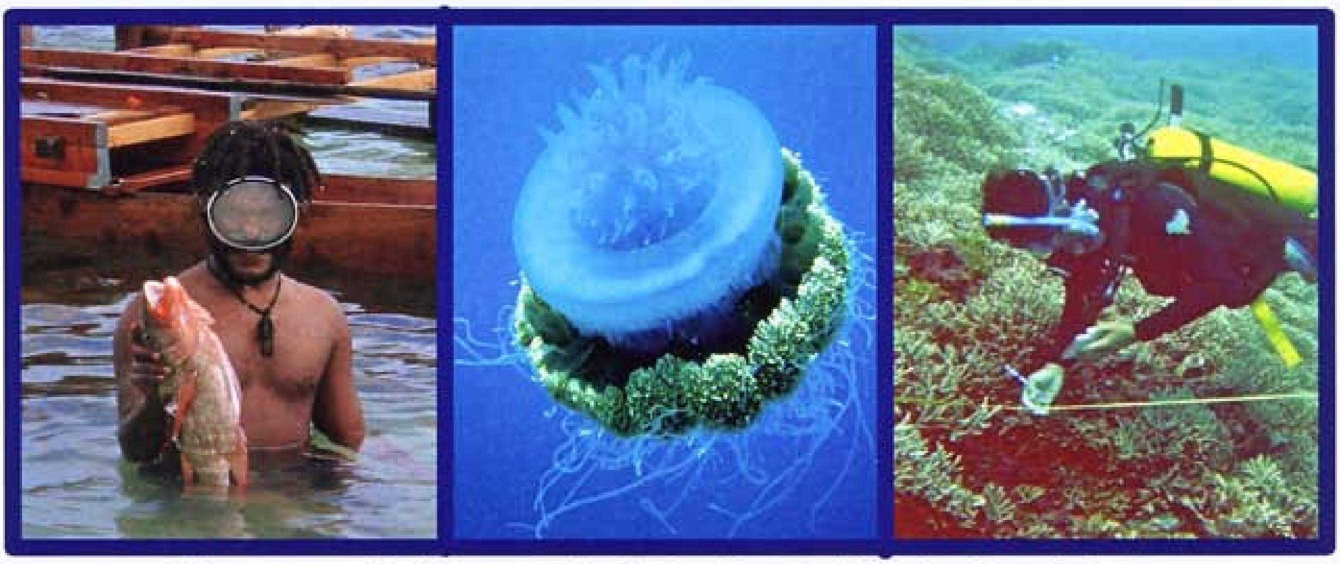
WCS AND CFMDP
MARINE TRAINING PROGRAM
COURSE NOTES

Motupore Island Research Centre,
Papua New Guinea.
January 29th – February 23rd 2006.



This course was kindly sponsored by the David and Lucile Packard Foundation, PNG National Fisheries Authority's Coastal Fisheries Management and Development Program, and the Australian Government's Regional Natural Heritage Program.

WILDLIFE CONSERVATION SOCIETY

The David and Lucile Packard Foundation

PNG NATIONAL FISHERIES AUTHORITY
COASTAL FISHERIES Management and Development Project
ASIAN DEVELOPMENT BANK

Mire

SeagrassWatch

Queensland Government
Department of Primary Industries and Fisheries

UPNG

Australian Government
Department of Environment and Heritage

Timetable

Sunday 29th January 2006

Afternoon	**1pm:** Students meet at Biological Sciences, UPNG. Minibus and boat transport to Motupore Island. Arrive at Motupore Island, Tour of research station.
Afternoon	Introductions; Course Outline; Safety Talk (MM) Snorkelling Activities – Try Out Snorkelling Gear (MM,CB,JB)
Evening	Guest lecture (MM)

Monday 30th January

Morning	Lecture 1: Introduction to Tropical Marine Ecosystems (CB) Lecture 2: Threats to Marine Ecosystems 1 (CB)
Afternoon	Lecture 3: Threats to Marine Ecosystems 2 (CB) Field exercise: Snorkelling skills /Collecting data underwater (MM, CB, JB)
Evening	Documentary

Tuesday 31st January

Morning	Lecture 1: Introduction to Marine Conservation 1 (CB) Lecture 2: Introduction to Marine Conservation 2 (CB)
Afternoon	Lecture 3: Introduction to Fisheries Management (CB) Field exercise: Reef fish identification (MM, CB, JB)
Evening	Documentary

Wednesday 1st February

Morning	Lecture 1: Sampling and Statistics 1 (MM) Lecture 2: Sampling and Statistics 2 (MM)
Afternoon	Lecture 3: Sampling and Statistics 3 (MM) Field Exercise: Reef fish size estimation and trophic roles (MM,CB,JB)
Evening	Data entry and interpretation

Thursday 2nd February

Morning	Lecture 1: Sampling and Statistics 4 (MM) Lecture 2: Sampling and Statistics 5 (MM)
Afternoon	Lecture 3: Sampling and Statistics 6 (MM) Lab exercise: Data storage and handling using Excel (MM,CB)
Evening	Movie

Friday 3rd February

Morning	Lab exercise: Data presentation (MM,CB)
Afternoon	Lecture 1: Sampling and Statistics 7 (MM) Field exercise: Sampling and Statistics – Optimisation (MM, CB)
Evening	Data Entry and Interpretation (MM,CB)

Saturday 4th February

Morning	Lecture 1: Invertebrates 1 (CB) Lecture 2: Invertebrates 2 (MB)
Afternoon	Lecture 3: Invertebrates 3 (CB, MM) Laboratory exercise: Invertebrate identification Field exercise: Invertebrate Identification and Sampling
Evening	Movie

Sunday 5th February

Morning	Rest
Afternoon	Rest
Evening	BBQ; Guest Lecture (CB)

Monday 6th February

Morning	Lecture 1: Fish Biology and Fisheries 1 (MM)
	Lecture 2: Fish Biology and Fisheries 2 (MM)
Afternoon	Lecture 3: Fish Biology and Fisheries 3 (MM)
	Laboratory exercise: Fish Identification, Measurement and Trophic Ecology (MM, CB)
Evening	Documentary

Tuesday 7th February

Morning	Field exercise: Reef fish survey methods 1 (MM, CB, JB)
Afternoon	Data entry and interpretation (MM, CB)
	Lecture 1: Fish Biology and Fisheries 4 (MM)
Evening	Guest lecture (MM)

Wednesday 8th February

Morning	Field Exercise: Fish survey methods 2 (MM, CB, JB)
	Data entry and interpretation (MM, CB)
Afternoon	Lecture 1: Seagrass Biology and Identification (LM)
	Field exercise: Seagrass Identification
	Laboratory exercise: Seagrass Identification (LM,CB)
Evening	Guest Lecture (LM)

Thursday 9th February

Morning	Lecture 1: Seagrass Ecology and Threats (LM)
	Lecture 2: Seagrass Mapping (LM)
Afternoon	Field exercise: Seagrass Mapping (LM,CB)
Evening	Data Entry and Interpretation (LM,CB)

Friday 10th February

Morning	Lecture 1: Seagrass Management (LM)
	Lecture 2: Seagrass Monitoring (LM)
Afternoon	Field exercise: Seagrass Watch – Monitoring (LM, MM, DA)
Evening	Data Entry and Interpretation (LM,CB)

Saturday 11th February

Morning	Rest
Afternoon	Rest
Evening	BBQ, Movie

Sunday 12th February

Morning	Lecture 1: Coral Biology (MP)
	Lecture 2: Coral Identification (MP)
Afternoon	Lecture 3: Coral Monitoring Methods (MP)
	Field/Lab Exercise: Coral Identification an Survey Methods (MP, MM, JB)
Evening	Guest Lecture (MP)

Monday 13th February

Morning	Lecture 1: Coral Ecology (MP)
	Lecture 2: Threats to Corals (MP)
Afternoon	Lecture 3: Management of Corals/ Restoration (MP)
	Field Exercise: Coral Monitoring Methods (MP, MM, JB)
Evening	Data entry and interpretation (MP, MM)

Tuesday 14th February

Morning	Lecture 1: Disturbance to Corals (MP)
	Field exercise: Disturbance to Corals (MP, MM, JB)
Afternoon	Lecture 1: Mangrove Biology (TM)
	Lecture 2: Mangrove Taxonomy and Identification (TM)
Evening	Data entry and interpretation

Wednesday 15th February

Morning	Field exercise: Mangrove Biology and Identification (TM, MP, JB)
Afternoon	Lecture 1: Mangrove Ecology (TM)
	Lecture 2: Threats to Mangroves (TM)
Evening	Documentary

Thursday 16th February

Morning	Field exercise: Mangrove Ecology and Monitoring (TM, MP, JB)
Afternoon	Lecture: Mangrove Management and Restoration (TM)
	Field Exercise: Mangrove Restoration (TM, MP, JB)
Evening	Data entry and interpretation (TM, MP)

Friday 17th February

Morning	Lecture 1: Sampling and Statistics 8 (UK)
	Laboratory: Sampling and Statistics Working Groups (UK)
Afternoon	Lecture 3: Sampling and Statistics 9 (UK)
	Laboratory exercise: Data Analysis (UK, MP)
Evening	Guest lecture (UK)

Saturday 18th February

Morning	Lecture 1: Sampling and Statistics 10 (UK)
	Lecture 2: Sampling and Statistics 11 (UK)
Afternoon	Laboratory Exercise: Data Analysis and Presenting Results (UK, MP)
Evening	Movie

Sunday 19th February

Morning	Rest/study for exams
Afternoon	Rest/study for exams
Evening	BBQ

Monday 20th February

Morning	Exam; Introduction to student projects; Sampling design; Study site selection (MM, MP)
Afternoon	Start student project sampling (MM, MP, JB)
Evening	Data entry (MM, MP)

Tuesday 21st February

Morning	Finish student project sampling (MM, MP, JB)
Afternoon	Data entry; Data analysis (MM, MP)
Evening	Data analysis; Lecture: How to write a scientific report (MP)

Wednesday 22nd February

Morning	Report write-up (MM, MP)
Afternoon	Report write-up; Hand in report by **3pm** (MM, MP)
Evening	Presentation Dinner

Thursday 23rd February

Morning	Pack up gear; Clean up station; Return to UPNG Campus by **1pm**

MM = Michael Marnane; CB = Chris Bartlett; MB = Mark Baine; TM = Thomas Maniwauve; JB = John Ben; UK = Ursula Kaly; MP = Morgan Pratchett; LM = Len McKenzie

ASSESSMENT GUIDE

Student grades for the course will be determined by performance in a number of different areas, including written reports, an examination, and the degree of participation and enthusiasm shown during the fieldwork. Depending on performance in this course, some university students may be able to credit this mark towards their degree.

The total grade for the course is divided up as follows:

General Participation:	**20%**
Student Research Project and Report:	**30%**
Final Examination:	**50%**

WILDLIFE CONSERVATION SOCIETY'S
MARINE TRAINING COURSE

Motupore Research Station February 2006

Seagrass

Wednesday 8th February 2006	
Afternoon	Field exercise: Seagrass Identification (MM)
	Lecture 1: Seagrass Biology and Identification (LM)
	Laboratory exercise: Seagrass Identification (LM)
Evening	TBA

Thursday 9th February 2006	
Morning	Lecture 1: Seagrass Ecology & threats (LM)
	Lecture 2: Seagrass Mapping Pt 1 (LM)
	Lecture 3: Global Position Systems (LM)
	Lecture 4: Seagrass Mapping Pt 2 (LM)
Afternoon	Field exercise: Seagrass Mapping (LM)
Evening	Lecture 5: Seagrass Mapping Pt 3 (LM)
	Data Entry and Interpretation (LM)

Friday 10th February 2006	
Morning	Lecture 1: Seagrass Management (LM)
	Lecture 2: Seagrass Monitoring (LM)
Afternoon	Field exercise: Seagrass-Watch Monitoring (LM)
Evening	Data Entry and Interpretation (LM)

Lecture 1 - Seagrass biology & taxonomy

This section will provide you with some background knowledge of

- what are seagrasses
- characteristics to ID seagrass
- How to make a herbarium press specimen

Lecture 2 - Seagrass ecology & threats

This section will provide you with some background knowledge of

- why seagrasses are important
- The variety of seagrass habitats
- Factors important for seagrass growth
- How seagrass can be damaged
- What happens if you damage seagrass

Lecture 3 - Seagrass mapping 1

This section will provide you with some knowledge of how to plan and conduct a seagrass mapping exercise, including

- Pre-mapping considerations
- Issues of Scale & Accuracy
- Choosing a Survey/Mapping strategy
- General field procedure

Lecture 4 - GPS training

This section will provide you with some knowledge of the simple theories of GPS

- You will be shown how to operate a handheld GPS receiver

Lecture 5 - Seagrass mapping 2

This section will provide you with some knowledge of the types of information collected at a field survey mapping point

Lecture 6 - Seagrass mapping 3

This section will provide you with some background knowledge of

- How to download GPS data
- Using MapSource download software
- Types of maps
- Geographic Information Systems
- Drawing maps
- Use of seagrass maps

Lecture 7 - Seagrass management

This section will provide you with some knowledge of the issues and approaches to managing seagrass habitats, using the example from Queensland Coastal Waters

Lecture 8 - Seagrass monitoring

This section will provide you with some knowledge of

- What is monitoring ?
- Designing monitoring programs
- Common drivers for monitoring
- Why monitor ?
- Who uses monitoring information ?
- Monitoring protocols

Lecture 9 - Seagrass-Watch

This section will provide you with some background knowledge of

- What is Seagrass-Watch?
- Who participates & where?
- Sampling protocols & how they were developed
- What parameters we measure & why?
- What are some of results?
- Who uses the information?
- What is the information used for?

Lecture 10 - Seagrass-Watch data entry & analysis

This section will provide you with some background knowledge of

- How to enter Seagrass-Watch data
- Preliminary analysis of data for trends

CHAPTER 5. SEAGRASSES

Len McKenzie

5.1. Background

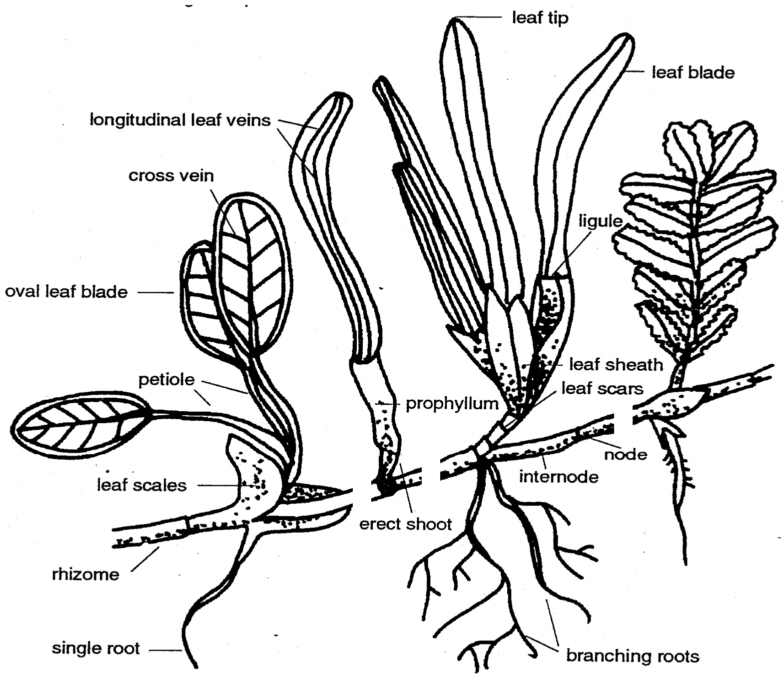
Seagrasses are specialized marine flowering plants that have adapted to the nearshore environment of most of the world's continents. Seagrasses form an ecological group and not a taxonomical group. Most are entirely marine although some species cannot reproduce unless emergent at low tide. Some seagrasses can survive in a range of conditions encompassing fresh water, estuarine, marine, or hypersaline. There are relatively few species globally (about 60) and these are grouped into just 13 Genera and 5 Families.

The families in which the seagrasses are incorporated belong to the Division Magnoliophyta (Angiosperms), Class Liliopsida (Monocotyledons), but have been arranged within this class in various ways. The Hydrocharitaceae have always been recognized as a distinct family. However, the taxonomy at a subfamily level has not yet been resolved (see Kuo & den Hartog 2001).

Early taxonomic studies on seagrasses were carried out in Europe by botanists who were interested in aquatic plants as a whole, the Helobiae, or by phycologists who were primarily interested in the algal epiphytes on seagrasses. Linnaeus (1753) was the first to designate a scientific name for the most well-known seagrass species, *Zostera marina*. He was followed by other scientists who provided new genus names and described new species of seagrasses. Ascherson, however, was the first to produce a monographic compilation of all that was known about seagrass classification and distribution. He updated his work continually, and in 1906 published a modern review on the taxonomy and geographical distribution of seagrasses in the form of a monograph, in which he recognized 32 species in 8 genera worldwide (Ascherson 1906).

The monograph entitled 'The Sea-Grasses of the World' by den Hartog (1970) is by far the most complete taxonomic work on seagrasses with species descriptions, notes on ecology and distribution of each species and genus as well as keys for identification including drawings and distribution maps. den Hartog (1970) recognized 47 species (with 4 subspecies) in 12 genera, arranged within 2 families (Potamogetonaceae and Hydrocharitaceae). Since then, a few taxonomic works have been carried out on certain groups of seagrasses including descriptions of new species. Based on den Hartog's monograph (1970) and more recent taxonomic works, currently 60 species of seagrass in 12 genera are recognized. It is anticipated that the number of species will change in the near future, as new highly advanced techniques for taxonomic research have become available, such as the molecular approach. Further, new diving techniques may lead to the discovery of new species in deep-water habitats, and finally there are still many stretches of coast that are still unexplored.

Traditionally, the characters used in classifying flowering plants are the reproductive structures, e.g., petals, sepals, stamens, fruits and seeds. However, flowers and fruits of most seagrasses are not often collected and therefore identification of seagrass species and genera is more or less dependent on vegetative characteristics, such as blade width, blade tips, vein numbers, fibre distributions, epidermal cells, characteristics of the roots and rhizomes, etc. Some of these vegetative characters may show considerable variation, e.g., the leaf tips. Nevertheless, if used in conjunction with other features, this character can be valuable taxonomically.



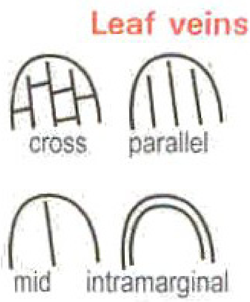
Composite illustration demonstrating morphological features used to distinguish main seagrass taxonomic groups.
from Lanyon (1986)

Leaf:

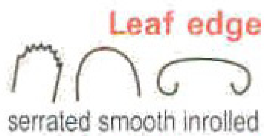
Tip — Can be rounded or pointed. Tips are easily damaged, so young leaves are best to observe.

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



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



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.

Attachment — The leaf can attach directly to the rhizome, where the base of the leaf attachment clasps the rhizome, from a vertical stem or from a 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. The remnants of leaf attachment are seen as scars.

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.

The following key is designed and arranged to identify all known seagrass species in the western Pacific. Seagrasses can be identified by using vegetative (rarely reproductive) morphological characters, usually two or three.

Seagrasses of western Pacific

Adapted from *Waycott, M, McMahon, K, Mellors, J., Calladine, A., and Kleine, D (2004) A guide to tropical seagrasses in the Indo-West Pacific. (James Cook University Townsville) 72pp.*

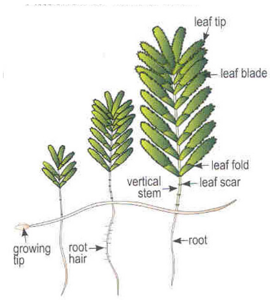
Leaves cylindrical

Syringodium isoetifolium

- Leaf tip pointed
- Leaves contain air cavities
- Inflorescence a "cyme"

Leaves oval to oblong

obvious vertical stem with more than 2 leaves



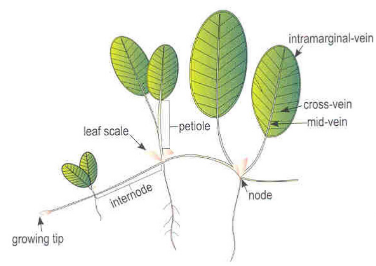
Halophila spinulosa

- leaves arranged opposite in pairs
- leaf margin serrated

Halophila tricostata

- leaves arranged in clusters of 3, at a node on vertical stem
- leaf margin serrated
- leaf clusters do not lie flat

leaves with petioles, in pairs



Halophila ovalis

- cross veins more than 10 pairs
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Halophila decipiens

- leaf margins serrated
- fine hairs on both sides of leaf blade
- male & female flowers on same plant

Halophila minor

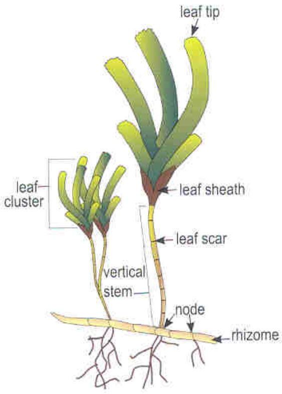
- Leaf less than 5mm wide
- cross veins up to 10 pairs
- leaf margins smooth
- no leaf hairs
- separate male & female plants

Halophila capricorni

- leaf margins serrated
- fine hairs on one side of leaf blade
- separate male & female plants

Leaves strap-like

Leaves can arise from vertical stem



Thalassia hemprichii

- Leaf with obvious red flecks, 1-2mm long
- Leaf tip rounded may be slightly serrated
- Leaf often distinctly curved
- Distant scars on rhizome

Cymodocea serrulata

- Leaf tip rounded with serrated edge
- Leaf sheath broadly flat and triangular, not fibrous
- Leaf sheath scars not continuous around upright stem

Cymodocea rotundata

- Leaf tip rounded with smooth edge
- Leaf sheath not obviously flattened
- Leaf sheath scars continuous around upright stem

Halodule uninervis

- Leaf tip tri-dentate or pointed, not rounded
- Leaf with 3 distinct parallel- veins, sheaths fibrous
- Rhizome usually white with small black fibres at the nodes

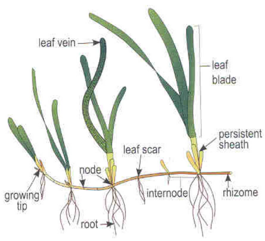
Halodule pinifolia

- Leaf tip rounded
- Leaf with 3 distinct parallel- veins, sheaths fibrous
- Rhizome usually white with small black fibres at the nodes

Thalassodendron ciliatum

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

Leaves always arise directly from rhizome



Enhalus acoroides

- large plant, leaves >30 cm long, >1 cm wide
- inrolled edges of leaves
- long, black bristles protruding from thick rhizome

Zostera capricorni

- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- rhizome usually brown or yellow in younger parts

5.2. Seagrass of Papua New Guinea

Seagrass meadows are an important marine habitat of Papua New Guinea coastlines. Seagrasses are a functional grouping referring to vascular flowering plants which grow fully submerged and rooted in soft bottom estuarine and marine environments.

In the last few decades, seagrass meadows have received greater attention with the recognition of their importance in stabilising coastal sediments, providing food and shelter for diverse organisms, as a nursery ground for fish and invertebrates of commercial and artisanal fisheries importance, as carbon dioxide sinks and oxygen producers, and for nutrient trapping and recycling. Seagrass are rated the 3rd most valuable ecosystem globally (on a per hectare basis) and the average global value for their nutrient cycling services and the raw product they provide has been estimated at 1994US$19,004 ha^{-1} yr^{-1} (Costanza *et al.* 1997). This value would be significantly greater if the habitat/refugia and food production services of seagrasses were included.

Seagrasses are also food for the endangered green sea turtle (*Chelonia mydas*) and dugong (*Dugong dugon*) (Lanyon *et al.* 1989), which are found throughout the PNG region, and used by traditional PNG communities for food and ceremonial use. Tropical seagrasses are also 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 slow water movement, causing suspended sediment to fall out, and thereby benefiting corals by reducing sediment loads in the water.

Nutrient availability is one of the major factors determining seagrass presence across PNG. Seagrasses frequently grow on intertidal reef platforms and mud flats influenced by pulses of sediment laden, nutrient rich freshwater, resulting from high volume seasonal summer rainfall (Carruthers *et al.* 2002). Cyclones and severe storms or wind waves also influence seagrass distribution to varying degrees. On reef platforms and in lagoons the presence of water pooling at low tide prevents drying out and enables seagrass to survive tropical summer temperatures. Often, the sediments are unstable and their depth on the reef platforms can be very shallow, restricting growth and distribution. Most PNG species are found in water less than 10m deep and meadows may be monospecific or consist of multispecies communities, with up to 10 species present at a single location.

The earliest records of seagrasses in the PNG region come from Salamaua in the Huon Gulf in 1890 (den Hartog 1970). However apart from these early collections, the majority of study on seagrasses in PNG did not occur until after the mid 1970's. It is generally agreed that there are 13 seagrass species present in PNG (Short *et al.* 2001). Seagrass species diversity is highest in the southern part of the country (adjacent to Torres Strait) and declines towards the east. The highest number of species reported is 13 from Daru (Johnstone 1979), followed by Motupore Island (Bootless Inlet) and the Fly Islands each with 10 species (Brouns & Heijs 1985; Johnstone 1978a 1978b). No species are considered endemic to PNG and none are listed as threatened or endangered.

Seagrass communities in PNG grow on fringing reefs, in protected bays and on the protected side of barrier reefs and islands. Major seagrass meadows occur around Manus Island, in the coastal bays surrounding Wewack and Port Moresby, on the island reef complexes of Milne Bay province and on the reef platforms surrounding the Tigak Islands and Kavieng. Seagrass meadows are also a significant feature at several other localities (eg. Rabaul, Kimbe) and scattered areas of seagrasses line much of the coastline of NG mainland (eg. Madang, Morobe and Western provinces) and the offshore islands (including Lihir and Mussau). Areas of the coast were seagrasses do not exist are either steep slopes exposed to oceanic swells or along the 500km of gulf coast east of Daru, a possible consequence of high silt loads and large volumes of fresh water in the run off from the Fly and Purari Rivers (Johnstone 1979).

Seagrass zonation appears fairly similar across PNG (Johnstone 1982) and seems to be determined by comparable biotic and abiotic parameters. From intertidal to subtidal, the zonation pattern of seagrasses generally begin with a zone of 1 or 2 species (mostly *Halodule uninervis, H. pinifolia* or *Halophila minor*[1]). Subsequently, in the lower eulittoral zone, other seagrass species join in a mixed seagrass meadow generally dominated by *Cymodocea rotundata, Halodule uninervis* and *Thalassia hemprichii*, with isolated patches of *Halophila ovalis.* In the upper sublittoral zone, the mixed seagrass meadow is dominated by *T. hemprichii* and *Enhalus acoroides*, with isolated patches of *Syringodium isoetifolium, C. serrulata* and *H. uninervis*. This zone is generally the most abundant and usually constitutes the bulk of the meadows throughout PNG. The lower edge of the meadow consists of a combination or 2-4 species when a reef plateau is present or monospecific *H. decipiens* or *H. spinulosa* at the deepest depths on the sublittoral sandy slopes. The remaining species are less common and not widely distributed. Monospecific patches of *Thalassodendron ciliatum* have been reported to occur on coral rubble banks in 6-8m depth on the deeper edges of the reef slopes on Manus, Kavieng and the Fly Islands. *Zostera capricorni* has only been reported from Daru (Johnstone 1982) and is one of the most northern locations for the species in the western Pacific.

Local conditions may often determine which seagrass species are present. Extensive mixed seagrass meadows are the dominant community type in the bays, harbours and sheltered capes along the coasts of the NG mainland and the islands of New Britian and New Ireland (Den Hartog 1970, Brouns & Heijs 1985, Heijs & Brouns 1986, Johnstone 1982). These extensive seagrass meadows are dominated by *T. hemprichii* and/or *E. acoroides*, with up to another 10 species present to varying degrees. *H. decipiens* meadows sometimes occur in the deeper areas and meadows of *E. acoroides* border the gentle sloping mangrove fringes in the more protected bays and the shallow lagoons surrounding Kavieng.

Throughout the rest of the PNG archipelago, most seagrass occurs in shallow lagoons adjacent to large islands, or on the reef platforms and leeward shores of small vegetated cays/islands of the Solomon and Bismarck Seas. A survey in 2001 of seagrasses in the Milne Bay province found that seagrass mainly occurred on the tops of the reefs and shoals with reef flats, and cover was generally low in regions without large islands (eg. Louisiade and Bwanabwana regions). Some of the most abundant seagrass meadows in the Bismarck Sea occur on the reef plateaus on the eastern and northern coastlines of Seeadler Harbour (Manus Island) (Heijs & Brouns 1986). These communities are dominated by colonizing and intermediate species, such as *T. hemprichii C. rotundata* and *H. uninervis* which can survive a moderate level of disturbance. *E. acoroides* occurs in protected small bays or behind the reef crest on the sublittoral reef flat, as it has low resistance to perturbation (Walker *et al.* 1999).

Smaller islands are generally characterised by relatively small fringing reef platforms, such as Niolam Island (Lihir group) where the mean extent of inter-tidal habitat is approximately 81m from shore to reef crest (D Dennis CSIRO pers comm). Seagrass communities in these cases, are restricted to locations with shallow fringing reef-flat with lagoons (0-2 m depth). Most inter-tidal seagrass communities are dominated by *C. rotundata* and *T. hemprichii*; with small quantities of

[1] *Halophila minor* was originally reported as *H. ovata*, however taxonomists now regard *H ovata* in the Indo-western Pacific as only present in the South China Sea and Micronesia (Kuo 2000).

H. ovalis (D Dennis CSIRO pers comm). *E. acoroides* dominates the intertidal reef flats on the protected sides of islands (eg. Duke of York, Nanuk and Talele Islands) and in the bays and harbours protected from oceanic swells (eg. Luise Harbour, Malie Harbour, Lakakot Bay, Londolovit Bay) (D Dennis CSIRO pers comm, S Foale ANU pers comm).

The total area of seagrasses world-wide is estimate to be at least 177,000 sq km (Spalding *et al.* 2003). The total area of seagrass meadows in PNG however is unknown, as no broad scale mapping exercise has been conducted (Coles *et al.* 2003). This is because mapping in tropical systems is generally from field observations as remotely sensed data (satellite and aerial imagery) is generally ineffective for detecting tropical seagrasses of low biomass and/or in turbid water (McKenzie *et al.* 2001b). Some estimation could be possible using a simple modelling approach, based on the high likelihood that between 4-5% of almost all shallow water areas of reef and continental slope within the depth range of most seagrasses (less than 10 metres below MSL) would have at least a sparse seagrass cover. This however, has not been attempted. The closest attempt so far is a new dataset prepared by the United Nations Environment Programme World Conservation Monitoring Centre (http://stort.unep-wcmc.org/maps). These maps however should be interpreted with caution as they have been migrated to GIS based on literature review and outreach to expert knowledge. Much of the information is from only a few localities and is generally historic (eg. Wewak, Manus, Kavieng, Rabaul, Port Moresby).

There are also many anecdotal reports of extensive un-mapped seagrass meadows covering the reef flats and shallow lagoons around the Fullerborne region, Cape Gloucester, Stettin Bay (Kimbe Bay), Mussau Island, Heina - Ninigo Islands, and along the perimeter of the sea corridor between Buka and Bougainville. Recent mapping initiatives in Milne Bay province (T Skewes CSIRO pers comm) and the Lihir group (D Dennis CSIRO pers comm) are a major step forward. In 2001, a survey by CSIRO and CI estimated 11,717 ha of seagrass in the Milne Bay area (J Kinch CI pers comm). Such efforts will serve as important baselines against which future changes can be assessed.

Tropical seagrass meadows are known to fluctuate seasonally and between years (Mellors *et al.* 1993, McKenzie 1994, McKenzie *et al.* 1996), however losses have been reported from most parts of the world, sometimes from natural causes such as cyclones and floods (Poiner *et al.* 1989, Preen *et al.* 1995, Campbell & McKenzie 2004). More commonly, loss has resulted from human activities such as dredging, land reclamation, industrial runoff, oil spills or changes in land use and agricultural runoff (Short and Wyllie-Echeverria 1996).

The major changes in PNG seagrass meadows would have occurred post World War Two and are related to coastal development, agricultural land use, or population growth. In general though there is insufficient information and no long-term studies from which to draw direct conclusions on historic trends. Munro (1999) does report that 2000 year old mollusc shell middens in PNG have basically the same composition as present day harvests suggesting indirectly that the habitats including seagrass habits and their faunal communities are stable and any changes occurring are either short term or the result of localised impacts.

These localised impacts are likely to be from soil erosion related to coastal agriculture (palm oil plantations), land clearing (logging and mining), bush fires and from the discharge of mine tailings. For example, there are unconfirmed reports of losses due to mining operations in Luise Harbour (Lihir) where the seagrass has declined significantly compared to before the mine (M. Macintyre ANU pers comm). Other effects include sewage discharge, industrial pollution and overfishing. Most of these impacts can be managed with appropriate environmental guidelines, however climate change and associated increase in storm activity, water temperature and/or sea level rise has the potential to damage seagrasses in the region or to influence their distribution. Sea level rise and increased storm activity could lead to large seagrasses losses.

To provide an early warning of change, scientific and community-based (Seagrass-Watch) long-term monitoring sites have been established as part of the Global Seagrass Monitoring Network (www.SeagrassNet.org, www.seagrasswatch.org Short *et al.* 2002, McKenzie *et al.* 2001a). Sites are monitored quarterly in Kavieng, Tigak Islands and Madang, and the program hopes to expand to include other regions of PNG. By working with both scientists and local communities, it is hoped that many anthropogenic impacts on seagrass meadows which are continuing to destroy or degrade these coastal ecosystems and decrease their yield of natural resources can be avoided.

5.3. Monitoring a seagrass meadow

Environment monitoring programs provide coastal managers with information and assist them to make decisions with greater confidence. 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. 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 effect 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.

A simple method for monitoring seagrass resources is used in the Seagrass-Watch program. This method uses 50m by 50m sites established within representative intertidal meadows to monitor seagrass condition. The number and position of sites can be used to investigate natural and anthropogenic impacts.

Seagrass-Watch is the largest community-based seagrass monitoring program in the world. The Seagrass-Watch monitoring program was established in 1998 as an initiative of the Queensland Department of Primary Industries and Fisheries (QDPI&F). Seagrass-Watch has expanded to the Indo and western Pacific, with volunteers in Micronesia, Palau, Japan, Philippines, Malaysia, Indonesia, Papua New Guinea, Solomon Islands and Fiji. Monitoring is now occurring at approximately 150 sites.

This program monitors the seasonal dynamics of seagrass meadows, the relationships between seagrass condition and climate change and the loss and recovery of seagrass meadows and provides an early warning of change. It involves local community groups assisting in mapping and monitoring seagrass habitats vital for fisheries, turtles and dugongs. Local community volunteers are trained by QDPI&F in the application of methods for scientifically rigorous assessment of seagrass resources. The sampling design and the parameters were developed in collaboration with the community and research scientists.

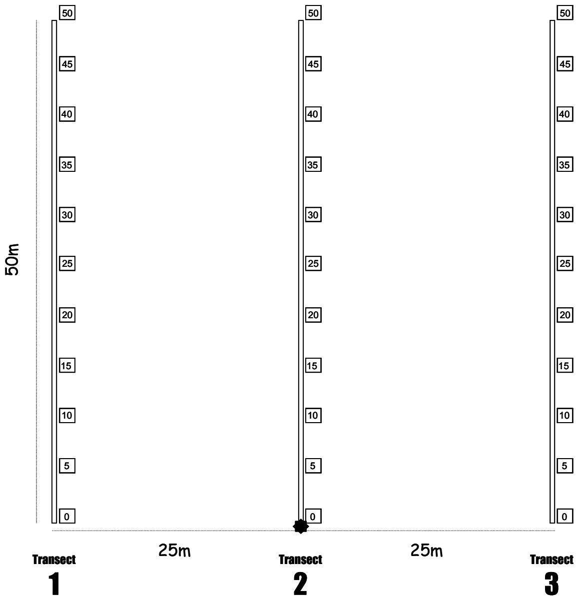
Monitoring sites are selected in consultation with community volunteers, management agencies, local government, and seagrass researchers. Seagrass-Watch monitoring is coupled where possible with existing environmental monitoring programs (e.g. seagrass depth range, water quality and beach profile) to increase the ability to identify causes for change. The monitoring is conducted using a nested design at three scales: transect (metres), sites (kilometres) and locations (10s kilometres). Monitoring sites are established in areas of a.) relatively high usage, b). where usage may be high in the near future and c.) in comparable 'control' sites where current and predicted usage is low and likely to remain low. Generally, three sites are established at each location. At each site, three parallel 50 m transects (each 25 m apart) are established, the middle transect is permanently marked. The seagrass habitats along each transect are assessed by visual observation. At each transect, eleven quadrats are sampled (1 quadrat every 5 m) for seagrass cover and species composition, every three or six months, depending on site access and availability of volunteers. Quadrats are photographed to ensure standardisation/calibration of observers and to provide a permanent record.

To learn more about the program, visit www.seagrasswatch.org .

Seagrass-Watch Monitoring Summary

Source: McKenzie, L.J., Campbell, S.J. & Roder, C.A. (2001) Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers. (QFS, NFC, Cairns) 100pp

Site layout



Quadrat code = site + transect+quadrat
e.g., PN1225 = Poona site 1, transect 2, 25m quadrat

Pre-monitoring preparation

Make a Timetable

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

Have a Contact Person

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

Safety

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

Necessary equipment and materials

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

Quarterly sampling

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

Step 1. Take a Photograph of the quadrat

- Photographs are taken at the 5m, 25m and 45m quadrats along each transect, or at quadrats of interest. First place the photo quadrat labeller beside the quadrat with the correct code on it.
- Take the photograph from as vertical as possible, to include the entire quadrat frame, quadrat label and tape measure. Try to avoid any shadows or patches of reflection off any water in the field of view. Check the photo taken box on the datasheet for that quadrat.

Step 2. Describe sediment composition

- Dig your fingers into the top centimetre of the substrate and feel the texture. Describe the sediment, by noting the grain size in order of dominance (e.g., Sand, Fine sand, Fine sand/Mud).

Step 3. Estimate seagrass percent cover

- Estimate the total % cover of seagrass within the quadrat – use the percent cover photo standards as a guide.

Step 4. Estimate seagrass species composition

- Identify the species of seagrass within the quadrat and determine the percent contribution of each species to the cover (must total 100%). Use seagrass species identification keys provided.

Step 5. Measure canopy height

- Measure canopy height of the seagrass ignoring the tallest 20% of leaves. Measure from the sediment to the leaf tip of at least 5 shoots.

Step 7. Estimate algae percent cover

- Estimate % cover of algae in the quadrat. Algae are seaweeds that may cover or overlie the seagrass blades. Use "Algal percentage cover photo guide".

Step 8. Estimate epiphyte percent cover

- Epiphytes are algae attached to seagrass blades and often give the blade a furry appearance. First estimate how much of the blade surface is covered, and then how many of the blades in the quadat are covered (e.g., if 20% of the blades are each 50% covered by epiphytes, then quadrat epiphyte cover is 10%).

Step 9. Describe other features and ID/count of macrofauna

- Note and count any other features which may be of interest (eg. number of shellfish, sea cucumbers, sea urchins, evidence of turtle feeding).

Step 10. Take a voucher seagrass specimen if required

- Seagrass samples should be placed inside a labelled plastic bag with seawater and a waterproof label. Select a representative specimen of the species and ensure that you have all the plant part including the rhizomes and roots. Collect plants with fruits and flowers structures if possible.

At completion of monitoring

Step 1. Check data sheets are filled in fully.

- Ensure that your name, the date and site/quadrat details are clearly recorded on the datasheet. Also record the number of other observers assisting.

Step 2. Remove equipment from site

- Remove all tent pegs and roll up the tape measures. If the tape measures are covered in sand or mud, roll them back up in water.

Step 3. Wash & pack gear

- Rinse all tapes, pegs and quadrats with freshwater and let them dry.
- Review supplies for next quarterly sampling and request new materials
- Store gear for next quarterly sampling

Step 4. Press any voucher seagrass specimens if collected

- The voucher specimen should be pressed as soon as possible after collection. Do not refrigerate longer than 2 days, press the sample as soon as possible.
- Allow to dry in a dry/warm/dark place for a minimum of two weeks. For best results, replace the newspaper after 2-3 days.

Step 5. Submit all data

- Data can be entered from a downloadable spreadsheet (www.seagrasswatch.org) and emailed
- Mail original datasheets, photos and herbarium sheets

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5.4. Managing seagrass resources

5.4.1. 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 reclamation and changes in land use. Increases in dredge and fill, construction on the shoreline, damage associated with commercial overexploitation of coastal resources, and recreational boating activities along with anthropogenic nutrient and sediment loading have dramatically reduced seagrass distribution in some part of the world Anthropogenic impacts on seagrass meadows continue to destroy or degrade coastal ecosystems and decrease seagrass functions and values, 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.

5.4.2. 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*) are listed as threatened or vulnerable to extinction in the IUCN Red List (IUCN 2000). 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.

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. These are sometimes overlaid partially by arrangements put in place by colonising powers during and after World War II, leaving the nature and strength of protective arrangements open for debate.

Both Australia and the United States have developed historically as Federations of States with the result that coastal issues can fall under State or Federal legislation depending on the issue or its extent. In contrast, in Europe and much of South East Asia, central Governments are more involved. Intercountry agreements in these areas such as the UNEP Strategic Action Plan for the South China Sea and the Mediterranean Countries Barcelona Convention (http://www.unep.org/) are required to manage marine issues that encompass more than one country.

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.

Six precursors to successful management of coastal seagrasses are:

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.

5.5. Mapping seagrass distribution

Information on seagrass distribution is a necessary prerequisite to managing seagrass resources. The first step is to provide baseline maps that document the current extent, diversity and condition of the seagrasses. The next step is to establish monitoring programs designed to detect disturbance at an early stage, and to distinguish such disturbance from natural variation in the meadows.

To make informed management decisions, coastal managers need maps containing information on the characteristics of seagrass resources such as where species of seagrasses occur and in what proportions and quantities, how seagrasses respond to human induced changes, and whether damaged meadows can be repaired or rehabilitated. Knowledge of the extent of natural changes in seagrass meadows is also important so that human impacts can be separated from normal background variation (Lee Long *et al.* 1996b). Changes can occur in the location, areal extent, shape or depth of a meadow, but changes in biomass, species composition, growth and productivity, flora and fauna associated with the meadow, may also occur with, or without a distributional change (Lee Long *et al.* 1996b). Seagrass resources can be mapped using a range of approaches from *in situ* observation to remote sensing. The choice of technique is scale and site dependent, and may include a range of approaches.

McKenzie et al (2001b) provided a decision tree to facilitate the formulation of a survey/mapping strategy.

Table 1. *A decision tree. The data capture methods used to map the distribution of seagrass meadows vary according to the information required and the spatial extent.*

What is the size of the region or locality to be mapped?

Less than 1 hectare	**1**
1 hectare to 1 km^2	**2**
1km^2 to 100 km^2	**3**
greater than 100 km^2	**4**

1. Fine/Micro-scale (Scale 1:100 1cm = 1m)

Intertidal	aerial photos, *in situ* observer
Shallow subtidal (<10m)	*in situ* diver, benthic grab
Deepwater (>10m)	SCUBA, real time towed video camera

2. Meso-scale (Scale 1:10,000 1cm = 100m)

Intertidal	aerial photos, *in situ* observer, digital multispectral video
Shallow subtidal (<10m)	*in situ* diver, benthic grab
Deepwater (>10m)	SCUBA, real time towed video camera

3. Macro-scale (Scale 1:250,000 1cm = 250 m)

Intertidal	aerial photos, satellite
Shallow subtidal (<10m)	satellite & real time towed video camera
Deepwater (>10m)	real time towed video camera

4. Broad-scale (Scale 1:1,000,000 1cm = 10 km)

Intertidal	satellite, aerial photography
Shallow subtidal (<10m)	satellite, aerial photography & real time towed video camera
Deepwater (>10m)	real time towed video camera

Generally, an area can be mapped from a field survey using a grid pattern or a combination of transects and spots. When mapping a region of relatively homogenous coastline between 10 and 100 km long, it is recommended that transects should be no further than 500-1000 m apart. For regions between 1 and 10 km, it is recommended to use transects 100-500 m apart and for localities less than 1 km, 50-100 m apart is recommended. This however may change depending on the complexity of the regional coastline, i.e., more complex, then more transects required.

When mapping, ground truthing observations need to be taken at regular intervals (usually 50 to 100m apart). The location of each observation is referred to a point, and the intervals they are taken at may vary depending on the topography. When ground truthing a point, there are a variety of techniques that can be used depending on resources available and water depth (free dives, grabs, remote video, *etc*). A point can vary in size depending on the extent of the region being mapped. In most cases a point can be defined as an area encompassing a 5m radius. Observations recorded at a point should ideally include some measure of abundance and species composition.

5.5.1. Intertidal field survey

The objective of the field survey is to determine the edges/boundaries of any seagrass meadow and record information on species present, % cover, sediment type, and depth (if subtidal). Field surveys are also essential if using remote methods like aerial photographs to evaluate image signatures observed, or examine areas where the imagery does not provide information (e.g., such as in areas of heavy turbidity), and produce reference information for later accuracy assessment.

General field procedure

You will need:

- ❑ *Hand held compass or portable Geographic Positioning System (GPS) unit*
- ❑ *Standard 50 centimetre x 50 centimetre quadrat.*
- ❑ *Seagrass identification and percent cover sheets (see Appendix)*
- ❑ *Clipboard with pre-printed data sheets (see Appendix) and pencils.*
- ❑ *Suitable field clothing & footware (e.g., hat, dive booties, etc)*
- ❑ *Aerial photographs or marine charts (if available) of the locality*
- ❑ *Plastic bags - for seagrass samples with waterproof labels*
- ❑ *Weatherproof camera (optional)*

First, define the extent of the study area. Check the tides to help you plan when is the easiest time to do the mapping, e.g., spring low is best for intertidal meadows. If mapping can be conducted at low tide when the seagrass meadow is exposed, the boundaries of meadows can be mapped by walking around the perimeter of each meadow with single position fixes recorded every 10-20metres depending on size of the area and time available. An important element of the mapping process is to find the inner (near to the beach) and outer (towards the open sea) edges of the seagrass meadow. To survey an area quickly, it is possible to work from a hovercraft or helicopter.

Alternatively, an area can be mapped using a grid pattern or a combination of transects and points. Estimate distances along transects and between points, rather than using a tape measure. The number of mapping points you survey will be entirely up to you. If you need to accurately map an area, then intensive surveying (sample lots of mapping points) is recommend. It is also beneficial to try to get a good spread of mapping points over the area, as some of the changes in the seagrass meadow will not necessarily be obvious.

Field survey point measures

Step 1. Use a GPS to record the geographic position of the point

Step 2. Record general information such as: observer, location (e.g., name of bay), date, time and water depth if not exposed

Step 3. Describe sediment composition by noting the grain size in order of dominance (e.g., Sand, Fine sand, Fine sand/Mud)

Step 4. Record % seagrass cover/abundance and composition from within 3 haphazardly tossed 50cm x 50cm quadrat (use the percent cover photo standards as a guide (Appendix II)

Step 5. Estimate algae percent cover

Step 6. Describe other features and ID/count of macrofauna

Step 7. Take a photograph from every 10th mapping point (not essential)

Step 8. Collect a voucher specimen of each new seagrass species encouncoutered

5.5.2. Creating the map

The simplest way to map a seagrass meadow is to draw the boundaries on a paper marine chart from the GPS positions of the ground truth points. The problem with this type of mapping however is that the final map is in a format that does not allow manipulation and transformation. A paper map is permanent, which makes it difficult for future seagrass mapping studies to be compared, queried and analysed. If resources are available, it is recommend that the data be transferred to a digital format and a Geographic Information System (GIS) be used.

GIS are software systems of highly accurate digital maps that can be overlaid to reveal relationships that might not otherwise be detected on traditional paper maps. Digitally-stored cartographic databases can be altered much quicker than hard copies and shared data can be standardised. The key element of a GIS is the separation of differing data sets into thematic layers. GIS software provides the functions and tools needed to store, analyse, and display geographic information. Two of the most common GIS packages are ArcGIS® and MapInfo®. Mapping seagrass meadows with a GIS can help to identify emergent patterns or relationships in geographically referenced data. For further reading on the application of GIS to aquatic botany, see Lehmann and Lachavanne (1997).

Boundaries of meadows can be determined based on the positions of survey points and the presence of seagrass, coupled with depth contours and other information from aerial photograph interpretation. Errors that to be considered when interpreting GIS maps include those associated with digitising and rectifying the aerial photograph onto the basemap and those associated with GPS fixes for survey points.

In certain cases seagrass meadows form very distinct edges that remain consistent over many growing seasons. However, in other cases the seagrass tends to grade from dense continuous cover to zero cover over a continuum that includes small patches and shoots of decreasing density. Boundary edges in patchy beds derived from aerial imagery or direct observation are vulnerable to interpreter variation. Given the uncertainty surrounding the determination of meadow edges it is suggested that each mapping effort include its own determination as to what it considers seagrass habitat based on the purpose of the mapping (Lee Long *et al.* 1996a, McKenzie *et al.* 1996, 1998, 2001b).

The final map can be presented on screen and in hard copy. The final maps need a clear legend describing the features highlighted, a scale, and a source. The maps are best accompanied by metadata. Metadata is information about the data and not to be confused with a summary of the data. Metadata describes data source, data reliability, conditions of use, limits on interpretation and use-by date, and usually includes the correct form of citation to be used for acknowledging the data source. It holds information about the quality of the data. The project metadata for all spatial data should have some statement about the accuracy of a map product. The Australian New Zealand Land Information Council has a very useful guide for metadata (http://www.anzlic.org.au/).

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Exam questions

1. Seagrass communities are generally susceptible to changes in water quality and environmental quality that make them a useful indicator of environmental health. When reporting on the health of seagrasses it is important to consider the type of factors that can effect growth and survival. Name at least 4 factors and briefly describe how they effect seagrasses.
    - 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.

2. Briefly explain why seagrasses are good bio-indicators of environmental health?
    - sessile plants (individuals, populations and communities) which can all be easily measured.
    - often at the downstream end of catchments (receiving runoff from a range of agricultural, urban and industrial land-uses)
    - plants which generally remain in place so that the prevailing anthropogenic impacts can be monitored
    - plants which show measurable and timely responses to environmental impacts.

3. Briefly describe the Seagrass-Watch monitoring protocol.
    - 50m by 50m sites established within representative intertidal meadows. The number and position of sites can be used to investigate natural and anthropogenic impacts.
    - Each site has 3 transects which run perpendicular to shore. Transects are 25m apart and parallel.
    - Quadrats are placed every 5m along transect and information collected from each quadrat includes

        Description of sediment composition
        Description of other features and ID/count of macrofauna
        Estimate of seagrass percent cover
        Estimate of seagrass species composition
        Measure canopy height
        Estimate of algae percent cover
        A photograph of quadrat at 5, 25 and 45m
        A voucher seagrass specimen if required

4. If you were to map a region of coastline which encompassed a size of 1 hectare to 1 km2, what types of data capture (sampling) methods would you use and briefly describe the field procedure.

Data capture (sampling) methods for meso-scale (Scale 1:10,000 1cm = 100m) include

Intertidal	aerial photos, *in situ* observer, video
Shallow subtidal (<10m)	*in situ* diver, benthic grab
Deepwater (>10m)	SCUBA, real time towed video camera

General field procedure

- Define the extent of the study area
- Check the tides
- Conduct a reconnaissance survey if possible
- Choose the most appropriate technique depending on time, funding and logistical constraints.
- Use grid pattern or a combination of transects and spots
- Important to find the inner (near to the beach) and outer (towards the open sea) edges of the seagrass meadow (eg travel around the perimeter - single position fixes every 10-20 metres)
- Determining geographic position using a GPS
- Observations taken at regular points/intervals (usually 50 to 100m)
- Point measures to include
    1. General information
    2. Describe sediment composition
    3. Seagrass characteristics
    4. Estimate algae percent cover
    5. Describe other features and ID/count of macrofauna
    6. Take a photograph
    7. Collect a voucher specimen
- Points sampled within each depth category (e.g., 0.5m to 10m intervals depending on topography).