Guidelines for the rapid assessment and mapping of tropical seagrass habitats.
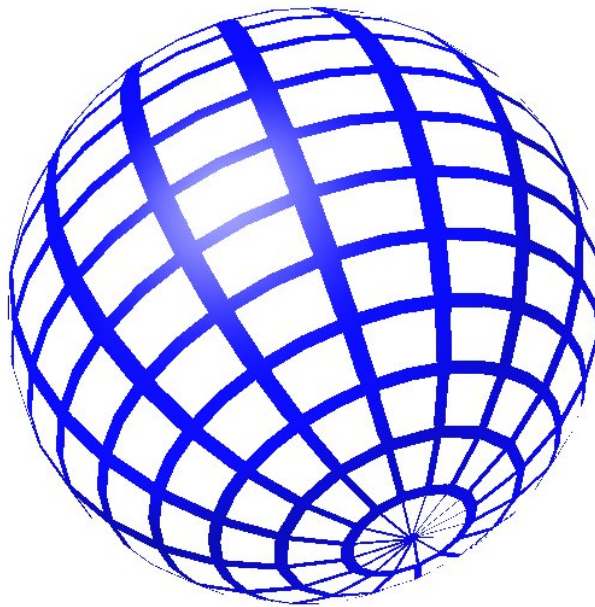
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Chapter 1.

Overview of Seagrass Mapping

Information on seagrass distribution is a necessary prerequisite to managing seagrass resources. 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. Additionally, coastal managers may also need to know where seagrasses might have occurred for the purposes of recovery, restoration and to allow for natural spatial dynamics.

Knowledge of the extent of natural changes in seagrass meadows is also important so that human impacts can be separated from normal background variation (Lee Long *et al.* 1996). 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.* 1996).

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. Earlier standards for seagrass mapping, e.g., Phillips and McRoy (1990) and Walker 1989, are being superseded as improvements in navigation and remote sensing technology and sampling design lead to more efficient and precise methods for mapping. Recent published descriptions of methods for mapping coastal seagrasses include English *et al.* (1994), Coles *et al.* (1995), Dobson *et al.* (1995), Kirkman (1996), Lee Long *et al.* (1996c), Short and Burdick (1996).

The need to map and monitor the meadows of seagrass over a range of spatial and temporal scales, is therefore of prime importance in assessing the status of coastal systems. 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 (Kirkman 1996; Lee Long *et al.* 1996; Kendrick *et al.* 2000).

Chapter 2.

Pre-mapping considerations

The most important information that is required for management of seagrass resources is their *distribution*, i.e. a map. The following section provides a guide of how to plan and then map the seagrass resources in a region or locality.

When planning a mapping task, there are several issues that need to be considered.

2.1. Scale

The selection of an appropriate scale is critical for mapping. Mapping requires different approaches depending on whether survey area is relative to a region (tens of kilometres), locality (tens of metres to kilometres) or to a specific site (metres to tens of metres).

The next consideration is that scale includes aspects both of extent and resolution. In both broad and large scale approaches, the intensity of sampling will be low (low resolution), with a statistical sampling design that allows the results to be extrapolated from a few observations to the extent of the study area. For finer scale examinations of seagrass meadows, the sampling intensity required can be high with greater precision (high resolution).

Scale also influences what is possible with a limited set of financial and human resources. The financial, technical, and human resources available to conduct the study is also a consideration.

2.2. Accuracy

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

2.3. Choosing a Survey/Mapping strategy

The selection of a mapping scale represents a compromise between two components. One is the maximum amount of detail required to capture the necessary information

about a resource. The other is the logistical resource available to capture that level of detail over a given area.

To map the extent of seagrass meadows requires methods that are used on terrestrial vegetation with allowances for the difficulties of working through water. Some of these difficulties are:

- At a depth greater than 2-3 m mainly blue light penetrates.

- All light is attenuated to different degrees through water.

- Light is refracted through water.

- For ground truthing, there are difficulties in working underwater, and

- Sun reflection and angle must be taken into account

The mapping of seagrass areas generally involves at some stage the interpretation of remotely sensed data, whether from an aircraft or satellite, and then interpreting the images onto hardcopy or computer, coupled with field (proximal/*in situ*) assessment to provide "ground truth".

The remote sensing of seagrasses and their related environments is based on the principle that a remote sensor can "see" the substrate and the vegatation growing on or in that substrate. A remote sensing instrument measures light from the sun after it has passed through the atmosphere, interacted with the target, and has been reflected back through the atmosphere to where it is measures by a sensor mounted on an aircraft or a satellite. Whether a benthic feature such as seagrass can actually be discriminated depends on the spectral optical depth of the water column, on the brightness and density of the seagrass and the spectral contrast between it and the substrate, as well as on the spectral, spatial and radiometric sensitivity of the remote sensing instrument. As the remote sensing image usually covers a much larger area than the fieldwork, extrapolation is performed using a variety of either subjective or statistically developed techniques. Unfortunately, there is no guarantee that extrapolations are valid.

The most traditional remote sensing technique is aerial photographs. Visual interpretation of air photographs can be time consuming and require specialist knowledge of the species, their habitat preferences and the area being mapped. Often, aerial photographs are used as only as basemaps onto which seagrass meadows can be mapped to provide a more superior visualisation of the area as apposed to simple line/contour maps.

Assessements from aerial techniques are performed by experienced seagrass experts, where as sophisticated digital multi- or hyperspectral remote sensing requires a combination of mathematical, software, hardware, physics and biogeochemistry skills. Such resources can be beyond the means of most western Pacific agencies.

Mapping seagrass resources using remote techniques however is beyond scope of this guide. If you are interested in remote sensing techniques, for a more thorough

discussion of mapping from satellite and airborne scanners and an explanation of the various uses for mapping at different scales, it is recommended you consult publications by Kirkman (1996) and McKenzie et al (2001)

It is recommend that aerial photos be used as one of a number of tools available to assist the mapping process. Other tools should include proximal/in situ observation (ground truthing, diver/video observations) and GIS to determine the location and extent and coverage pattern of seagrass meadows. McKenzie et al (2001) provided a decision tree to facilitate the formulation of a survey/mapping strategy.

Table 2.1. 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. *From McKenzie et al. 2001.*

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.

To assist with choosing a mapping strategy, it is a good idea to conduct a reconnaissance survey. An initial visual (reconnaissance) survey of the region/area will

give you an idea as to the amount of variation or patchiness there is within the seagrass meadow. This will influence how to space your ground truthing points.

Reconnaissance surveys can be done in the field (using a boat or aircraft) or simply using aerial photographs and marine charts. This pre-mapping activity will help give more accurate information regarding the location and general extent of seagrass meadows to be mapped.

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). First the position of a point must be recorded, preferably using a GPS. 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. Although only one observation (sample) is necessary at a ground truth point, replicate samples spread within the point (possible 3 observations) to ensure the point is well represented is recommended.

Observations recorded at a point should ideally include some measure of abundance and species composition. Also record the depth of each point and other characteristics such as a description of the sediment type, or distance from other habitats (reefs or mangroves).

Chapter 3.

Field survey of seagrass meadows

3.1. Introduction

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.

There are a number of methods for ground truthing, including underwater towing, bounce free-dives, benthic grabs and bathyscopes (Kirkman 1990). The type of method is also dependent on the type of environment.
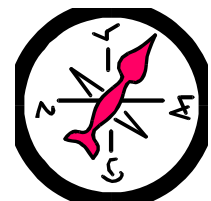
Regardless of method, the first and most important parameter to measure is position. This can be done relatively easily today by using a GPS.
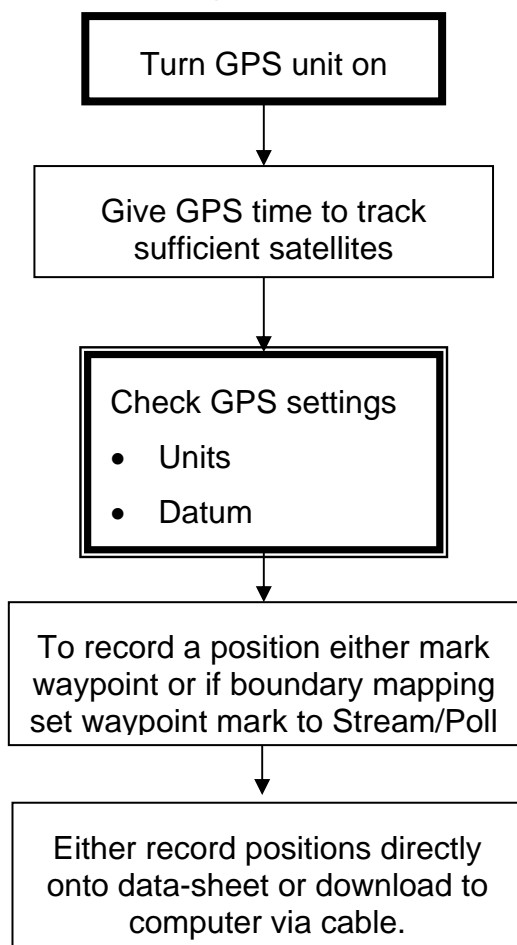
3.2. Determining geographic position

✍ Geographic position is determined usingusing a GPS or compass. If using a hand-held compass to determine the position, use at least 3 permanent landmarks or markers as reference points. Record the compass bearings and mark the reference markers on the map. Roughly mark the point on the chart and assign it a code.

3.2.1. Using a compass

- Hold the compass in front of you at chest height and level to allow the needle to travel freely.

- Turn to the direction for which you want to take a bearing.

- Allow the needle to stabilise.

- Move the bezel (wheel) on the compass until the bezel arrow is over the needle and pointing to zero degrees, indicating north.

- Your bearing is the intersection of the bezel and the red arrow on the base plate.

- Record the bearing on your data sheet, e.g., 80°.

3.2.2. Using a GPS

```
┌─────────────────────────────┐
│    Turn GPS unit on          │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│  Give GPS time to track      │
│  sufficient satellites       │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│  Check GPS settings          │
│  • Units                     │
│  • Datum                     │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│  To record a position either │
│  mark waypoint or if boundary│
│  mapping set waypoint mark to│
│  Stream/Poll                 │
└─────────────────────────────┘
              │
              ▼
┌─────────────────────────────┐
│  Either record positions     │
│  directly onto data-sheet or │
│  download to computer via    │
│  cable.                      │
└─────────────────────────────┘
```

Trouble shooting & hints

- When position fixing it is important to give the GPS antenna a clear signal of the sky. A GPS needs to receive signals from a number of satellites (usually more the 4) to take an accurate fix. Be aware that when using a GPS amongst high terrain, signals from some the satellites may be blocked or unclear.

- It is important to give the GPS sufficient time to position fix. If you are moving when the position is fixed, it may add error. The less movement, the greater the accuracy. Give the GPS at least 5-10 seconds to position fix.

- GPSs that are more accurate when moving, are those which have the ability to "stream" or "poll". These can be useful when boundary mapping. If the GPS does not "stream" then the operator will need to take a waypoint every few metres.

- Ensure the GPS units are known to the user, as it is often common to miss read decimal minutes as minutes and seconds (e.g., 14° 36.44' is not the same as 14° 36' 44").

- When using a GPS for the first time or in a new region (world zone), ensure the almanac is set correctly. Most GPSs today will detect that they are in a new region, and will automatically download the new almanac which may take approximately 15 minutes.

- When position fixing a subtidal ground truth point with a GPS, it is important for the observer to be as close as possible to the GPS antenna to minimise position fix error. This can be difficult in small boats under conditions of strong wind and current.

- Global Positioning Systems (GPS's) have the ability to record your location on the earths surface using different datums (different fixed starting points). Datums that record positions in longitudes/latitudes coordinates you could be familiar with include WGS (World Geodetic System) or AGD (Australian Geodetic Datum). You can choose which datum (AGD or WGS) your GPS screen shows. Both are equally correct to use. However, if you are trying to find coordinates from a map which are written down as AGD, and your GPS is following WGS – there could be up to 160m discrepancy. Check out and know your GPS - CONSISTENCY IS THE KEY.

3.3. Mapping an intertidal meadow

3.3.1. Necessary material and equipment

You will need:

- ☐ *Hand held compass or portable Geographic Positioning System (GPS) unit*
- ☐ *Standard 50 centimetre x 50 centimetre quadrat (preferably 5mm diameter stainless steel).*
- ☐ *Seagrass identification and percent cover sheets (see Appendix)*
- ☐ *Clipboard with pre-printed data sheets 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)*

3.3.2. General field procedure

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 spots. When mapping a region of relatively homogenous coastline between 10 and 100 km long, it is recommend that transects should be no further than 500-1000 m apart. For regions between 1 and 10 km, it is recommend transects 100-500 m apart and for localities less than 1 km, it is recommend 50-100 m apart. This however may change depending on the complexity of the regional coastline, i.e., more complex, then more transects required. Transects do not have to be accurately measured using a tape.

Observations need to be taken at regular intervals (usually 50 to 100m) along transects. The location of each observation is referred to a point, and the intervals they are taken at may vary depending on the topography. Estimate distances between points, rather than using a tape measure. As the distribution of seagrass is depth dependent (depth limits vary between regions and localities due to water clarity), it is advise that representative points be sampled within each depth category (e.g., 0.5m to 10m intervals depending on topography). In some cases the sampling may need to be stratified (the number of points greater in some depth categories than others) when the probability of finding seagrass varies between strata.

3.3.3. Field survey point measures

Step 1. Geographic position

When arriving at a point, the first thing that should be recorded is the position of a point, preferably using a GPS. If a GPS is not available, use a handheld compass to determine the bearing, with reference to at least 3 permanent landmarks or marker established as reference points.

A point can vary in size depending on the extent of the region being mapped. In most cases a point can be defined as are area encompassing a 5m radius.

When ground truthing a point, there are a variety characteristics beside the geographic position that should be recorded.

Step 2. General information

When at a mapping point, the minimum information required on the mapping datasheet includes:

- Record the observer, location (e.g., name of bay), date and time.

- Record the water depth if the point is subtidal (this can be later converted to depth below mean sea level).

Step 3. Describe sediment composition

- Next, note the type of sediment

- To assess the sediment, dig your fingers into the top centimetre of the substrate and feel the texture. Remember that you are assessing the surface sediment so don't dig too deep!!

- Describe the sediment, by noting the grain size in order of dominance (e.g., Sand, Fine sand, Fine sand/Mud).
  - mud - has a smooth and sticky texture. Grain size is less than 63 μm
  - fine sand - fairly smooth texture with some roughness just detectable. Not sticky in nature. Grain size greater than 63 μm and less than 0.25mm
  - sand - rough grainy texture, particles clearly distinguishable. Grain size greater than 0.25mm and less than 0.5mm
  - coarse sand - coarse texture, particles loose. Grain size greater than 0.5mm and less than 1mm
  - gravel - very coarse texture, with some small stones. Grain size is greater than 1mm.

- If you find that there are also small shells mixed in with the substrate – you can make a note of this.

Step 4. Seagrass characteristics

Observations recorded at a point should ideally include some measure of seagrass abundance (at least % cover or a visual estimate of biomass) and species composition. Percentage seagrass cover is the easiest measure of abundance and observers should use a set of standard measures to ensure consistency.

An alternative measure of abundance is a visual estimate of biomass (Mellors 1991). In this method observers record an estimated rank of seagrass biomass and species composition in replicates of a 0.25 m^{-2} quadrat per point. Observers ranks are then regressed against a set of harvested ranks for which the above-ground dry biomass (g DW m^{-2}) is measured. The regression curve representing the calibration of each observer's ranks is then used to calculate above-ground biomass from all estimated ranks during the survey. For a detailed worked example, see Appendix IV.

Although only one observation (sample) is necessary at a ground truth point, it is recommend to take replicate samples spread within the point (possible 3 observations) to ensure the variation of point characteristics are well represented.

ᣔ At the mapping point, haphazardly toss a quadrat within an area of an approximate 5 metre radius around you.

ᣔ Within the quadrat complete the following:

Estimate seagrass percent cover

ᣔ Estimate the total cover of seagrass within the quadrat – use the percent cover photo standards as a guide (Appendix II)

Estimate seagrass species composition

ᣔ Identify the species of seagrass within the quadrat and determine the percent contribution of each species to the cover.

ᣔ Use seagrass species identification keys provided (Appendix III).

Replicate quadrats

ᣔ Haphazardly toss the quadrat another two times within the point area, recording the data for each of the quadrats.

Step 5. Estimate algae percent cover

ᣔ Estimate the percentage cover of algae in the quadrats. Algae are seaweeds that may cover or overlie the seagrass blades. Algal cover is recorded using the same visual technique used for seagrass cover.

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

✤ Also note any other features which may be of interest (e.g., dugong feeding trails, number of shellfish, sea cucumbers, sea urchins, evidence of turtle feeding). The detail of identifications and comments is at the discretion of the observer.

Step 7. Take a photograph

Photographs provide a permanent record and can ensure consistency between observers.

✤ Photographing every quadrat would be expensive, so instead it is recommend that you photograph a quadrat from every 10th mapping point (ie. 10% of the mapping points will have a quadrat that has been photographed) or if the meadow changes or if there is something unusual. It is best to photograph a quadrat from two angles:

- from directly above and

- from 45-60 degrees (navel height?)

✤ Make sure the photo details are noted on the data sheet so the photo can be matched with the quadrat details.

✤ Another option is to video the quadrats and analyse back at home or in the laboratory.

Step 8. Collect a voucher specimen

✤ Collect a voucher specimen of each seagrass species you encounter for the day (only 1 or 2 shoots which have the leaves, rhizomes and roots intact). Label each specimen clearly and put into a plastic bag.

3.3.4. Continue mapping

✤ Move on to the next mapping point and repeat the process. 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.

3.3.5. At completion of field mapping

Step 1. Clean & pack gear

✤ When you return from the field even though you will be tired it is worth checking through the information you have gathered to make sure there are no data gaps.

✿ Before returning the sampling kit, ensure it is clean, batteries removed from GPS, equipment rinsed with fresh water and let dry before long term storage,

Step 2. Press any voucher seagrass specimens if collected

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

✿ Wash seagrass sample in clean water and carefully remove any debris, epiphytes or sediment particles. Divide the sample into two complete specimens.

✿ Layout specimen on a clean sheet of white paper, spreading leaves and roots to make each part of the specimen distinct.

✿ Fill out specimen labels (2) with point information (including: location & point code, lat/long, depth, %cover, substrate, other species present, collector, comments) and place the label on lower right hand corner of paper.

✿ Place another clean sheet of paper over the specimen, and place within several sheets of newspaper.

✿ Place the assemblage of specimen/paper within two sheets of cardboard and then place into the press, winding down the screws until tight (do not over-tighten).

✿ 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.

3.4. Mapping shallow-subtidal (<10m) meadows

Check the tides to help you plan when is the easiest time to do the mapping, e.g., neap tides are best for subtidal meadows.

3.4.1. Necessary material and equipment

You will need:

❑ Small boat, with outboard motor and safety equipment

❑ Hand held compass or portable Geographic Positioning System (GPS) unit

❑ Standard 50 centimetre x 50 centimetre quadrat (preferably 5mm diameter stainless steel).

❑ Seagrass identification and percent cover sheets (see Appendix)

❑ Clipboard with pre-printed data sheets and pencils.

❑ Suitable free-diving (snorkelling) equipment

❑ *Depth measuring equipment (eg. depth sounder)*

❑ *Bathyscope (not essential)*

❑ *Benthic grab (e.g., van Veen)*

❑ *Aerial photographs or marine charts (if available) of the locality*

❑ *Plastic bags - for seagrass samples with waterproof labels*

❑ *Weatherproof camera (optional)*

3.4.2. General field procedure

If water clarity and seagrass abundance is high, then the boundaries of subtidal meadows can be mapped from a boat driven slowly (1-2 kts) around the perimeter of each meadow with single position fixes recorded every 20-30m. A bathyscope can be used to assist in identification of the presence of continuous or sparse meadows and the determination of deep edge meadows. Abundance or cover estimated can also be visually assessed.

If the water clarity is low, and/or the seagrass abundance low and highly variable, then a different strategy is employed. An area can be mapped ideally using a grid pattern or a combination of transects and spots, in the same manner as when mapping an intertidal meadow.

The most commonly used and simplest ground-truth method is in situ observation through free diving or snorkelling. Any direct observation of the bottom is limited by the amount of time a person can spend snorkelling or their field of view when in the water. The diver swims to the bottom, or as deep as is required to recognise the seagrass, presence or absence or species. If nothing is growing on the bottom the diver can turn back without having to go to the full depth of the bottom. Free-dives are also useful for obtaining a vegetation or sediment sample.

Where depth or poor visibility prohibits free-diver estimates, a small benthic grab or dredge is a useful tool for determining the bottom type. This dredge can be used in boats from small inflatables to ocean going research vessels. Benthic grabs can also be used to sample the sea floor and samples of sediment can also be obtained. Long *et al.* (1994) tested the use/efficacy of a modified "orange-peel" grab in different sediment and vegetation types, and reported acceptable results.

3.5. Mapping deep-water (>10m) meadows

3.5.1. Necessary material and equipment

You will need:

- ❑ *Large boat*
- ❑ *Underwater video camera (video recorder) and sled*
- ❑ *Geographic Positioning System (GPS) unit, hand held compass or RADAR*
- ❑ *Depth measuring equipment (eg. depth sounder)*
- ❑ *Benthic grab (e.g., van Veen)*
- ❑ *Clipboard with pre-printed data sheets and pencils.*
- ❑ *Plastic bags - for seagrass samples with waterproof labels*

3.5.2. General field procedure

A deep-water area can be mapped ideally using a grid pattern or a combination of transects and spots. The approach is very similar to mapping an intertidal or shallow subtidal meadows, however the points will be generally further apart and the replication at a point will be significantly reduced. When ground-truthing a point, there are a variety of techniques that can be used depending on resources available and water depth (SCUBA, benthic grab, remote camera/video, etc).

Self Contained Underwater Breathing Apparatus (SCUBA) can be used to conduct *in situ* assessment of deep-water points. This however, can be restrictive due to the number of points that can be assessed in a day, and the restrictions imposed by diving at depth. Safety should be foremost when conducting *in situ* assessment using SCUBA, paying particular attention to tidal regimes, turbidity, sea-state, dangerous marine animals and other human activities and impacts. Local knowledge of the above factors should always be sought. It is strongly recommend that diving policies be developed by each organisation and national safety standards be met.

Due to the restrictions of working at depth, virtually all deep-water mapping is conducted remotely. One remote method uses active acoustic sensors that characterise the sea-floor by transmitting a pulse of sound energy downward into the water column and then collecting the return echoes for analysis. This method requires specialised sensors and technical expertise to interpret, and is considered beyond the scope of this guide. For more information we recommended Lee Long et al. (1998) and Urick (1983).

The other common method is Real Time Towed Video Camera. Underwater video is a widely used tool for seagrass mapping (Coles et al. 2000, Lee Long et al. 1996a,

Norris et al. 1997). The record provided by underwater video provides information on seagrass presence and abundance, the species of seagrass and the nature of the non-vegetated bottom. The system is useful in deepwater environments where SCUBA diving is restricted and in localities where dangerous marine animals are a significant threat.

Chapter 4.

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.

4.1. Geographic Information Systems (GIS)

GIS are software systems of highly accurate digital maps that can be overlaid to reveal relationships that might not otherwise be detected on traditional paper maps. Digitally-stored cartographic databases can be altered much quicker than hard copies and shared data can be standardised. The key element of a GIS is the separation of differing data sets into thematic layers. GIS software provides the functions and tools needed to store, analyse, and display geographic information.

Two of the most common GIS packages are ArcInfo® (including ArcView®) 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).

4.2. Creating the basemap and importing captured data

A basemap is the spatial framework by which all other information is referenced. Basemaps are generally boundary files which are fundamental building blocks for any mapping system. For example, basemaps may be coastlines or property tenure boundaries. Basemaps are constructed from georeferenced features on plans or remote images. Sometimes basemaps can be sourced from government planning agencies or private contractors who specialise in planning.

If no basemaps are available or are difficult to access (e.g., limited funds), an aerial photo or paper topographic chart can be used. It is also advised to be aware of copyright restrictions and possible infringements.

The first task is to scan the aerial photographs (or charts) typically using a flat-bed scanner (a resolution of 300 dpi is usually sufficient) to produce a digital raster image. Once scanned, aerial photographs can be pasted together in most standard

image/drawing packages to create larger images. Ensure the final image includes some topographic features spread over the entire image: such as major or minor roads, coastlines, buildings, jetties or piers. If the ground truthing included determining the position fixes of such topographic features, then these can be used as ground control points. Using ground control points, the digital images can now be fixed or rectified in space. Maximum spread of ground control points over an image will result in a more accurate rectification. This image now becomes the basemap for the GIS layers.

It is possible to map seagrass meadows directly from raster images using image analysis programs (e.g., Optimas® and ENVI®) or the user can trace (digitise) the boundary. Alternatively, the boundary can be determined by importing the ground truthed points and using contour mapping programs (e.g., Surfer® and S-Plus®). All these techniques require a combination of software, hardware, mathematical, physics and biogeochemistry skills which is beyond the scope of this guide.

An easier alternative is importing the seagrass position data (ground truthed points) from the database in which it has been entered and overlaying it on a basemap derived from a scanned and rectified aerial photograph. Once imported, it can be linked in overlapping layers to form a mosaic covering the whole region or locality.

4.3. Boundary Determination

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.

Sometimes, it can be assumed that light limits the deeper edge of seagrass beds and, in this case, bathymetric measures can map this boundary. The light limiting depth to most seagrasses is usually the Secchi disc depth (Dennison and Kirkman, 1996).

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 As long as the logic is clearly described and the results are repeatable, the data should be suitable for baseline characterisation or change detection. Using the GIS, meadow boundaries can be assigned a "quality" value based on the type and range of mapping information available for each area and determined by the distance between survey points and GPS position fixing error. These meadow boundary "errors" can be used to estimate

the likely range of area for each meadow mapped (Lee Long *et al.* 1996b, McKenzie *et al.* 1996, 1998, 2001).

4.4. Map accuracy

The expected accuracy of the map product gives some level of confidence in using the data. Traditional methods can carry an inherently large capacity for mapping error because of the need for spatial interpolation between the data points. Inaccurate maps can also result in poor management decisions (Bruce et al. 1997). Mapping accuracy can be divided into the two general classes of thematic and spatial accuracy.

Thematic accuracy is a determination of the correctness of the features identified on the map product. This covers whether a patch of seagrass was correctly labelled as seagrass in the map or whether it was incorrectly labelled as algae or some other feature.

Spatial accuracy is a measure of the positional correctness of boundaries and features in a map product. For seagrass mapping, high levels of both thematic and spatial accuracy are critical. With the advent of GPS, spatial accuracy has greatly improved. However, care must be taken not to enlarge a map beyond its stated scale and try to make decisions from this artificially enlarged map. The need for rectification has been emphasised throughout this chapter and estimates of accuracy should be given with each mapping project. At sea, control points are difficult to find for rectification purposes so that spatial errors increase in magnitude the further from controls the point of interest is.

The accuracy of a map also needs to consider temporal effects. Rarely are maps generated at a time close to the date at which field accuracy assessment occurs. This can make assessing the thematic or spatial accuracy of a map more difficult. It is particularly noticeable when seagrass beds undergo large seasonal changes.

4.5. Data visualisation and output

If the data contains information of greater resolution than presence or absence, it can be used to in digital elevation modelling programs (such as Surfer® and S-plus®). Digital elevation models can be created with information such as seagrass abundance, water depth, etc.

Detailed data capture information can enable maps to be constructed from more features than simply presence and absence. Maps of different seagrass communities or habits for example, can be constructed by using information such as seagrass species composition, seagrass abundance, sediment type and other associated flora and fauna.

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 any caveats on data reliability, eg., changes in data quality during sampling because of physical changes such as sea state. This is important when data is loaded into a GIS that is used by managers. GIS data also requires a use-by date. Original (master) copies of final GIS maps are usually stored in two places: the source laboratory and a regional or central archive. Always attach a metadata file or script to each map, and include the correct form of citation to be used for acknowledging the data source.

4.6. 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/).

References

Bridges, KW, C McMillan. 1986. The distribution of seagrasses of Yap, Micronesia, with relation to tide conditions. Aquatic Botany 24: 403-407.

Bruce E, I Elliot, D Milton. 1997. Methods for assessing the thematic and positional accuracy of seagrass maps. Mar. Geod. 20:175-193.

Coles, RG, WJ Lee Long, LJ McKenzie. 1995. A Standard for Seagrass Resource Mapping and Monitoring in Australia. In: Australian Marine Date Collection and Management Guidelines Workshop, 5-6 December 1995. CSIRO Marine Laboratories, Hobart, Tasmania. URL: http://www.environment.gov.au/marine/coastal_atlas/documentation/standards/general/coles.html

Coles, RG, WJ Lee Long, BA Squire, LC Squire, JM Bibby. 1987. Distribution of seagrasses and associated juvenile commercial penaeid prawns in northeastern Queensland waters, Australaia. Aust. J. Mar. Freshwater Res. 38: 103-120.

Coles, RG, WJ Lee Long, LJ McKenzie, AJ Roelofs, G De'ath. 2000. Stratification of seagrasses in the Great Barrier Reef world heritage area, northeastern Australia, and the implications for management. Biol. Mar. Medit. 7: 345-348.

Coles R G, Lee Long W J, Watson R A and Derbyshire K J 1993 Distribution of seagrasses, and their fish and penaeid prawn communities, in Cairns Harbour, a tropical estuary, northern Queensland, Australia. Aust. J. Mar. Freshwater Res. **44**: 193-210.

Congalton R. 1988. A comparison of sampling schemes used in generating error matrices for assessing the accuracy of maps generated from remotely sensed data. Photogram. Eng. Rem. Sens. 54: 593-600.

Dennison, WC, H Kirkman. 1996. Seagrass survival model. pp. 341-344. In: J Kuo, R Phillips, DI Walker, H Kirkman (eds) Seagrass Biology: Proceedings of an international workshop, Rottnest Island, Western Australia, 25-29 January 1996. Faculty of Science, The University of Western Australia.

Dobson, JE, EA Bright, RL Ferguson, DW Field, LL Wood, KD Haddad, H.III Iredale, JR Jensen, VV Klemas, RJ Orth, JP Thomas. 1995. NOAA Coastal Change Analysis Program (C-CAP) Guidance for Regional Implementation. NOAA Technical Report NMFS 123. 92 pp.

Dreyser, LE. 1993. Evaluation of remote sensing techniques for monitoring giant kelp populations. Hydrobiologia 260/261: 307-312

English, S, C Wilkinson, V Baker. 1994. Survey Manual for Tropical Marine Resources. ASEAN-Australia marine science project: living coastal resources. Australian Institute of Marine Science, Townsville. 368 pp.

Fortes, MD. 1998. Indo_West Pacific affinities of Philippine seagrasses. Bot. Mar. 31:237-242.

Fonseca M S and Fisher J S 1986 A comparison of canopy friction and sediment movement between four species of seagrass with reference to their ecology and restoration. *Mar. Ecol. Prog. Ser.* **29**:15-22.

Hyland, SJ, AJ Courtney, CT Butler. 1989. Distribution of seagrass in the Moreton Region from Coolangatta to Noosa. QDPI Information Series QI89010. Queensland Department of Primary Industries, Brisbane. 42 pp.

Jagtap, TG, AG Untawale, SN Inamdar. 1994. Study of mangove environment of Maharashtra coast using remote sensing data. Indian J. Mar. Sci. 23: 90-93.

Kelly, MG. 1980. Remote sensing of seagrass beds. pp. 69-85. In: RC Phillips, CP McRoy (eds). Handbook of Seagrass Biology: An Ecosystem Perspective. Garand STMP Press, New York.

Kennedy, M. 1996. The Global Positioning System and GIS: An introduction. Ann Arbor Press, Inc. Chelsea, Michigan. 267 pp.

Kirkman, H. 1990. Seagrass distribution and mapping. pp 19-25. In: RC Phillips, CP McRoy (eds). Seagrass research methods: Monographs on oceanographic methodology 9, UNESCO Paris.

Kirkman, H. 1996. Baseline and monitoring methods for seagrass meadows. J. Env. Mgt. 47: 191-201.

Lehmann, A, JB Lachavanne. (eds.) 1997. Special Issue: Geographic Information Systems and remote sensing in aquatic botany. Aquat. Bot. 58: 195-440.

Lee Long, WJ, JE Mellors, RG Coles. 1993. Seagrasses between Cape York and Hervey Bay, Queensland, Australia. Australian J. Mar. Freshw. Res. 44: 19-31.

Lee Long, WJ, RG Coles, LJ McKenzie. 1996a. Deepwater seagrasses in northeastern Australia - how deep, how meaningful? pp. 41-50. In: J. Kuo, RC Phillips, DI Walker, H Kirkman. (eds) Seagrass Biology: Proceedings of an International Workshop, Rottnest Island, Western Australia 25-29 January, 1996. Faculty of Sciences, The University of Western Australia.

Lee Long, WJ, LJ McKenzie, RG Coles. 1996b. Seagrass communities in the Shoalwater Bay region, Queensland - Spring (September) 1995 and Autumn (April) 1996. Queensland Department of Primary Industries Information Series QI96042. QDPI, Brisbane. 36 pp.

Lee Long, WJ, LJ McKenzie, MA Rasheed, RG Coles. 1996c. Monitoring seagrasses in tropical ports and harbours. pp. 345-50. In: J. Kuo, RC Phillips, DI Walker, H Kirkman. (eds.) Seagrass Biology: Proceedings of an International Workshop, Rottnest Island, Western Australia 25-29 January, 1996. Faculty of Sciences, The University of Western Australia.

Lee Long, WJ, RG Coles, LJ McKenzie. 2000. Issues for seagrass conservation management in Queensland. Pacific Conservation Biology 5: 321-328.

Lee Long, WJ, AJ Hundley, CA Roder, LJ McKenzie. 1998. Preliminary Evaluation of an Acoustic Technique for Mapping Tropical Seagrass Habitats. Great Barrier Reef Marine Park Authority Research Publication No. 52, 30 pp.

Lehmann, A, JM Jaquet, JB Lachavanne. 1997. A GIS approach of aquatic plant spatial hetergeneity in relation to sediment and depth gradients, Lake Geneva, Switzerland. Aquat. Bot. 58: 347-361.

Long, BG, TD Skewes, IR Poiner. 1994. An efficient method for estimating seagrass biomass. Aquat. Bot. 47: 277-292.

McKenzie L.J., Finkbeiner, M.A. and Kirkman, H. (2001) Methods for mapping seagrass distribution. Chapter 5 pp. 101-122 IN Short, F.T. and Coles, R.G. (eds) 2001. Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam. 473pp.

McKenzie, LJ, MA Rasheed, WJ Lee Long, RG Coles. 1996. Port of Mourilyan Seagrass monitoring, Baseline Surveys - Summer (December) 1993 and Winter (July) 1994. EcoPorts Monograph Series No 2. PCQ, Brisbane. 51 pp.

McKenzie, LJ, WJ Lee Long, AJ Roelofs, CA Roder, RG Coles. 1998. Port of Mourilyan Seagrass Monitoring - First 4 Years. EcoPorts Monograph Series No 15. Ports Corporation of Queensland, Brisbane. 34 pp.

Norris, J, S Wyllie-Echeverria, T Mumford, A Bailey, T Turner. 1997. Estimating basal area coverage of subtidal seagrass beds using underwater videography. Aquat. Bot. 58: 3-4.

NOS/NMFS Centre for Coastal Fisheries and Habitat Research. 1999. Progress Report Essential Fish Habitat: Deepwater seagrass beds of the west Florida Shelf-an overlooked essential fish habitat. Unpublished Internal report, Nov. 1999.

Phillips, RC, CP McRoy. 1990. Seagrass Research Methods. Monographs on oceanographic methodology 9. UNESCO, Paris. 210 pp.

Sheppard, C, K Matheson, J Bythell, P Murphy, C Blair-Meyers, B Blake. 1995. Habitat assessment in the Caribbean for management and conservation-use and assessment of aerial photography. Aquat. Cons. 5: 277-298.

Short F T 1987 Effects of sediment nutrients on seagrasses: Literature review and mesocosm experiment. Aquat. Bot. **27**: 41-57.

Short, F.T. and Coles, R.G. (eds) 2001. Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam. 473pp.

Short, FT, CA Short. 1984. The seagrass filter: purification of coastal water. In VS Kennedy (ed.) The Estuary as a Filter. Academic Press. pp. 395-413.

Short, FT, S Wyllie-Echeverria. 1996. Natural and human-induced disturbance of seagrasses. Environmental Conservation 23(1): 17-27.

Short, FT, RG Coles, C Pergent-Martini. 2001. Global Seagrass Distribution. Chapter 1, pp. 5-30. In: FT Short, RG Coles (eds.) Global Seagrass Research Methods. Elsevier Science B.V., Amsterdam.

Short, FT, DM Burdick. 1996. Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. Estuaries 19: 730-739.

Stoms, DM, FW Davis, CB Cogan. 1992. Sensitivity of wildlife habitat models to uncertainties in GIS data. Photogram. Eng.Rem. Sens. 58: 843-850.

Tsuda, RT, S Kamura. 1990. Comparative review on the floristics, phytogeography, seasonal aspects and assemblage patterns of the seagrass flora in Micronesia and the Ryukyu Islands, Galaxea 9:77-93.

Thomas, M, P Lavery, RG Coles. 1999. Monitoring and assessment of seagrass. pp. 237-268. In: A. Butler, P Jernakoff (eds.) Seagrass Strategic Review and Development of an R and D plan. A national Review for the Fisheries Research and Development Council. CSIRO Publishing, Collingwood, Australia.

Udy, JW, WC Dennison, WJ Lee Long, LJ McKenzie. 1999. Responses of seagrasses to nutrients in the Great Barrier Reef, Australia. Mar. Ecol. Prog. Ser. 185: 257-271.

Urick, RJ. 1983. Principles of Underwater Sound. 3rd Edn. Mcgraw-Hill, New York. 423 pp.

Virnstein, RW. 2000. Seagrass management in Indian River Lagoon, Florida: dealing with issues of scale. Pac. Cons. Biol. 5: 299-305.

Walker, DI. 1989. Methods for monitoring seagrass habitat. Victorian Institute of Marine Science Working paper No. 18, Melbourne. 21 pp.

Watson R A, Coles R G and Lee Long W J 1993 Simulation estimates of annual yield and landed value for commercial penaeid prawns from a tropical seagrass habitat, northern Queensland, Australia. Aust. J. Mar. Freshwater Res. **44**: 211-21.

Appendix I

Data sheets

SEAGRASS-WATCH MAPPING

Recorder: ………..................... GPS#/Vessel: …….……...........…... Date: …..../…. /.......

	% cover	Species / % composition of cover
Point#: ....….......Location…………………….…..... Lat …..….°…..………... **S** Long …..….°…...…………**E** Time…..……...hrs Depth:.........m Observer…..………... Sediment: ....…..... Algae (%)…....……....…... Algae (spp./comp) .... Comments:		

	% cover	Species / % composition of cover
Point#: ......…........Location…………………….…..... Lat …..….°…..………... **S** Long …..….°…...…………**E** Time…..……...hrs Depth:.........m Observer…..………... Sediment: ....…..... Algae (%)…....……....…... Algae (spp./comp) .... Comments:		

	% cover	Species / % composition of cover
Point#: ......…........Location…………………….…..... Lat …..….°…..………... **S** Long …..….°…...…………**E** Time…..……...hrs Depth:.........m Observer…..………... Sediment: ....…..... Algae (%)…....……....…... Algae (spp./comp) .... Comments:		

	% cover	Species / % composition of cover
Point#: ......…........Location…………………….…..... Lat …..….°…..………... **S** Long …..….°…...…………**E** Time…..……...hrs Depth:.........m Observer…..………... Sediment: ....…..... Algae (%)…....……....…... Algae (spp./comp) .... Comments:		

	% cover	Species / % composition of cover
Point#: ......…........Location…………………….…..... Lat …..….°…..………... **S** Long …..….°…...…………**E** Time…..……...hrs Depth:.........m Observer…..………... Sediment: ....…..... Algae (%)…....……....…... Algae (spp./comp) .... Comments:		

	% cover	Species / % composition of cover
Point#: ......…........Location…………………….…..... Lat …..….°…..………... **S** Long …..….°…...…………**E** Time…..……...hrs Depth:.........m Observer…..………... Sediment: ....…..... Algae (%)…....……....…... Algae (spp./comp) .... Comments:		

Appendix II
Seagrass percent cover standards

Percent cover standards

1%

3%

5%

10%

12%

15%

20%

32%
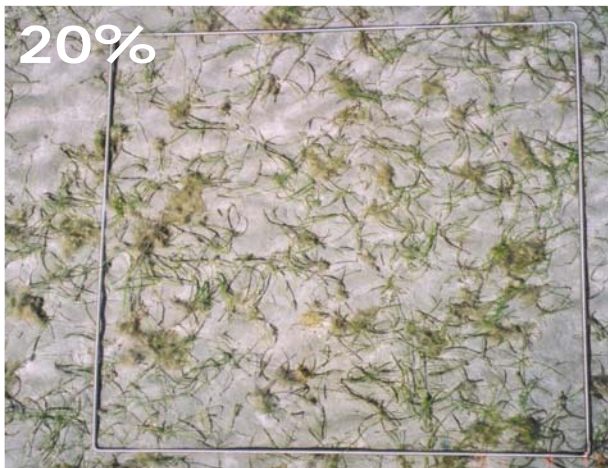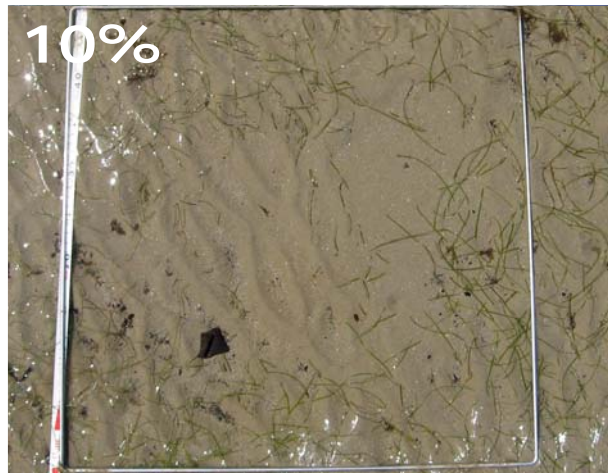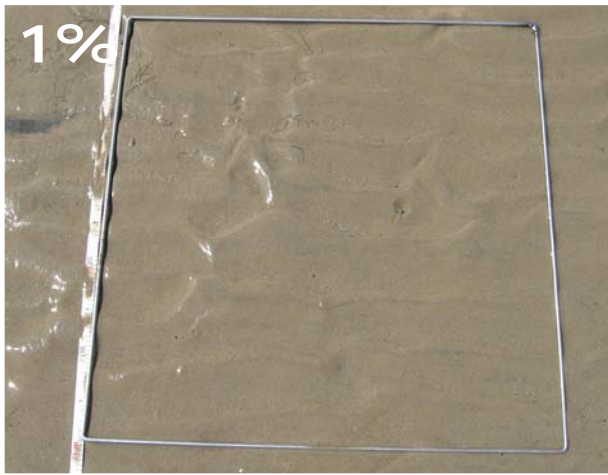
Coastal - *low*

Percent cover standards
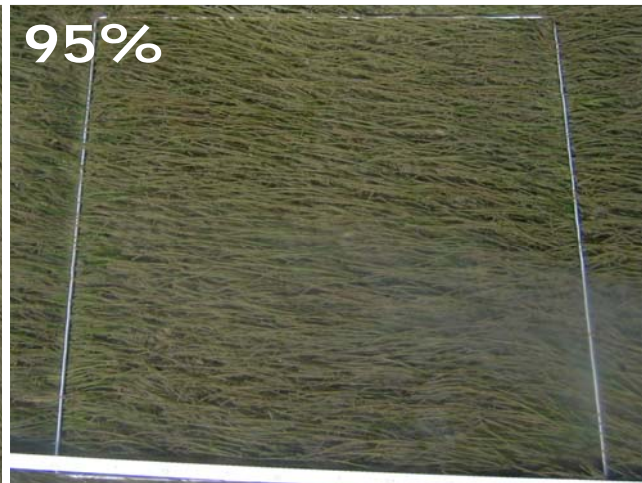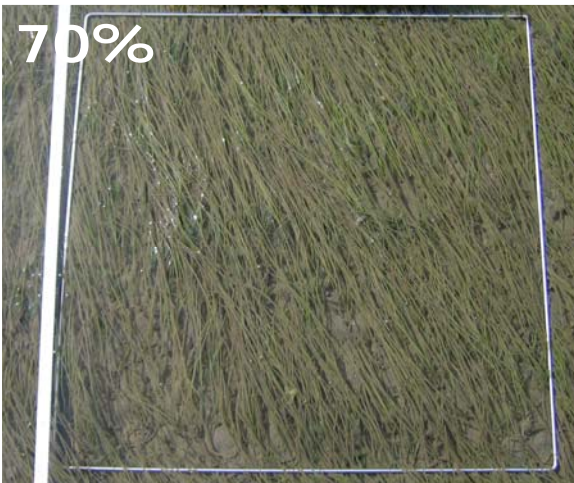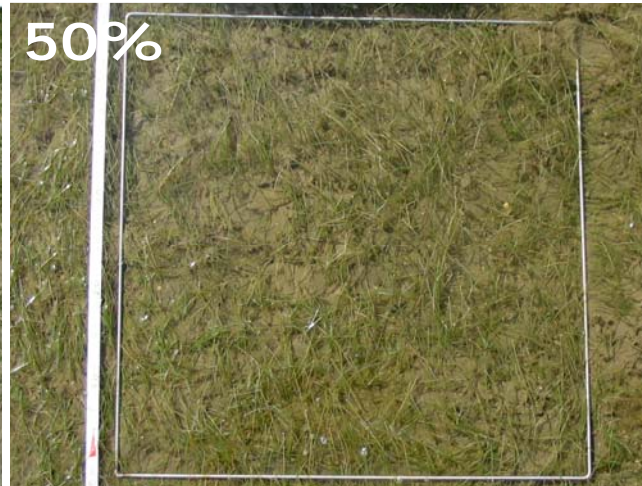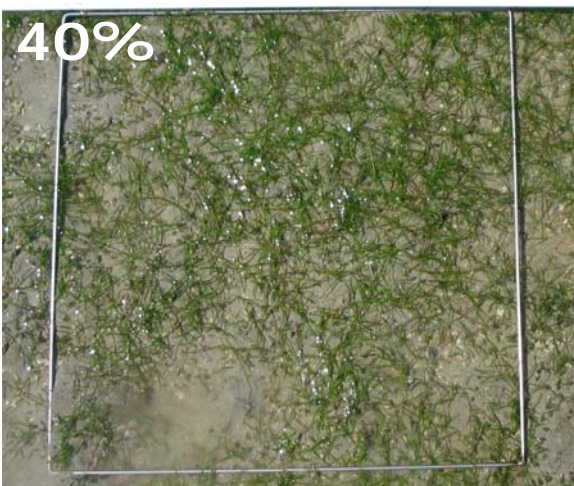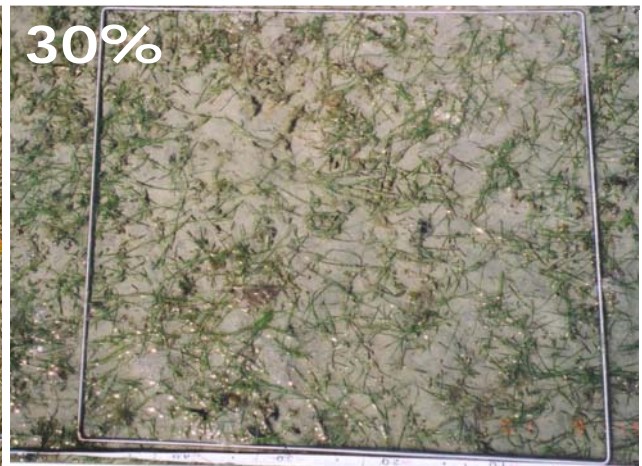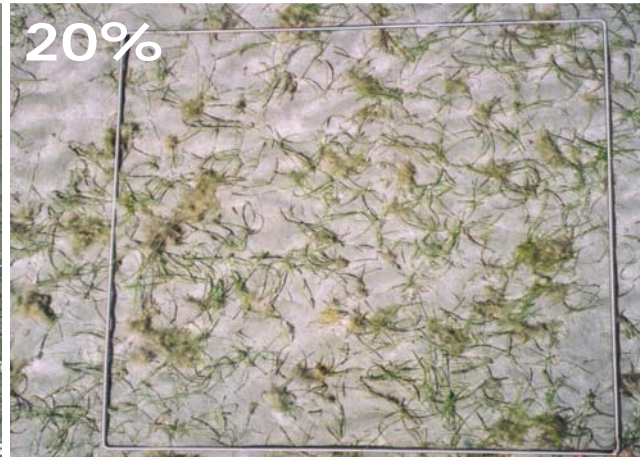
Coastal - *high*
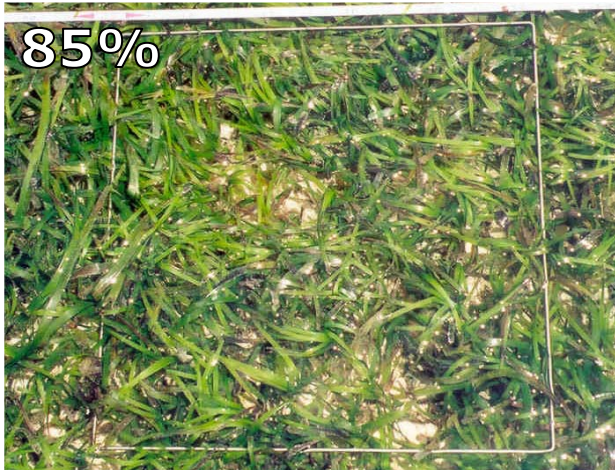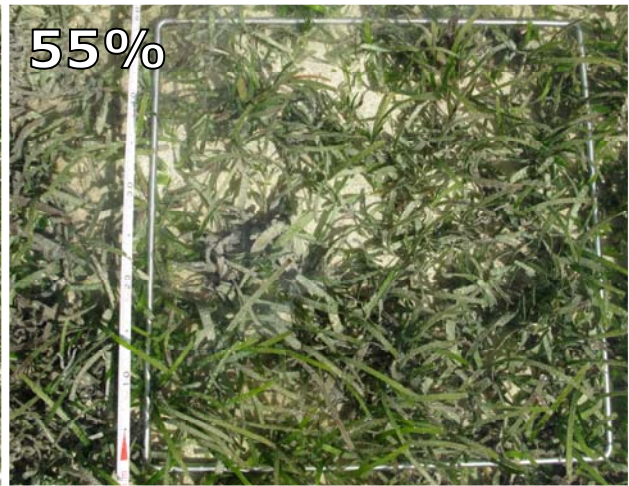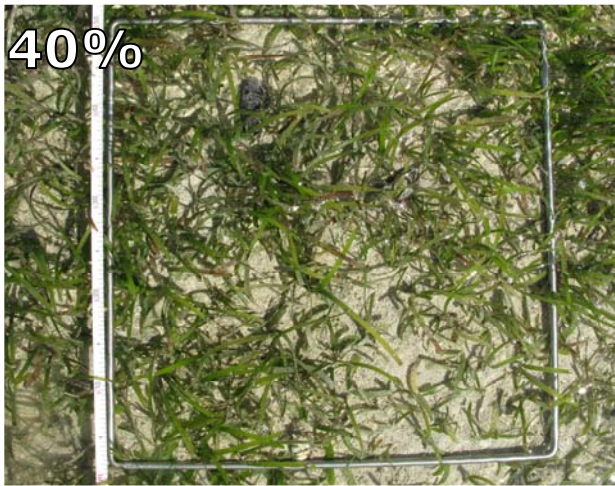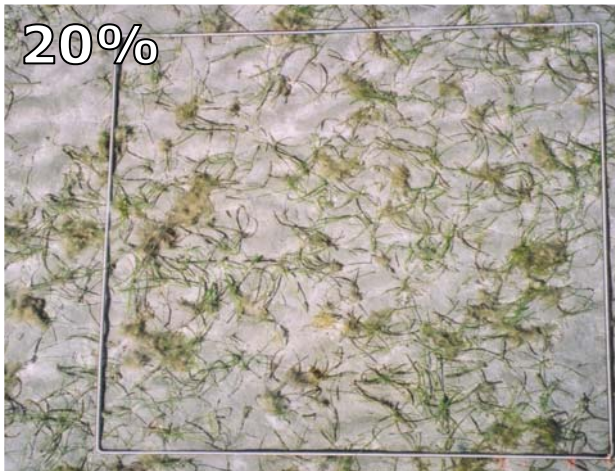
Percent cover standards

2%

5%

7%
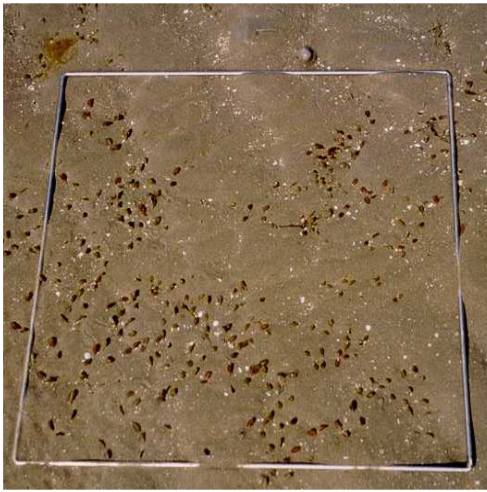
17%
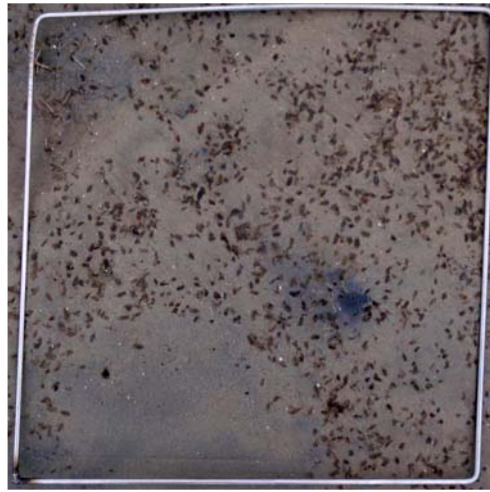
25%

38%

60%

70%

Coastal – *H. ovalis*

Percent cover standards

5% 10% 20% 35% 50% 70% 85% 95%
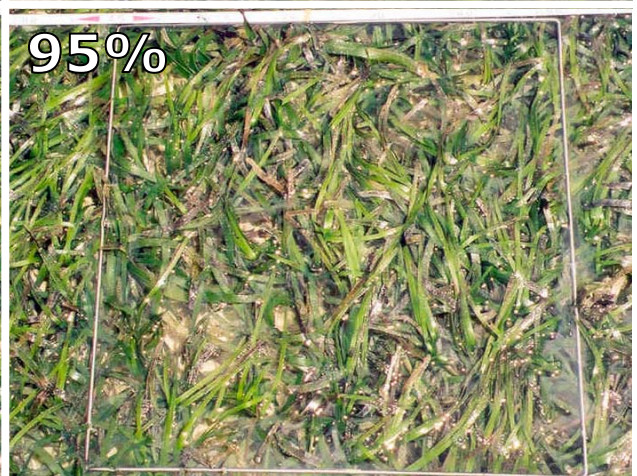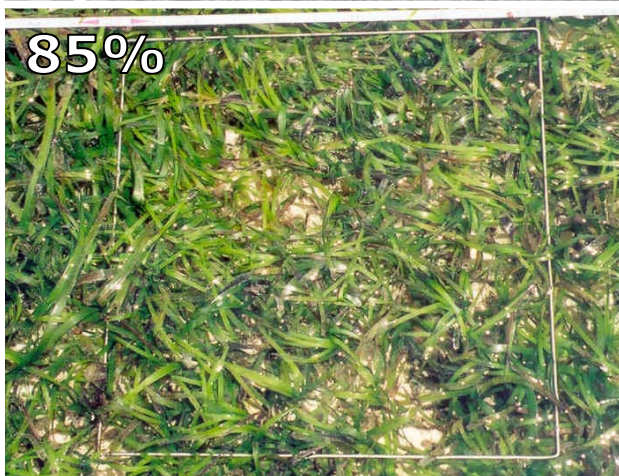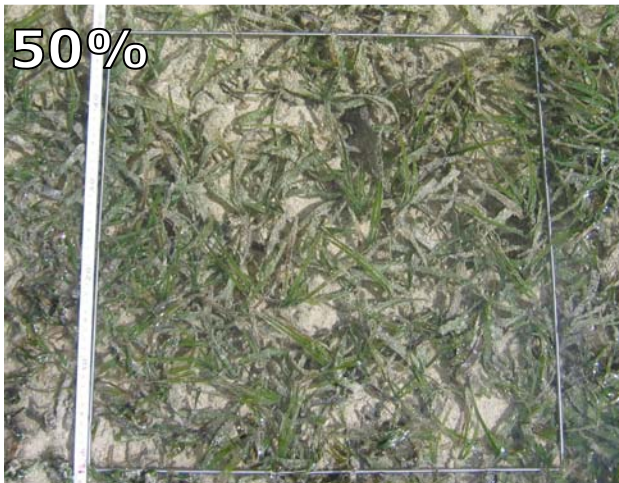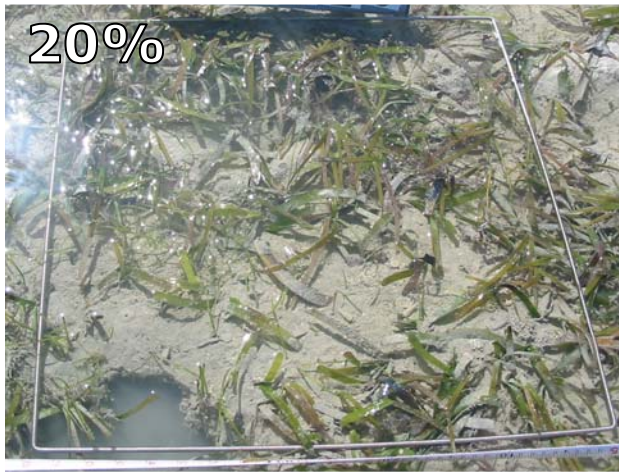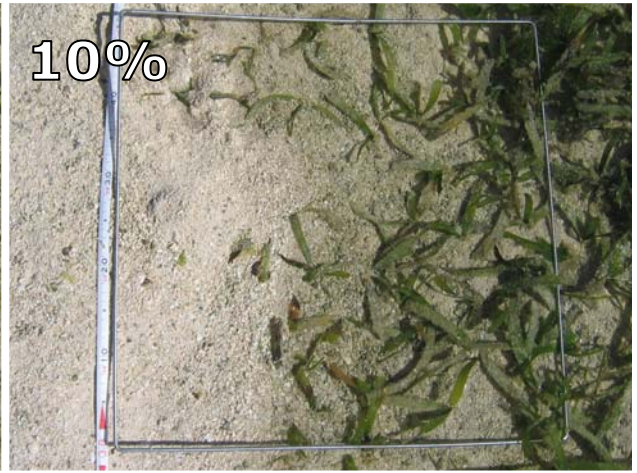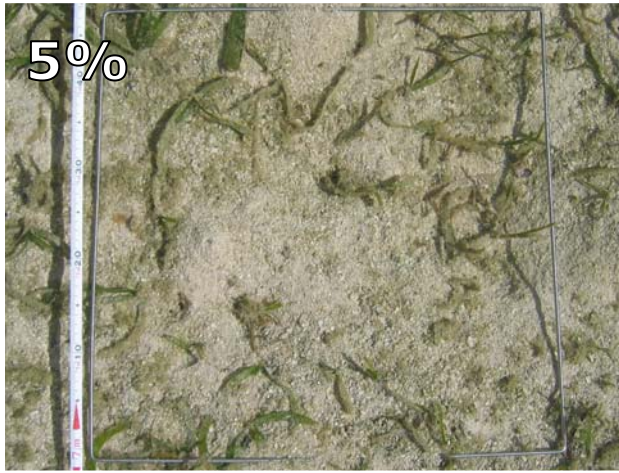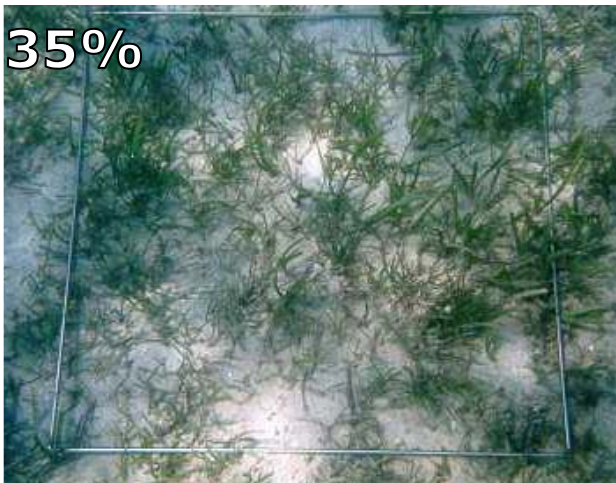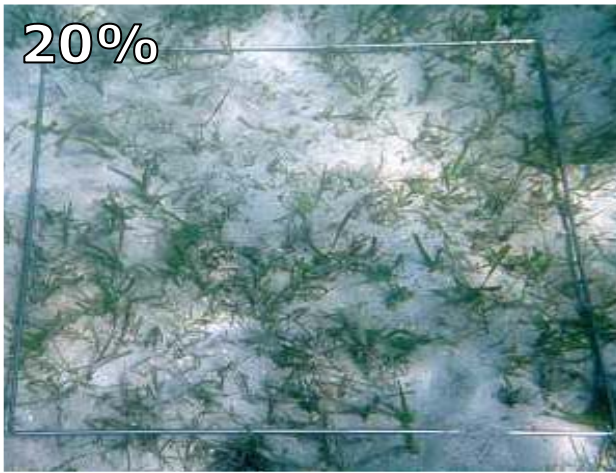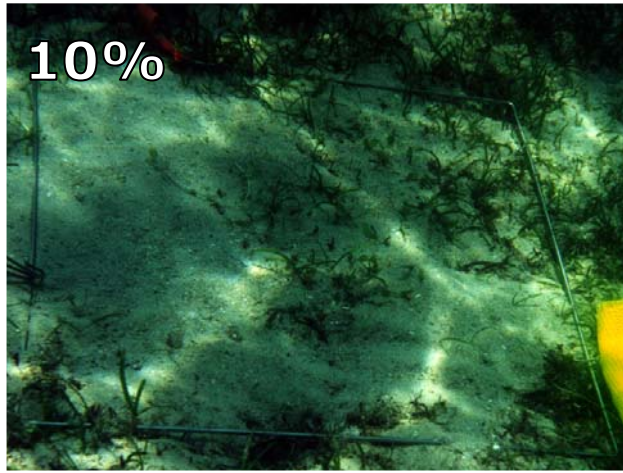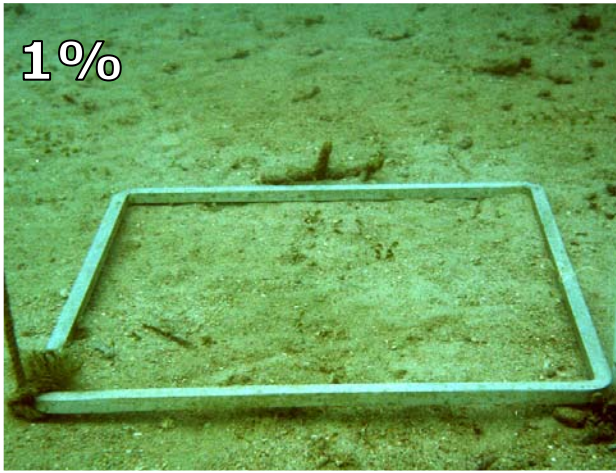
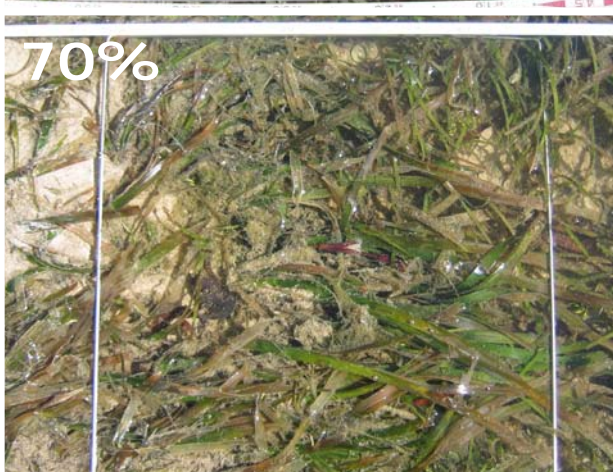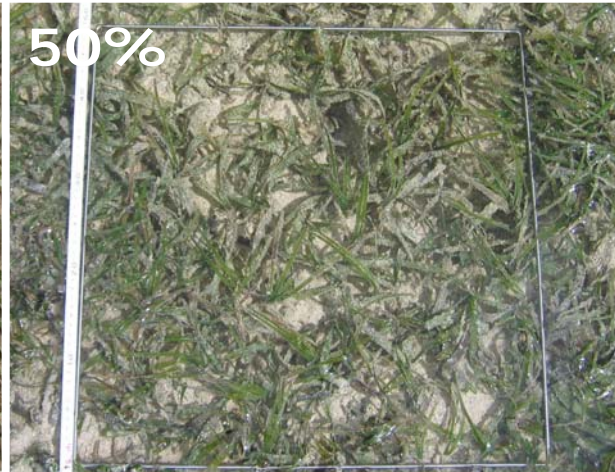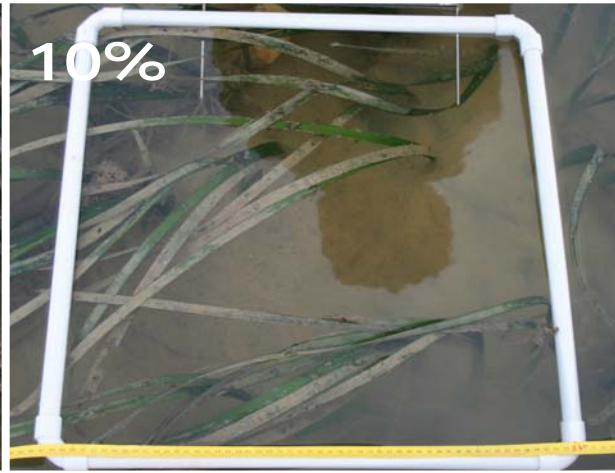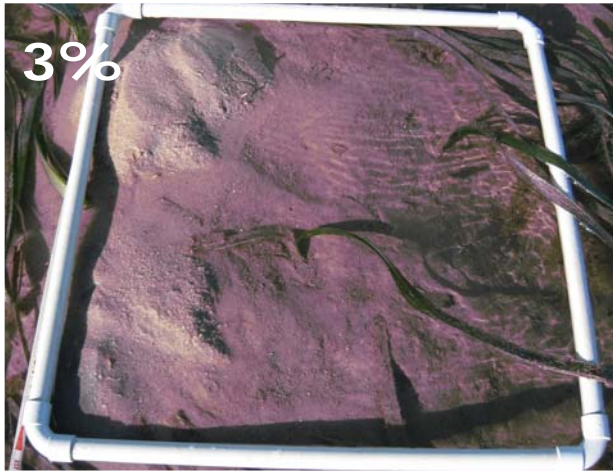Reeftop – mixed *Thalassia/Cymodocea/Enhalus*

Percent cover standards

2% 12% 20% 30% 40% 55% 85% 95%
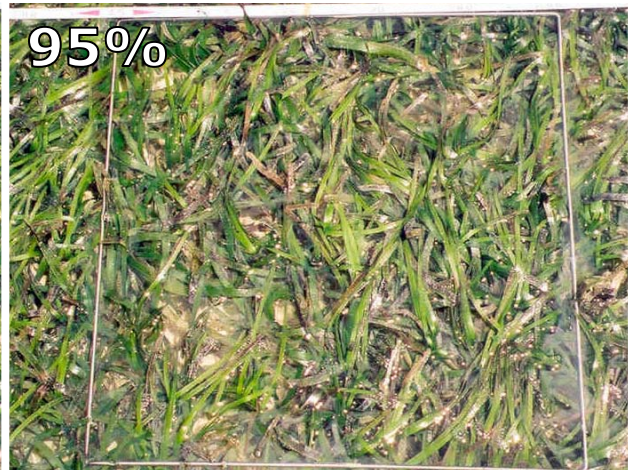
Reeftop –*Cymodocea/Halodule*

Percent cover standards
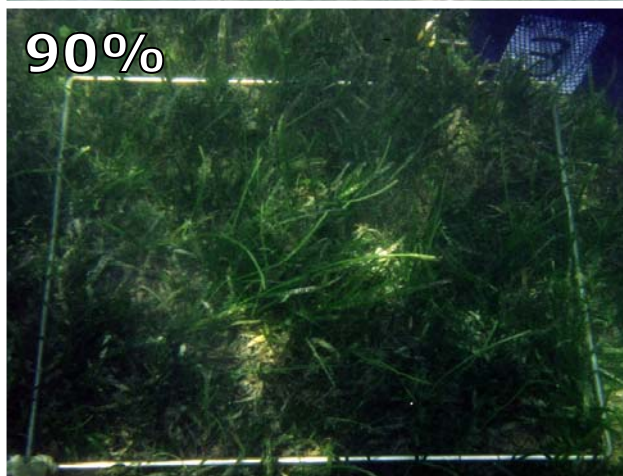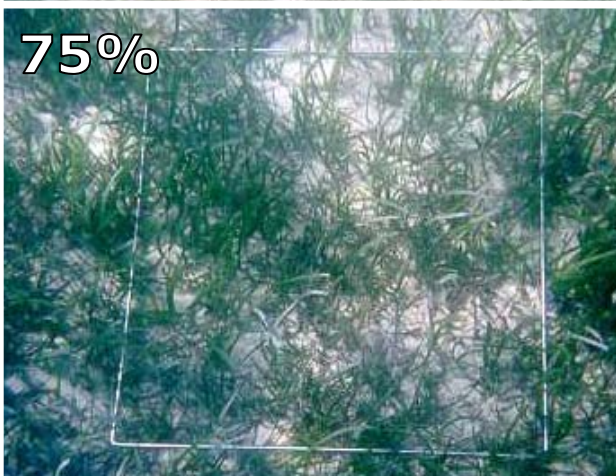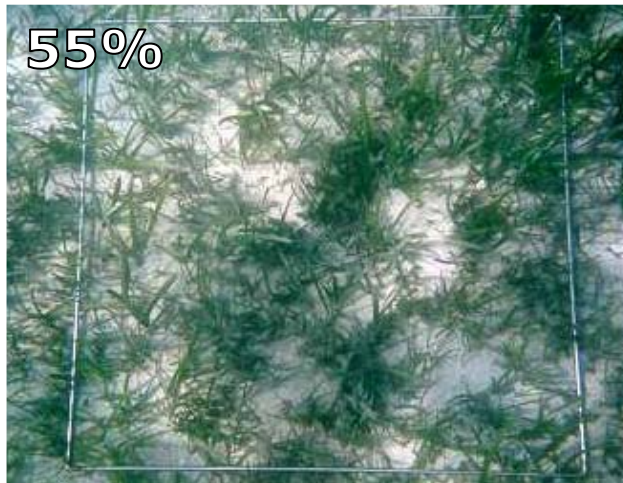
Subtidal

Percent cover standards

3%

10%

16%

28%

40%

50%

70%

95%
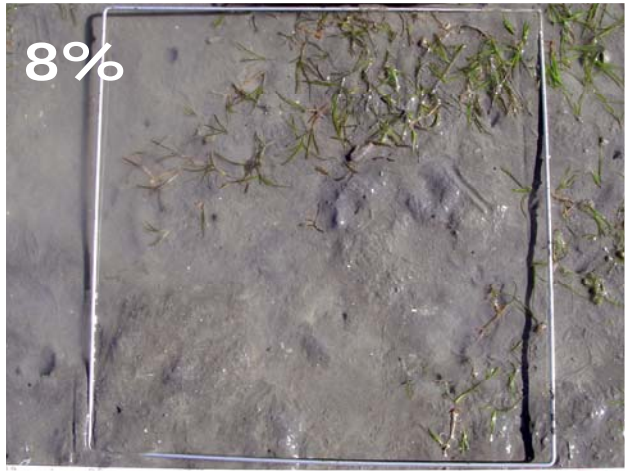
Reeftop – *Enhalus*

Percent cover standards
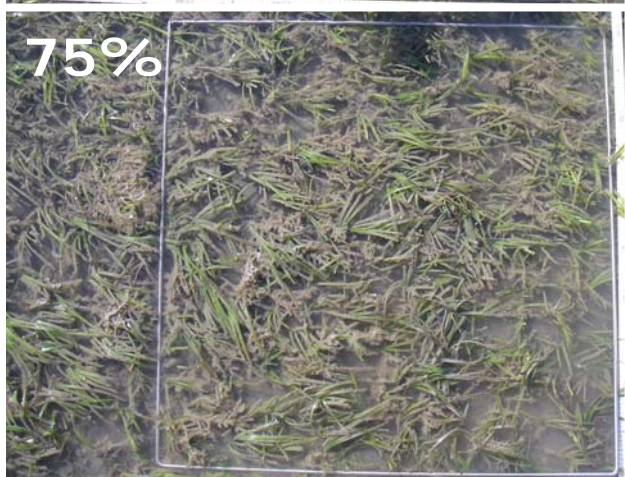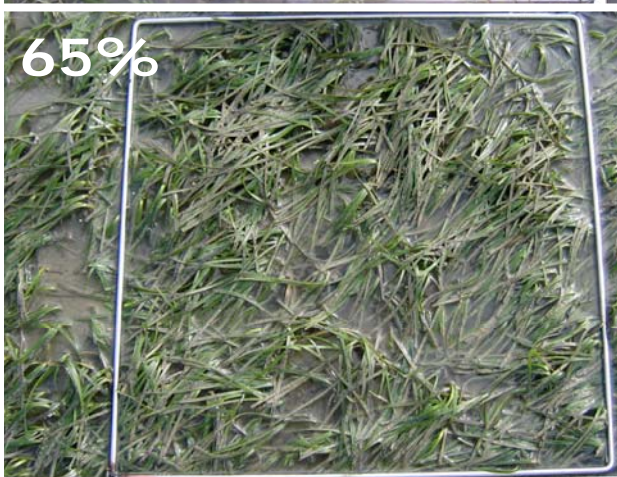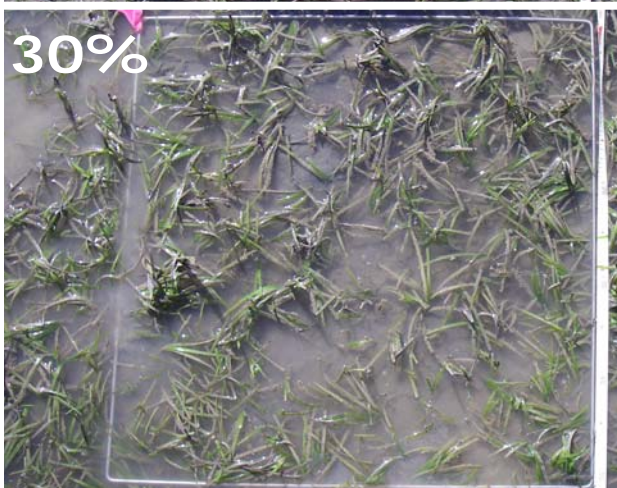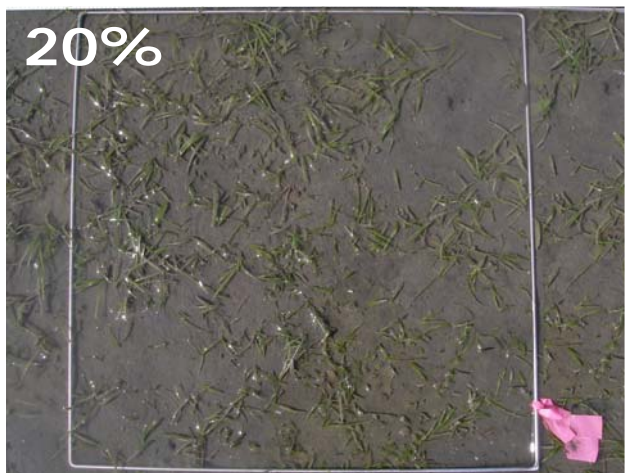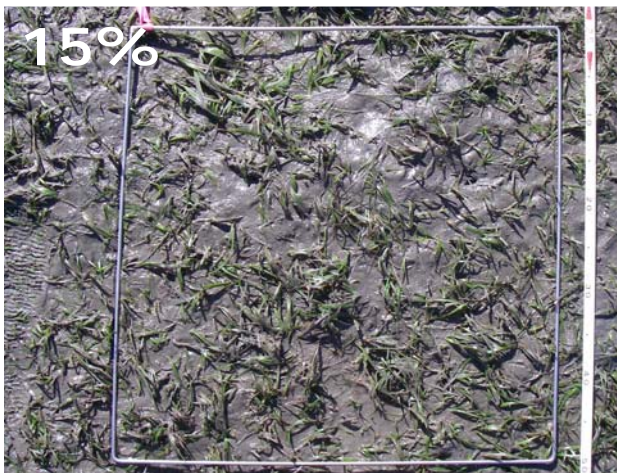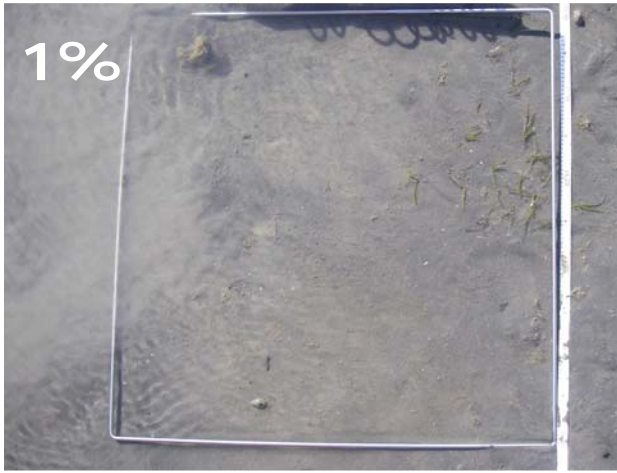
Estuary – *Zostera*

Appendix III

Seagrass identification sheets

SEAGRASS SPECIES CODES

Ea
Enhalus acoroides

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

Th
Thalassia hemprichii

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

Cr
Cymodocea rotundata

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

Cs
Cymodocea serrulata

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

Hb
Halophila beccarii

- leaves arranged in clusters of 5-10 on vertical stem
- leaves elongate, no obvious cross-veins
- short vertical stem between clusters
- leaf clusters do not lie flat
- leaf margin finely serrated
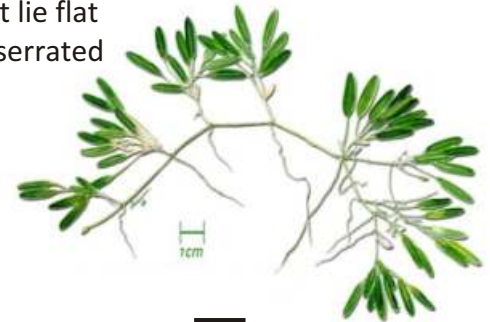
Rm
Ruppia maritima

- leaves fine and thread-like
- pointed tip on leaves, sometimes serrated
- inflorescence on a long stalk, sometimes spiralled
- rhizome fragile
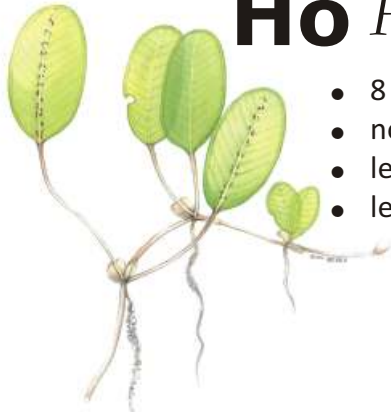- semi-fresh or estuarine environments

Tc
Thalassodendron ciliatum

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

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SEAGRASS SPECIES CODES

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

Hd *Halophila decipiens*
- small oval leaf, slightly pointed
- 6-8 cross veins
- leaf hairs on both sides
- leaf 10-25mm long
- found at subtidal depths

Hs *Halophila spinulosa*
- fern like
- leaves arranged in opposite pairs
- erect shoot to 15cm long
- found at subtidal depths

Hm *Halophila minor*
- less than 8 pairs of cross veins
- small oval leaf blade less than 5mm wide
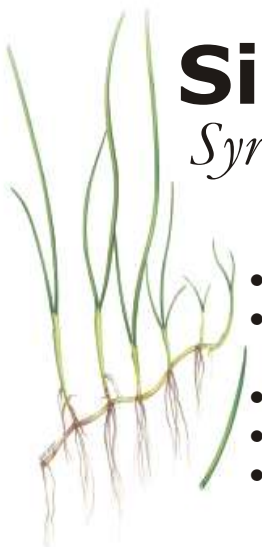- leaf margins smooth
- no leaf hairs

Hu *Halodule uninervis*
- trident leaf tip
- 1 central vein
- usually pale rhizome, with clean black leaf scars
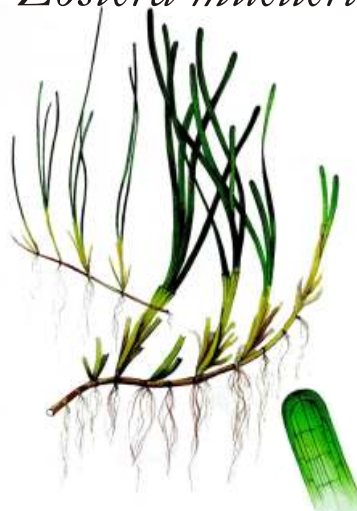
Hp *Halodule pinifolia*
- rounded leaf tip
- 1 central vein
- usually pale rhizome, with clean black leaf scars

Zc *Zostera muelleri* subsp. *capricorni*
- leaf with 3-5 parallel-veins
- cross-veins form boxes
- leaf tip smooth and rounded, may be dark point at tip
- leaf grows directly from rhizome ie no stem
- rhizome usually brown or yellow in younger parts

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

Appendix IV

An alternative method for estimating seagrass abundance

A detailed worked example:

A group of 3 experienced observers were requested to map the distribution and abundance of seagrass meadows within a bay. The group had been requested by DPI to use the seagrass biomass ranking method of Mellors (1991). The survey was conducted over a 1 week period. At the beginning of the survey, the 3 observers gathered together to decide on the "standard ranks" for the study. As one of the observers had been to the area before, they went to a meadow which had both the greatest and lowest above-ground biomass that they expected to see within the bay. They placed a quadrat over an area they all agreed was the highest biomass (referred to as "**standard rank 5**") then another quadrat over an area they all considered was comparatively low biomass (referred to as "**standard rank 1**"). Then using this approach they found an area they all agreed was mid-way between the 5 and 1 (referred to as "**standard rank 3**"), and similarly set up standard ranks **2** and **4**. The standard ranks they set up were what they believed to be a "linear" relationship between the ranks and the above-ground seagrass biomass. They also took photos of the standard rank quadrats so they could refer back during the week of surveying if required.

The observers then proceeded to survey the bay. Each observer recorded their own visual estimate ranks independently of the other observers estimates, and ranks were each estimated to one decimal place. The observers surveyed 1100 points with 3 biomass estimates at each point (a point was agreed to be an area of 5 m radius). At the end of the survey the observers gathered at another meadow which had the highest and lowest biomasses, similar to those found during the survey. At this location the observers threw down 10 quadrats, spread over the range of biomasses observed. Each observer then independently ranked the above-ground biomass in each quadrat, in the same way as they did during the survey. After each observer had ranked each quadrat (being careful not to discuss and compare ranks with other observers), each quadrat was harvested and taken back to the laboratory for sorting.

In the laboratory, the above-ground biomass was separated from the below-ground biomass for each harvested calibration sample (the entire sample was separated, no subsampling). The above-ground component was then dried and weighed to 2 decimal places.

The observer's ranks of the calibration quadrats were then regressed against the actual above-ground biomass for the calibration quadrats (g dry wgt m^{-2}) (see Table 1).

Table 1. Biomass and respective observer ranks for each calibration quadrat.

Calibration Quadrat	Above ground Biomass (g dry wgt 0.25m^{-2})	Observer1	Observer2	Observer3
1	1.55	1.3	1.1	0.5
2	1.95	0.2	0.2	0.1
3	8.75	4.5	4.6	4.8
4	10.93	3.9	3.6	4.3
5	7.18	4.3	4.2	4.4
6	4.93	2.4	2.20	2.1
7	6.53	2.5	3.8	2.4
8	3.95	2.1	2.4	1.4
9	0.7	0.8	0.6	0.2
10	1.01	0.5	0.8	0.4
r^2		0.89	0.94	0.92

A regression is a mathematical equation that allows us to predict values of one dependent variable (in this case the actual above-ground biomass) from known values of one or more independent variables (ie. the observers ranks).

From a plot of each observers ranks against actual above-ground biomass (Figure 1), it appears that quadrat # 4 was an outlier (it was well outside the 95% confidence limits). This means that all the observers had ranked quadrat # 4 too low - possibly because many of the shoots may have been covered with sediment, making estimation difficult, *etc*). After quadrat # 4 was removed, a regression for each observer was calculated (Table 2).

Table 2. Regression of observers ranks

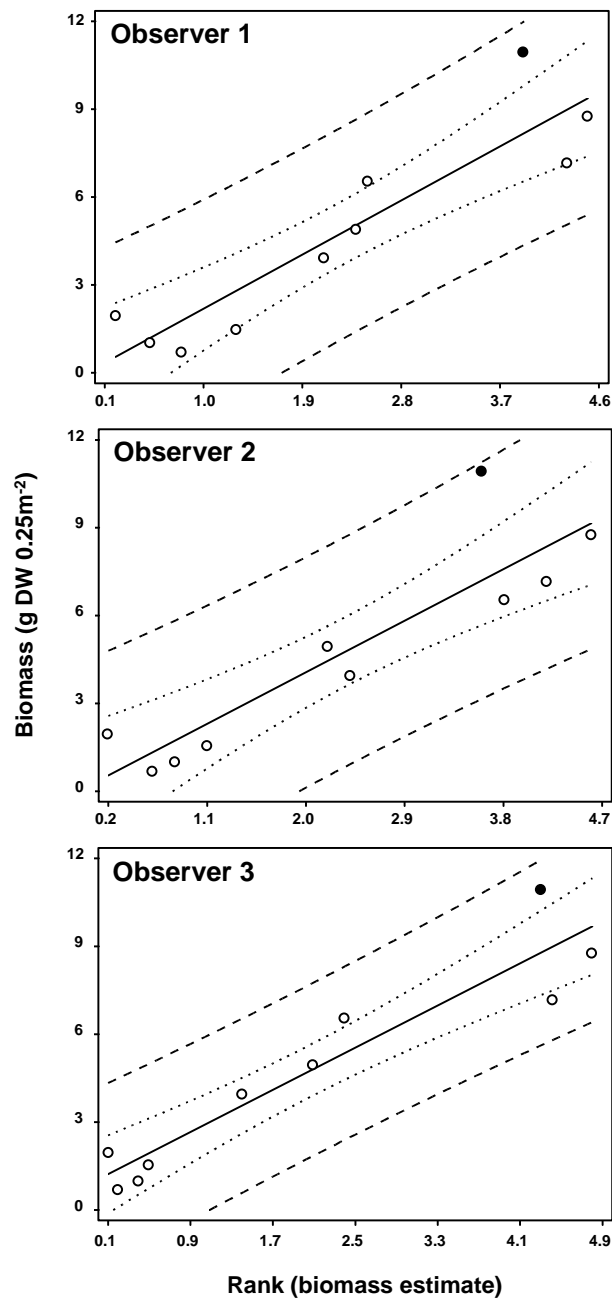| Observer	Regression
Observer1	Biomass = 1.7908 x Rank + 0.3601
Observer2	Biomass = 1.7227 x Rank + 0.2520
Observer3	Biomass = 1.5888 x Rank + 1.1836

Figure 1. Linear regressions to explain the relationship between observer rank and above ground seagrass biomass. (filled circles signify outlier).

Using the regression for each observer, the field ranks estimated by each observer were converted to above-ground biomass (g dry wgt m-2). All calculations of seagrass abundance within the bay were then done using the g dry wgt m-2 values.

Further comments:

- Mellors (1991) *does not recommend using integers, or categories.* An observer can estimate to 1 decimal place without difficulty (I suppose if you rank on a scale from 0.1 to 5.0 you in fact have 50 categories??)

- There is no need for observers to agree in the field after the standard ranks have been established. You do not want a single regression for all observers pooled. This is because *observers will always differ - there is no point observers practicing to get the same rank.* What is important is that **each observer has their own regression,** and that **each observer rank the same way each time**. In fact it is best that observers do not compare ranks at all when surveying an area, as this causes *bias*.

- The only values you are concerned with in the end is the above-ground biomass (g dry wgt m^{-2}). The ranks only mean something to the particular observer who estimated them. **Only the converted biomass estimates should be used for analysis.**

- Re-calibration should be done for each sampling/survey event (*what an observer ranks this week may differ from what they rank next month*) and at different locations.

- There are instances when 2 sets of standard ranks have to be used within the same survey (1 set for low abundance meadows (eg. *Halophila*), 2nd set for high abundance meadows (eg. *Zostera*)) as this allows greater accuracy for biomass estimates.