Methods for Mapping and Monitoring Eelgrass Habitat in British Columbia

Draft 4
December 2002

Precision Identification Biological Consultants

Environment Canada
Canadian Wildlife Service

Environnement Canada
Service Canadien de la faune

Canada

Preface

Field Methods for Mapping and Monitoring Eelgrass Habitat in British Columbia was designed to provide readers with a basic understanding of eelgrass (*Zostera marina* L.) ecology and to provide a standardized set of methods to map, classify, and monitor eelgrass habitat on a local level. The mapping and monitoring system described herein enables community groups and other agencies to contribute consistent and reliable data to a central database.

The manual will be expanded to include a series of monitoring protocols to study various faunal assemblages within eelgrass beds (e.g. fish, zooplankton, and invertebrates). All contributions and comments will be welcomed and acknowledged.

Acknowledgements

The development of this manual was funded by the Canadian Wildlife Service, Environment Canada, Pacific & Yukon Region, Delta; B.C. Jacqueline Booth (Jacqueline Booth and Associates, Salt Spring Island, B.C.) developed the database structure and user interface for storing and retrieving field data on eelgrass beds. She also provided advice based on her experience working with community mapping. Brad Mason (Fisheries & Oceans Canada, Vancouver, B.C.) and Don Chamberlain (Project Watershed, Comox, B.C.) contributed information and guidance relating to the use and limitations of GPS technology. Brad Mason (Fisheries & Oceans Canada, Vancouver, B.C.), Suzanne Richer (Community Mapping Network), and the Community Mapping Network created the internet application and assisted with development of the database structure and functions for providing the online base maps and digitizing tools.

Precision Identification would like to thank and acknowledge the following individuals for their review of the manuscript.

Brad Mason, Fisheries and Oceans Canada, Vancouver, B.C.
Cliff Robinson, Parks Canada, Vancouver, B.C.
Gretchen Harlow, Canadian Wildlife Service, Environment Canada, Vancouver, B.C.
Michele Jones, Mimulus Biological Consultants, Royston, B.C.
Nikki Wright, SeaChange, Victoria, B.C.
Sarah Verstegen, SeaChange, Victoria, B.C.
Rob Butler, Canadian Wildlife Service, Environment Canada, Vancouver, B.C.
Sean Boyd, Canadian Wildlife Service, Environment Canada, Vancouver, B.C.
Ramona C. deGraaf, Dept. of Zoology, University of British Columbia, Vancouver, B.C.
The Seagrass Conservation Group, B.C.

Table of Contents

1.0 Introduction

Land use changes and developments have led to a loss of natural estuarine habitat in British Columbia. Agriculture, forestry, and dredging for commercial and residential development have all contributed to the loss. It is anticipated that the pressure to modify natural estuarine habitat for the development of commercial facilities and residential units within coastal areas will intensify in the near future. It is therefore necessary to identify, classify, quantify, and develop a scientifically defensible management strategy for estuarine habitat in order to protect and maintain these valuable areas.

Eelgrass (*Zostera marina* L.) meadows represent one of the habitat types that are threatened by estuarine development. Various types of disturbance in coastal and estuarine environments have led to a decline in seagrass abundance around the world (Short & Wyllie-Echeverria, 1996). Losses in Chesapeake Bay, United States, have resulted from impaired water quality caused by upland development, agriculture, and shoreline development (Orth & Moore, 1983, Dennison et al. 1993). Pollution induced seagrass declines have been documented in the Mediterranean and along the Atlantic coast of Europe (Nienhuis 1983; Hanekom & Baird 1988; Giesen et al. 1990; Short et al. 1991; DeJong & DeJong 1992; den Hartog 1994).

Seagrasses, including eelgrass, have been used as indicators of nearshore ecosystem health in many areas of the world (Sewell et al., 2002). In Chesapeake Bay, a submerged vegetation monitoring program (eelgrass & freshwater vascular plants) identified a link between decreased productivity within the Bay and degraded water quality from upland watershed activities (Orth & Moore, 1983). The data was used to enact legislation to restrict the activities responsible for the impairment of water quality, which was successful in reversing the trend of vegetation loss (Dennison et al., 1983).

Eelgrass provides critical habitat for numerous species including; outmigrating juvenile salmon (*Oncorhynchus* spp.), Pacific herring (*Clupea harengus*), Dungeness crab (*Cancer magister*), and black brant (*Branta bernicla*) (Norris & Wyllie-Echeverria, 2001). The productivity of eelgrass meadows rivals that of cultivated tropical agriculture (Zieman & Wetzel, 1998). Research in Denmark discovered that detritus, primarily derived from eelgrass, was the basic source of nutrition for animals in Danish coastal waters, and that the historic abundance of fish in Denmark was mainly due to eelgrass (Phillips, 1984). The leaves of eelgrass baffle currents, reducing water velocity and promoting sedimentation. The root-rhizome network forms an interlocking matrix, which binds sediment and restricts erosion (Phillips, 1984).

A study by Helfferich and McRoy in 1978 calculated the U.S. dollar value of eelgrass meadows to be $12,325.00 per acre per year based on its contribution to commercial and recreational fisheries and hunting.

The governments of many countries including the United States, Australia, New Zealand, South Africa, and Britain have recognized the value of seagrass habitat and have implemented seagrass mapping and monitoring programs. These programs involve locating and mapping seagrass communities, usually through analysis of aerial photographs, followed by detailed monitoring of specific sites on the ground. The costs associated with these types of inventories are prohibitive in British Columbia at this time.

Eelgrass has been mapped in several areas of British Columbia, by various groups, using various methods. The majority of the eelgrass mapping information (e.g. herring spawn surveys) was completed in the late 1970s, and may not reflect current conditions.

Environment Canada commissioned the following report to provide the necessary understanding of eelgrass ecology and mapping methodologies to identify, classify, and quantify eelgrass habitat in British Columbia on a local level. The mapping and monitoring system enables local groups and organizations to contribute consistent and reliable data to a central database.

An interactive data entry tool has been developed for this purpose, and is available on the Community Mapping Network website (http://www.shim.bc.ca/eelgrass/main.htm). The data that are collected will be integrated into a larger scale province wide inventory. It is hoped that this information will promote the development of a comprehensive eelgrass mapping and monitoring strategy for British Columbia that may be used to protect eelgrass habitat.

2.0 Eelgrass Ecology

Eelgrass meadows are naturally highly dynamic systems, often changing from year to year or from season to season, reflecting changes in the environment. It is important to understand the natural variability within these ecosystems, in order to avoid false conclusions when assessing changes over time. The following sections were designed to provide an overview of eelgrass ecology and an appreciation for the inherent natural variability both within and between meadows.

Reproduction

Eelgrass reproduces both sexually (seeds) and asexually (branching). The plants flower annually and produce many viable seeds; however very few successfully mature into plants. The flowers are produced on reproductive shoots that develop from vegetative shoots. Once the seeds have developed, the shoot begins to senesce, breaks free from the rhizome, and floats away. Detailed monitoring of eelgrass densities should include enumeration of flowering shoots as well as vegetative shoots, due to the ephemeral nature of the flowering shoots.

Eelgrass reproduces vegetatively by forming new shoots at the base of the parent shoot. The rhizome branches, allowing the new shoot to grow away from the parent shoot. A single plant may have numerous shoots connected via a single branched rhizome. As time passes, older rhizomes decay, so that one plant eventually becomes two or more plants. An eelgrass meadow could, in theory, be composed of many shoots that originated from a single individual.

Species and Ecotypes

There are two species of eelgrass in British Columbia; the native species *Zostera marina* and the introduced species *Zostera japonica*. It is believed that *Z. japonica* was accidentally introduced with oyster spat brought from Japan to aquaculture sites in Washington State (Harrison, 1976). The introduced species is generally smaller and can tolerate exposure (due to its morphology) better than the native species. The introduced species can not compete with the native species due to its smaller size, thus it is not a threat to the native eelgrass. *Z. japonica* is often found adjacent to, or intermixed with, *Z. marina* at higher elevations. The information provided for eelgrass in this document relates specifically to *Z. marina* although it could be easily modified to study populations or meadows of *Z. japonica*.

The leaf length and width of both species varies with depth; as depth increases leaf length and width increases. The leaf length and width of intertidal *Z. marina* is often within the range of *Z. japonica*. Fortunately, the two species have different types of sheaths; this enables one to easily differentiate the species. *Z. marina* has an entire sheath, it is closed to the base; when the lower leaves are slowly pulled in opposite directions the sheath will tear. The sheath of *Z. japonica* is open to the base; thus the sheath parts rather than tears when stress is applied.

It has been proposed that there are races, or ecotypes of *Z. marina* that account for part of the morphological variation (Beckman 1984). It is possible that three of the ecotypes occur in British Columbia. The attributes associated with each ecotype are summarized in Table 1.

Table 1. The habitat and morphological attributes associated with the three ecotypes of *Zostera marina* common in British Columbia. (adapted from Backman, 1984)

Ecotype	Relative leaf size	Leaf width (mm)	Depth range (m)	Seasonal variation in size	Current tolerance
typica	narrow	2 to 5	primarily intertidal	small variation	low
phillipsi	intermediate	4 to15	0 to - 4	large, plant length reduced in winter	moderate
latifolia	large	12 to 20	-0.5 to -10	minimal variation	strongest

An eelgrass meadow may contain one or more ecotype.

The smaller intertidal plants usually occur at a much greater density, due to their smaller size, than those growing in deeper water. For example, a dense meadow of intertidal eelgrass may have a density of 2000 shoots$\cdot$m^{-2}, while the adjacent subtidal habitat supports 120 shoots$\cdot$m^{-2}. The biomass (g$\cdot$m^{-2}) of the less dense subtidal plants can easily exceed that of the intertidal plants due to the larger size of the individual shoots; a factor that must be taken into consideration when sampling.

Cover

The aerial coverage of an eelgrass meadow reflects both the substrate and the hydrodynamic regime. A quiescent environment with a sandy mud substrate generally supports a dense continuous eelgrass bed with virtually 100% cover. The cover of eelgrass in areas subjected to strong currents is typically patchy. Areas with heterogeneous substrate (mixture of fine and coarse) also tend to be patchy.

Eelgrass meadows are spatially dynamic, the edges expand or recede in response to environmental variables. Severe storms may damage or destroy entire meadows. Severe frost (winter) and intense heat (summer) may also kill shoots exposed at low tide. Shifting sand (active sediment bed movement) can have a significant effect on eelgrass distribution.

Density

The density of shoots within an eelgrass bed may be consistent throughout the bed or it may vary in response to environmental parameters within the bed (currents, sediment type, depth, turbidity). In addition, if several ecotypes are present the density will vary depending on the distribution of each ecotype within the bed. In order to determine the mean density of shoots within a bed, the investigator must first establish whether there is any sort of density zonation within the bed, then design a sampling procedure to assess each zone independently. Permanent transects are not recommended as repeated trampling may alter the density along the transect, unless the site is surveyed at high tide using SCUBA or video. Additionally, permanent transect markers collect floating debris and often result in sediment scour.

Environmental Requirements

The growth and distribution of eelgrass is influenced by salinity, sediment type, current velocity, light availability, temperature, and pH. Temperature and pH are not usually restrictive along coastal British Columbia. A summary of the range and optimal levels for each of these parameters is provided in Table 2.

Table 2. Environmental requirements for vegetative growth of eelgrass (Phillips, 1974).

Parameter	**Range**	**Optimum**
salinity	freshwater to 42 ppt	10 to 30 ppt
sediment type	firm sand to soft mud	mixed sand and mud
current velocity	waves to stagnant water	little wave action gentle currents to 3.5 knots
light/depth	1.8 m above MLLW to –30 m	MLLW to – 6.6 m
temperature	-6 °C to 40.5 °C	10 °C to 20 °C
pH	7.3 to 9.0	7.3 to 9.0

MLLW- mean low low water ppt – parts per thousand

The literature reports that eelgrass is restricted to soft sediment; however it is often found in areas with significant amounts of gravel and cobble in British Columbia. There are two known areas where eelgrass has adapted to grow over hard substrate, one on rock in Port McNeil (Durance), and one on cement blocks near Victoria (Austin).

The maximum depth to which eelgrass can grow at a specific location depends on the turbidity of the water, since the amount of light that penetrates the water is reduced when turbidity increases.

3.0 Mapping and Monitoring Parameters

Eelgrass meadows possess many attributes that can be mapped and monitored to assess changes over time and track ecosystem health. The parameters that are selected for study depends on the objectives or goals of the study and the resources available. Monitoring specific meadows, using scientific sampling methods, can provide the data required to detect and assess environmental changes. There are many variables that are commonly measured to detect changes in eelgrass populations or meadows and the environment. The following section reviews the parameters that are frequently used to study eelgrass, and the value associated with each.

Location

An inventory that locates and characterizes eelgrass beds provides a valuable tool that can be used by various resource managers and assist with the development of Integrated Coastal Zone Management plans. Fisheries and Oceans Canada has a policy of 'no net loss', thus proposed development may not impact known eelgrass habitat unless it can be shown that adequate compensation will be provided. Knowing the location of each eelgrass bed would therefore assist in conservation.

Delineation

The delineation of eelgrass beds enables the detection of increases or decreases in area, or range, over time that can be tracked. Losses may be used to detect environmental change, and develop mitigation plans to prevent further degradation. In addition, any industry or development that can be shown to impact eelgrass habitat may be forced by Fisheries and Oceans to provide mitigation, restoration, or compensation.

Depth Distribution

The distribution of eelgrass across a bathymetric gradient is limited at the upper boundary by the degree of exposure at low tide (desiccation) and by light limitations at the lower boundary. In some cases substrate characteristics change with depth; this may also limit eelgrass distribution. Degradation of water quality that results in increased turbidity (e.g. suspended solids, chlorophyll A increases) leads to a decrease in the maximum depth possible for eelgrass survival. Trends in the maximum depth distribution of eelgrass over time can be used as 'a predictor of ecosystem health' (Dennison et al., 1983).

Shoot Density

Eelgrass shoot densities vary over time in response to environmental variables (natural and anthropogenic) and are therefore useful indicators of environmental change (Phillips et al., 1983, Olesen et al., 1994). The number of flowering shoots within the meadow is usually determined as part of the density estimate since it may reflect- environmental change or stress, and because the flowering shoots will senesce after they reach maturity, resulting in a decrease of total shoot density.

Distribution

The maximum coverage of eelgrass at a specific site is strongly influenced by the hydrodynamic setting. Quiescent bays tend to support homogenous eelgrass meadows, whereas areas that experience stronger currents and active seabed movement tend to have a patchy eelgrass distribution. The homogeneity of an eelgrass bed can also be reduced by anthropogenic disturbances (shellfish harvesting, boat anchoring, dredging activity, trampling, etc.).

The integrity of an eelgrass bed may be threatened by fragmentation. The plants within established eelgrass beds reduce currents, leading to increased sediment and organic detritus deposition. The dense rhizome and root matrix of the plants, in conjunction with the enhanced deposition rate assists in stabilization of the substrate. 'If an established, continuous bed becomes fragmented for any reason, the bed will tend to become less stable and more vulnerable to the normal forces of erosion. Channels may form, the cover may become patchier and if the trend continues, isolated patches will develop which are more likely to be washed away. It would appear that there is a threshold of loss, below which destabilization and further losses of beds can occur '(Holt et al., 1997).

Monitoring the homogeneity or patchiness of a meadow over time can help to identify impacts and lead to the implementation of mitigation programs to prevent further loss.

Leaf Area Index (LAI)

Leaf area indices are often used to estimate the productivity of eelgrass and the amount of habitat available for colonization by epifauna. The LAI is calculated according to the following formula:

$$\text{LAI} = \text{mean shoot length} \times \text{mean shoot width} \times \text{mean density of shoot} /m^2$$

LAI is potentially more sensitive to environmental stress than is a parameter such as leaf width since it integrates both density and area (Neckles, 1994).

Shoot Biomass

Mean shoot biomass (dry weight of plant material per unit area) estimates are commonly used to assess the productivity of eelgrass beds and detect changes over time. The technique is universally accepted, however it requires destructive sampling and equipment that may not be available in all regions (ovens and scales).

Water Quality

The physical properties of seawater, especially in estuarine environments, fluctuate constantly in response to tides, currents, and volume of fresh water inflow. Many eelgrass monitoring programs incorporate environmental parameters into their study to provide a 'snapshot' of conditions that may, in turn, provide clues to significant water quality differences (Sewell, 2001).

The environmental parameters that are included in several large scale eelgrass monitoring projects are listed in Table 4. A brief summary of each program is provided in Appendix 1.

Table 4. Environmental variables included in several large scale eelgrass monitoring projects.

Parameter	**Puget Sound Submerged Vegetation Monitoring Project**	**SeagrassNet**	**European Directorate Special Areas of Conservation Program**
Temperature	√	√	-
Salinity	√	√	-
Dissolved oxygen	√		-
Turbidity	√	√	√
Photosynthetically Active Radiation	√	-	-
Light parameters, back scatter, florescence	√	-	-
Surface sediment character	-	√	-
Nutrient Levels	-	-	√

4.0 Strategy

The following strategy integrates four levels of study to enable all interested parties to participate in a large scale mapping effort. The level of detail that is selected to map and/or monitor an eelgrass meadow will be dependant on the specific goal of the study and the resources available. The use of standardized data dictionaries and data sheets ensures that all of the data that are collected are useful and may be integrated into the interactive database and mapping website (www.shim.bc.ca/maps.html).

The goals associated with each of the four levels, and a list of data required to achieve these goals are summarized below. The set parameters that must be assessed in order to meet the data requirements associated with each level are listed in Table 5. Details relating to the requirements are provided in Section 5.

Level 1

Goal: Conservation of intertidal eelgrass habitat

Requirements:
- identify the location of intertidal eelgrass meadows
- characterize the habitat within the intertidal area of the meadow

Level 2

Goal: Conservation of intertidal and subtidal eelgrass habitat

Requirements:
- identify the location and area of all eelgrass meadows
- characterize the habitat within the entire meadow

Level 3

Goal: Conservation of eelgrass meadows and early identification of habitat degradation or loss

Requirements:
- identify the location and area of all eelgrass meadows
- monitor eelgrass meadows to detect changes

Level 4

Goal: Conservation of eelgrass habitat and early identification of habitat degradation or loss and environmental stressors

Requirements:
- identify the location and area of all eelgrass meadows
- monitor eelgrass meadows to detect changes
- monitor changes in the surrounding environment water quality

Table 5. Minimum parameters to be assessed for each Level.

Parameter	**Level 1**	**Level 2**	**Level 3**	**Level 4**
location of eelgrass meadows	√	√	√	√
overview of intertidal habitat	√	√	√	√
overview of subtidal habitat		√	√	√
delineation of meadow(s)		√	√	√
maximum and minimum depth			√	√
distribution (degree of patchiness)			√	√
shoot density, including sexual status			√	√
Leaf Area Index (LAI)			√	√
turbidity			√	√
salinity				√
Total Suspended Solids (TSS)				√
chlorophyll A				√

5.0 Methods

The following methods are based on protocols that have been employed to map and monitor eelgrass communities. The methods are provided to enable groups or agencies to map eelgrass in a consistent manner, and to contribute to a central database using a standardized data entry form.

Mapping exercises should be completed during the summer, this will minimize the amount of variation between beds that is due to seasonal change. Monitoring should also be conducted during the summer, although the frequency of monitoring will depend on the resources of the study team. Monitoring programs may collect data annually (summer), biannually (summer and winter), or seasonally. Multiyear monitoring programs should be designed to ensure that field surveys are conducted within two weeks of the calendar date (month and day) of the original monitoring.

There are a minimum set of parameters associated with each level, however any of the parameters from higher levels may be included a survey. For example, a group may elect to complete a Level 1 survey but decide to collect shoot density data for the intertidal area with the methods used for a Level 3 & 4 survey.

Strategies may be developed to suit the requirements of each sampling team by using combination of levels. A recommended strategy is to map all eelgrass within a geographical area at Level 2, and then to select several meadows of interest to monitor at Level 3 or 4 on a regular basis. The meadows that are selected for monitoring would be in areas of potential environmental concern and at least one that is in a relatively protected area to use as a reference site.

A list of the equipment required for each level of study is provided in Appendix 2. Safety considerations for working in intertidal and subtidal eelgrass beds are provided in Appendix 3. Appendix 4 provides a suggested list of steps to complete each level of survey. A field datasheet and a draft of the data entry form are included in Appendix 5.

Location of Eelgrass Beds – All Levels

The first step is to identify the location of local eelgrass beds. It may take several years to locate all of the beds within a specific geographical area; depending on the time and resources that a specific group or organization has to dedicate to the project.

There are many sources of information that may assist in identifying the location of eelgrass beds. Sources that should be reviewed include: Herring Spawn Maps, Airphotos, Orthophotos, and the Community Mapping Network website (www.shim.bc.ca/maps.html).

The locations of eelgrass beds may be identified through low tide surveys, community surveys, diver surveys, and/or the use of a towed underwater video camera.

A survey of the low intertidal, conducted during the lowest daytime tides of the year, may be used to identify the location of many local eelgrass meadows. A survey of this type would only detect meadows that extend into the intertidal and would not provide information on the location of meadows that are restricted to subtidal areas.

Information may be solicited from the community. Local residents can provide information on the general locations of beds, which can later be assessed by the study team. The Shorekeepers manual provides many suggestions for gathering information from the community (http://www.pac.dfo-mpo.gc.ca/sci/protocol/shorekeepers/Guide/default.htm).

Diver surveys of the entire coastline are impractical, but may be used in areas where subtidal eelgrass is suspected.

A towed underwater video system can be used effectively to detect eelgrass beds. Underwater cameras that feed information into an above water videorecorder are available for $300 (black & white) and $1000 (colour). It is suggested that the habitat around –2 m to –5 m (chart datum) be investigated, as most subtidal eelgrass beds will extend across this depth.

The boundary of an eelgrass bed may be difficult to establish. In some cases it is very distinct, yet often the density of shoots slowly decreases around the perimeter. In order to be consistent, the Puget Sound study decided that areas that supported a minimum density of one (1) shoot per m^2 would be included in the bed. It is recommended that we adopt the same criteria. The edge of the bed shall be defined as the point at which the density decreases below 1 $shoot \cdot m^{-2}$, beyond which it continues to decrease. In areas that support a patchy distribution of eelgrass, there may be distances of several metres between patches. In these areas the edge of the bed should be located at the outer edges of the first and last patch.

Preliminary testing suggests that a hand held GPS may be as accurate as a differential GPS for mapping eelgrass beds. The results obtained by using a hand held (Garmin GPS 12XL without differential) and a differential (Trimble Pathfinder Pro XR) GPS were compared in an intertidal area of Comox Harbour. The two types of GPSs provided results within 1 metre of each other. Bill Mather (Coast Guard, Bamfield) reports that he has found the accuracy of a hand held GPS to be consistently within 5 metres on the sea, and frequently within 1 metre. Handheld GPSs should only be used with 3D NAV available with the averaging function enabled for capturing point data. Track logs can be used effectively to walk perimeters of beds. The locations may be also be drawn on orthophotos, charts, cadastral maps, or TRIM sheets depending on the scales at which these products are locally available.

Overview of Intertidal Habitat – All Levels

The data form provides a series of fields and categories to describe each bed. The fields include form, distribution, density, and substrate type.

There are two basic forms of eelgrass beds in the Pacific Northwest; fringing beds that occur as relatively narrow bands usually on gentle slopes, and more expansive beds that cover large areas such as tidal flats.

The distribution of eelgrass within the bed will be recorded as either continuous or patchy. Patchy beds are those that contain isolated groups or patches of plants. Beds, which are not patchy, will be classified as continuous; a bed that has a few bare patches would rate the continuous classification. A graphic representation of each distribution type is provided in Appendix 6.

An estimate of the percent cover of eelgrass at low tide, according to the categories supplied on the datasheet, is required. If the cover varies significantly then the primary, secondary, and, if necessary, tertiary densities should be recorded. Similarly, the common substrates should be recorded in order of dominance. If more than one percent cover class or substrate type is present then the percentage that is occupied by each type should be recorded according to the categories provided on the datasheet. Appendix 7 provides additional detail relating to percent cover assessments.

Reference photographs of the exposed bed should be taken during each survey. The photographs should include a site view and several close up photos of the eelgrass. An object, such as a metre-stick or pencil should be included in each close-up photo to provide a scale reference. Photographs should be taken from similar locations during subsequent surveys.

Overview of Subtidal Habitat – Levels 2, 3, and 4

The data required to provide an overview of the subtidal habitat mirrors that required to describe intertidal habitat.

Bed Delineation – Levels 2, 3, and 4

A GPS is used to georeference the boundaries of the eelgrass bed and create a polygon, which may be used to determine the area covered by eelgrass. The boundaries of the bed may be determined using; an aquaviewer, a diver or snorkler with weighted floats (Appendix 8), or a towed underwater camera. The depth to which the aquaviewer may be used successfully would depend on the turbidity of the water and the depth range of the eelgrass at each location.

GPS readings should be recorded at roughly 15 metre intervals around the perimeter of the bed.

The rules for defining boundaries and describing the bed follow those provided for intertidal eelgrass meadows above.

A detailed protocol for using a GPS to map the perimeter of eelgrass beds will be included in a subsequent version of this manual.

Maximum & Minimum Depth – Levels 3 & 4

The maximum and minimum depths should be determined when the bed is submerged. Divers depth gauges may only be used if they are known to be accurate to +/- 0.2 metres. One of the preferred methods is to have a weight attached to the end of a metre tape, which is lowered to a diver at the deepest and most shallow edge of the eelgrass bed. The diver places the weight on the bottom then tugs three times to notify the assistant on the boat that the line is in place. The assistant checks to make sure that the line is taught and vertical then records the measurement.

It is important to record the exact time that the measurement is recorded so that the reading may be adjusted to chart datum. Tidal heights over time may be downloaded from many sources including http://tbone.biol.sc.edu/tide/sites_othernorth.html.

Distribution – Levels 3 & 4

The distribution and zonation of eelgrass within a bed must be assessed in order to select the appropriate method for estimating shoot density.

Distribution

The distribution of eelgrass within the bed may be described as either patchy or continuous. Patchy beds are those that contain isolated groups or patches of plants. Beds, which are not patchy, will be classified as continuous; a bed that contains bare patches surrounded by eelgrass would be classified as continuous. A graphic representation of each distribution is provided in Appendix 6.

Zonation

The density and leaf size of eelgrass may be consistent throughout the bed, or may vary with depth. Typically, there are two or three zones within the bed, each located along a slightly different depth gradient. Each zone blends over several metres into the next; these areas are referred to as transition areas. The density and size of the shoots is significantly different between zones, therefore each zone must be sampled individually. Sampling should be conducted outside of the transition areas. The zones should be classified numerically starting with the uppermost zone. Zones that are less than 4 metres in width do not need to be assessed. The width of each zone does not need to be recorded as the exact boundaries are difficult, if not impossible to determine.

It is necessary to determine the number of zones within a bed in order to establish the number and location of transects to be sampled.

The following hypothetical description of an eelgrass bed is intended to provide the reader with an understanding the zonation typical in British Columbia.

> Zone 1 is a narrow band 8 metres wide, located in the low intertidal and shallow subtidal. The zone is characterized by a sparse population of short eelgrass (length 25 cm, density 32 shoots/m^2). Zone 1 blends into Zone 2, at a slightly lower elevation. The plants in Zone 2 are larger and more dense (80 cm, 112 shoots/m^2) than in those located in Zone 1. Zone 2 is 50 metres in width. The majority of the bed is located in Zone 2. Zone 2 merges into a third zone of sparse but larger plants (160 cm, 20 shoots/m^2) as the depth increases. Zone 3 is 10 metres wide.

Shoot Density

The protocol for density was designed to measure the mean density of shoots within the vegetated areas of the bed. Shoot density needs to be quantified within each zone. A 0.25 m^2 quadrat (50cm x 50 cm) should be used to assess density in most cases. This represents ¼ of a m^2.

Intertidal eelgrass may reach densities in excess of 500 shoots·0.25m^{-2}. It is recommended that a smaller quadrat (25cm x 25 cm) be used to monitor density once the number of shoots·0.25m^{-2} exceeds 100. A quadrat of this size represents 1/16 of a m^2.

Continuous Eelgrass Meadows

A temporary transect using a metre tape or marked line should be established in each zone, roughly parallel to the shore, along a depth continuum. The length of each transect should be roughly 60% of the bed width, to a maximum of 60 metres. The transects should be centred in the bed to avoid edge effects.

Predetermined random numbers will establish the location along either side of the transect where quadrats should be placed. Initially, thirty quadrats should be assessed for density within each zone. It will be necessary to determine the number of replicates (quadrats) that are required to estimate the mean density of shoots on a site specific basis due to the natural variability within eelgrass communities. The accepted method by which to accomplish this is to plot the running mean. Sample size is adequate once the variation between samples, which decreases as the number of samples increases, is reduced to 5%. It is likely that the number of replicates required will be less, however this number of samples should be sufficient to determine the running mean.

The total number of shoots rooted in each quadrat should be recorded, along with the total number of reproductive shoots in each quadrat. The number of vegetative shoots is calculated by subtracting the number of reproductive shoots from the total number of shoots.

Patchy Eelgrass Beds

It is challenging to design a sampling method for patchy (fragmented) beds as the size and distribution of patches will vary between and within sites. The following method may require revision.

Establish a temporary transect line parallel to shore. Start at the zero metre mark and record the length along the transect that is occupied by the first patch located under the transect line. If the area of the patch exceeds 1m^2, use a quadrat to determine the density (total number of shoots rooted within the quadrat and number of reproductive shoots) within 0.25m^2, avoiding the edges of the patch. If the patch is greater than 6m^2, monitor two quadrats within the patch. Attempts should be made to sample randomly, one method is to hover over the patch and allow the quadrat to drop to the bottom, and sample wherever it lands. Follow the transect line recording the distance that it travels over each patch, the distance between each patch, and the density within patches >1m^2.

Leaf Area Index (LAI)- Level 3 and 4

The mean leaf length and width can be determined from a random sample of 30 shoots. The data may be collected at the same time as the density is assessed. In order to avoid sampling only the largest shoots, measure the shoot located nearest to the upper right corner and the lower left corner of the quadrat. Measure the leaf length from sheath to tip of the second oldest leaf and the width near the middle of the leaf.

Calculate the LAI according to the following formula:

LAI = mean shoot length x mean shoot width x mean density of shoot /m^2

There are variations in the way that researchers measure LAI; some include the sheath, and others measure each leaf. The above method was selected, as it requires the least amount of time to calculate and can be used to provide a relative estimate of biomass.

Turbidity - Level 3 and 4

A secchi depth reading is recommended to assess turbidity.

Salinity - Level 4

A salinometer should be used to determine salinity, in parts per thousand (ppt).

Total Suspended Solids - Level 4

Water samples should be collected and taken to a local laboratory for analysis. The laboratory will provide a specific protocol for collecting and storing the samples.

Chlorophyll A - Level 4

Water samples should be collected and taken to a local laboratory for analysis. The laboratory will provide a specific protocol for collecting and storing the samples.

References

DeJong, V.N. and D.J. DeJong. 1992. Role of tide, light, and fisheries in the decline of Zostera marina L. in the Dutch Wadden Sea. Netherlands Institute for Sea Research Publications Series 20:161-176

Den Hartog, C. 1994. Suffocation of a littoral Zostera bed by Enteromorpha radiata. Aquatic Botany 47:21-28

Dennison, W.C., R.J. Orth, K.A. Moore, J.C. Stevenson, V. Carter, S. Kollar, P.W. Bertgstrom, and R.A. Batiuk. 1993. Assessing water quality with submerged aquatic vegetation. Bioscience 43:86-94.

Geisen, W.B.J.T., M.M. Van Katwijk, and C. Den Hartog. 1990. Eelgrass condition and turbidity in the Dutch Wadden Sea. Aquatic Botany 37:71-85

Hanekom, N. & D. Baird. 1988. Distribution and variations in seasonal biomass of eelgrass Zostera capensis in the Kromme Estuary, St. Francis Bay, South Africa. South African Journal Marine Science 7:51-59.

Harrison, P.G. 1976. *Zostera japonica* Archers. & Green. in British Columbia, Canada. Sepsis 9:359-360

Helfferich, C. and C.P. McRoy. 1978. Economic evaluation of seagrass ecosystems. In: McRoy, C.P. and S. Williams, eds., Seagrasses in the United States: an ecological review in relation to human activities. Rep. to the Fish. and Wildlife Service, Inst. Mar. Sci., Univ. of Alaska, Fairbanks.

Holt, T.J., R.G. Hartnoll, & S.J. Hawkins. 1997. Sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, Zostera beds and Sabellaria spinulosa reefs. Peterbourough English Nature, Research Report No. 234

Neckles, H.A. (ed.) 1994. Indicator development: Seagrass monitoring and research in the Gulf of Mexico. U.S.E.P.A.

Neinhuis, P.H. 1993. Temporal and spatial patterns of eelgrass (*Zostera marina* L.) in a former estuary in the Netherlands, dominated by human activities. Marine Technology Society Journal 17:69-77.

Olesen, B. and K. Sand-Jensen. 1994. Patch dynamics of eelgrass, *Zostera marina*. Marine Ecology Progress Series. 106:147-156

Orth, R. J. & K.A. Moore. 1983. Chesapeake Bay: An unprecedented decline in submerged aquatic vegetation. Science 22:51-52

Phillips, R.C. and R.L. Lewis. 1983. Influence of environmental gradients on leaf widths and transplant success in North American seagrasses. Marine Technology Society Journal. 17:59-68.

Sewell, A.T., J.G. Norris, S. Wyllie-Echeverria, and J. Skalski. 2001. Eelgrass Monitoring in Puget Sound: Overview of the Submerged Vegetation Monitoring Project. Washington State Department of Natural Resources.

Short, F.T., G.E. Jones, & D.M. Burdick. 1991. Seagrass decline: Problems and Solutions, p. 439-453. In: H.S. Bolton (ed.), Coastal Wetlands, Proceedings of Coastal Zone '91 Conference, American Society of Civil Engineers, New York

Short, F.T., & S. Wyllie-Echeverria. 1996. Natural and human induced disturbance of seagrasses. Environmental Conservation 23.

Short, F.T. D.M. Burdick. 1996. Quantifying Eelgrass Habitat Loss in Relation to Housing Development and Nitrogen Loading in Waquoit Bay, Massachusetts. Estuaries Vol. 19 No. 3 p. 730-739.

Appendix 1 – Summary of Several Seagrass Mapping and Monitoring Programs

The following pages summarize several seagrass mapping and monitoring programs that have been recently implemented. Additional information may be obtained from the website addresses for each program.

Puget Sound Submerged Vegetation Monitoring Program

The objective of the Submerged Vegetation Monitoring Program is to 'quantify the state resource and its change over time' (Sewell et al., 2001). The four goals established by the program are:

1. Capture Temporal Trends in Eelgrass Distribution and Abundance in Puget Sound
2. Summarize Temporal Trends over Puget Sound and subareas
3. Monitor vegetation parameters that are strong indicators of eelgrass extent and quality
4. Link stressors to abundance and distribution. Six "core" sites will be sampled each year, and the remainder of Puget Sound will be sampled using rotational random sampling with partial replacement.

The program reviewed the available methodologies suited to goal 1 and selected linear transect sampling using a towed underwater video. Details are available in Norris et al., 2001a.

Methods that were considered and rejected included airborne remote sensing and colour air photo interpretation. Airborne remote sensing was rejected as the accuracy associated with this technique is +/- 40 feet which would not permit trend analysis, many of the beds in Puget Sound are located on beaches <40 feet wide, and the deep edge of many beds would not be visible. NOAA recommends using colour air photo interpretation, and stresses the importance of filming under optimal conditions, which are not always available in the Pacific Northwest.

SeagrassNet

*SeagrassNet is global monitoring program to investigate and document the status of seagrass resources world wide and the threats to this important and imperilled marine ecosystem (*www.seagrassnet.org*)*. The objectives of the program are to preserve seagrass ecosystems by increasing scientific knowledge and public awareness of this threatened coastal resource. The program began with seven countries in the Western Pacific and is expanding. The program uses a globally applicable monitoring protocol and a web-based interactive database. Each site is monitored on a quarterly basis.

The protocol involves determining distribution (including maximum and minimum depth), species composition, and abundance (cover, canopy height, shoot density (reproductive status) and above and below ground biomass) along permanent transects (parallel and perpendicular to the shore).

Environmental data is collected as follows:

water temperature - continuous reading at deep and shallow stations using tidbit data loggers,

light levels - % surface light using a Hobo light sensor, meters record data for two weeks at the time of each quarterly sampling, plus one land-based meter at a nearby location without shade,

salinity - water samples collected from three stations and analysed on a refractometer at a laboratory

surface sediment characteristics – estimates of the sediment type at three points on each cross transect and collect a core at each station on the primary transects

European Union Special Areas of Conservation

The European Union's Habitat Directive and developments to the Oslo and Paris Convention (OSPAR) lead to the creation of the Special Areas of Conservation (SAC) program. Eelgrass beds were identified as one of the habitats of major importance. Experts from academic and research institutes and nature conservation bodies compiled an Overview of Dynamics and Sensitivity Characteristics for Conservation Management of Zostera Biotopes. The review provides recommendations for mapping and monitoring.

The review states that "of the various monitoring techniques, airborne or sublittoral remote sensing (including side scan sonar) can rapidly map the distribution of beds over a large area, but must be ground-truthed by some other method. Underwater video and field observers (diving or shore) must be used to provide information on plant condition and associated biological community."

The review recommends the following parameters need to be monitored to detect change in the extent or health of eelgrass communities;

- distribution and extent of eelgrass coverage
- standing crop (biomass) and shoot density
- condition of shoots (leaf length, sexual status)
- occurrence of characteristic and representative species in the associated community
- local water quality (turbidity, nutrient levels)

Details are available at http://www.english-nature.org.uk/uk-marine/

Appendix 2 – Equipment

The following table lists the basic equipment that is required for each level of survey.

Equipment	Level 1	Level 2	Level 3	Level 4
Eelgrass Field Datasheets	√	√	√	√
maps or orthophotos at an appropriate scale, tidetables	√	√	√	√
boat (motor or paddle)		√	√	√
GPS		√	√	√
50 or 100 metre measuring tape or line			√	√
50 cm x 50 cm quadrats			√	√
metre stick			√	√
secchi disk			√	√
salinometer			√	√
Dive gear, snorkel gear, aquaviewer, or underwater camera			√	√
water quality sampling equipment				√

Waterproof notebooks or paper are highly recommended; these are available from stores that sell surveying equipment and some marine supply shops.

Quadrats may be constructed from any waterproof material. Local metal shops can usually make them out of aluminium for about $30. Aluminium quadrats are formed by a thin piece of 1" wide metal 2 metres in length that is bent to form a square and welded. Aluminium quadrats are recommended, as they are durable, rust proof, and are negatively buoyant so that they will lie flat on the substrate even if it is covered by water. Quadrats may also be made from wood or plastic pipe, although these types are more cumbersome to use and have a tendency to float.

A plastic coated surveyors measuring tape works well for marking transects. Alternatively, a thick nylon rope with labelled flagging tape to mark each metre may be constructed. The nylon tape has a tendency to float, this can be remedied by inserting short (e.g. 1" lengths) of lead wire into the rope at one metre intervals.

Secchi disks are used to measure the distance that one can see into the water, and to provide an indication of the turbidity. A secchi disk is a round flat disk, usually about 12" in diameter, with a cord attached in the centre. The surface of the disk is divided into four equal sized pie shaped triangles. The triangles are coloured white and black alternatively. The disk is lowered into the water and the depth at which it is no longer possible to distinguish the black from the white is recorded. A secchi disk may be purchased from a scientific supply company or hand made.

Tidetables are recommended to assist with planning the survey. Tidetables may be downloaded from http://tbone.biol.sc.edu/tide/sites_othernorth.html.

Appendix 3 – Safety Considerations

Intertidal Safety

The intertidal is a relatively safe place to work, however one should always be aware of the potential for injury. The most common cause of injury while working in and around intertidal eelgrass beds is from walking. Rocks and even mud, when covered with algae may be slippery. Rip rap (blasted rock that is often used as shore protection and to construct breakwaters), may be unstable; be cautious when climbing over it. People are often tempted to walk barefoot in soft glutinous mud, rather than loose their boots. However, broken shell embedded in the substrate can be sharp and may cut bare feet. Neoprene booties or old running shoes (with socks because the sand chaffs) work well.

Field work needs to be planned around the tides. On days when the low tide is less than 1 metre you can usually start work 1.5 to 2.0 hours before low tide, and continue for an hour afterwards. These times vary with other factors such as wind. If you are working around a headland, be sure to watch the tide; your return access may become blocked after the tide turns.

Never work alone, and carry a cellular phone or VHF radio in case of emergency. If possible try to include one member in each crew who has first aid certification. Always carry a first aid kit.

Bears and cougars frequent the backshore and sometimes intertidal areas in remote locations, so stay alert and keep an eye on the backshore for visitors.

It is a good idea to carry drinking water, as fecal coliform contamination and beaver fever is common in many of British Columbia's streams and rivers.

Subtidal Safety

Boating

Safety regulations are available from the Canadian Coast Guard (www.ccg-gcc.cg.ca). The Coast Guard is phasing in operator requirements over several years. Currently, anyone born after April 1, 1983 must have a 'proof of competency' licence to legally operate a power boat. After September 15, 2002, anyone operating a power boat less than 4 meters in length must have a licence.

The safety regulations vary with size and type of boat. Boats (pleasure craft) less than six metres in length must be equipped with at least one personal floatation device for each person on board. Small motorized boats must also carry a paddle in case of engine failure or an anchor with 15 metres of rope, a bailer or manual pump, a 15 metre heaving line, a watertight flashlight or three flares, a sound signalling device (whistle or air horn), and navigation lights after sunset.

A basic boating safety course is available free of charge, on line at http://www.boatsafe.com/

SCUBA

Anyone participating in a SCUBA survey must be certified. A dive flag must be readily visible to warn boaters that divers are in the water. PADI recommends that a dive master be in attendance whenever a diver is in the water. The Reefkeepers manual has a section on diving safety that is available on line at http://www.pac.dfo-mpo.gc.ca/sci/protocol/reefkeepers/Guide/default.htm. Divers and boat operators must be aware of each other's actions, and the danger associated with spinning propellers.

Appendix 4 – Project Planning

The following information is provided as a guide to assist with planning and organizing a field survey. Individual groups and organizations may want to modify the plan depending on the number of people available to assist with the survey.

The first step is to gather the background information (see Section 5 – Location of eelgrass beds) and review tide tables to select the best days for field work.

Level 1 Survey

1. Habitat Overview. Arrive on site within approximately 1 hour of low tide. Walk around the perimeter of the bed, then through it with the datasheet, thinking about the form, distribution, percent cover of eelgrass, and main substrate types in the bed. Avoid having many people follow the same path as excessive trampling can kill the eelgrass. Complete the Eelgrass Field Data Sheet – Section 1.
2. Georeference. Identify and map the edges of the bed with a GPS or on a map, airphoto, orthophoto, or chart.
3. Take photographs.

Tasks 1, 2, and 3 may be completed concurrently if the study team has enough members. The time required to complete a Level 1 survey will depend on the size of the study team and the area of the bed. A two member team could complete a Level 1 survey of a bed 100 metres wide or less within an hour.

Level 2 Survey

Intertidal areas of eelgrass beds should be surveyed at low tide as it will be much easier to assess them. Subtidal areas may be surveyed at any time, however the habitat may be easier to see if working from a boat, when there is less water at low tide.

1. Map the perimeter. It is always important to get a 'big picture' of the bed before you start the survey, either from a boat or underwater with SCUBA. Once the team has a fairly good idea as to the location of the bed, they can start mapping the perimeter.

2. Complete the Eelgrass Field Datasheet- Sections 1 and 2. In order to complete the datasheet, either the boat or divers will need to travel slowly over the bed, back and forth, until they feel that they have seen enough to complete the datasheet (habitat overviews). If possible, survey the intertidal area during low tide.

The perimeter mapping and habitat overviews may be completed simultaneously if there are adequate resources (boats and/or divers). It is estimated that one hour will be required to map the perimeter, and one hour to assess the habitat.

Level 3 Survey

Intertidal areas of eelgrass beds should be surveyed at low tide as it will be much easier to assess them. Subtidal areas may be surveyed at any time, however the habitat may be easier to see from a boat when there is less water at low tide. The entire survey does not need to be completed in one day, however it should be completed within one calendar week.

1. Map the perimeter. It is always important to get a 'big picture' of the bed before you start the survey, either from a boat or underwater with SCUBA. Once the team has a fairly good idea as to the location of the bed, they can start mapping the perimeter.

2. Complete the Eelgrass Field Datasheet – Sections 1 and 2. In order to complete the datasheet, either the boat or divers will need to travel slowly over the bed, back and forth, until they feel that they have seen enough to complete the datasheet (habitat overviews). If possible survey the intertidal area during low tide.
3. Determine maximum and minimum depths.
4. Determine the number of zones and select locations for transects.
5. Establish transects, collect shoot density data, and leaf length and width data.
6. Secchi depth reading may be taken at any time during the survey.

Study teams that include more than one pair of divers may decide to dedicate one team to mapping the perimeter and determining maximum and minimum depths, while the other pair(s) complete tasks 4 and 5.

Calculations (means, leaf area indices) may be completed subsequent to the field survey.

A study team of one boat tender and two divers would require approximately 5 hours to complete the survey. A study team of one boat tender, two teams of divers, and two people to assess the intertidal could complete the survey in less than 2 hours.

Level 4 Survey

Refer to the instructions for a Level 3 Survey. Collect water samples at any time, but remember to record the time of collection on the datasheet.

Appendix 5 – Field Data Form & Data Entry Form

A field data form (p. 22 – 27) and images of the electronic data entry forms are provided (p. 28-32). The 'Eelgrass Field Data Sheet' may be photocopied onto waterproof paper for use during fieldwork. The 'Eelgrass Bed Mapping Data Entry Form' (EBMDEF) is a snapshot of the one that can be used to enter data into the interactive web based database. In order to enter data into the Community Mapping Network database (http://www.shim.bc.ca/eelgrass/main.htm) each group will be assigned a username and password. The data from the field data sheet may then be submitted electronically. A help menu is available on the toolbar.

Eelgrass Field Data Sheet

Background

Location: ....

Date: ....*(dd/mm/yr)*

Primary Field Surveyor: ....

Crew: ....

....

Time start: .... Time finish: ....

Tide height start: .... Tide height finish: ....

Level of Survey: .... Tidal range of eelgrass bed (subtidal, intertidal, both):………………..

Platform used to survey eelgrass bed (shore, boat, dive, video): ....

Reference used to determine tide height: ....

Reference map type:……………………………………………………………………………………………….

Reference map name or number:………………………………………………………………………………………

Reference map scale:……………………………………………………………………………………………

Geographic (Lat./Long.) or Projection:…………………………………………………………………………………

Specifics of Projection (UTM, Albers, etc. including zone and other details):……………………………………………..

Method and Level of accuracy to which bed was mapped (circle one)

Code	Map Accuracy
1	Location measured using GPS (see GPS model and accuracy fields)
2	Location generalized from DFO log book lat/long positions
3	Location indicated to 2 mm at chart scale
4	Alongshore location indicated to 2mm at chart scale; across shore accuracy unknown
5	General location only; rough sketch on chart or place name (5 mm at chart scale)
6	Tied to shoreunit or other shoreline segment
7	Tied to DFO Statistical Subarea
8	Tied to DFO Statistical Area
9	Alongshore location indicated to 5 mm at chart scale, across shore accuracy unknown
10	Vague location only (1-2 cm at chart scale)

Method used to georeference (GPS/hardcopy map/orthophoto/airphoto): ....

Make and Model of GPS (if one was used):……………………………………………………………………………..

Comments specific to the eelgrass bed (health, adjacent backshore land use, backshore structures, possible threats)

1. Overview of Intertidal Habitat: All Levels – if bed is restricted to the subtidal go to Section 2.

Form	Fringing	❑	Flat	❑
Distribution	Continuous	❑	Patchy	❑

Percent Cover of intertidal eelgrass

Primary	1 to 10%	....	Secondary	1 to 10%	....	Tertiary	1 to 10%	....
	11 to 25	....	(optional)	11 to 25%	....	(optional)	11 to 25%	....
	26 to 50%	....		26 to 50%	....		26 to 50%	....
	51 to 75%	....		51 to 75%	....		51 to 75%	....
	> 75%	....		> 75%	....		> 75%	....

Substrate Type

Primary	mud	....	Secondary	mud	....	Tertiary	mud	....
	mud/sand	....	(optional)	mud/sand	....	(optional)	mud/sand	....
	sand	....		sand	....		sand	....
	gravel	....		gravel	....		gravel	....
	cobble	....		cobble	....		cobble	....
	boulder	....		boulder	....		boulder	....
	bedrock	....		bedrock	....		bedrock	....

2. Overview of Subtidal Habitat: Levels 2, 3, and 4

Form	Fringing	❑	Flat	❑
Distribution	Continuous	❑	Patchy	❑

Percent Cover of subtidal eelgrass ( )

Primary	1 to 10%	....	Secondary	1 to 10%	....	Tertiary	1 to 10%	....
	11 to 25	....	(optional)	11 to 25%	....	(optional)	11 to 25%	....
	26 to 50%	....		26 to 50%	....		26 to 50%	....
	51 to 75%	....		51 to 75%	....		51 to 75%	....
	> 75%	....		> 75%	....		> 75%	....

Area occupied by: ( )

Primary	1 to 10%	....	Secondary	1 to 10%	....	Tertiary	1 to 10%	....
	11 to 25	....	(optional)	11 to 25%	....	(optional)	11 to 25%	....
	26 to 50%	....		26 to 50%	....		26 to 50%	....
	51 to 75%	....		51 to 75%	....		51 to 75%	....
	> 75%	....		> 75%	....		> 75%	....

Substrate Types ( )

Primary	mud	....	Secondary	mud	....	Tertiary	mud	....
	mud/sand	....	(optional)	mud/sand	....	(optional)	mud/sand	....
	sand	....		sand	....		sand	....
	gravel	....		gravel	....		gravel	....
	cobble	....		cobble	....		cobble	....
	boulder	....		boulder	....		boulder	....
	bedrock	....		bedrock	....		bedrock	....

Area occupied by ( )

Primary	1 to 10%	....	Secondary	1 to 10%	....	Tertiary	1 to 10%	....
	11 to 25	....	(optional)	11 to 25%	....	(optional)	11 to 25%	....
	26 to 50%	....		26 to 50%	....		26 to 50%	....
	51 to 75%	....		51 to 75%	....		51 to 75%	....
	> 75%	....		> 75%	....		> 75%	....

3. Depth: Levels 3 and 4

Method used to determine Maximum Depth
(diver with depth gauge, diver with boat and metre tape or rod, survey rod without diver, other –explain)

………
………
………
………
………

…………………… Time measurement was taken
…………………… Depth Reading (metres e.g. 8.2 m)
…………………… Tide height at this time
…………………… Actual depth

Method used to determine Maximum Depth
(diver with depth gauge, diver with boat and metre tape or rod, survey rod without diver, other –explain)

………
………
………
………
………

……………… Time measurement was taken
……………… Depth Reading (metres)
……………… Tide height at this time
……………… Actual depth

4. Distribution & Density: Levels 3 and 4

Distribution Continuous - *proceed to Section 4A*
Patchy - *proceed to Section 4B*

4A. Continuous Eelgrass – complete one form for each zone

Number of Zones:...................................

Zone #:					
length of transect			**# of quadrats sampled**		
raw data (#/0.25m^2)					
total	**reproductive**	**total**	**reproductive**	**total**	**reproductive**
mean # total:			**mean # reproductive:**		

4B. Patchy Eelgrass – complete one form for each zone

Number of Zones: ....
Direction of Transect (e.g. 0m at north end):...........................

Zone #: ....

Distance across eelgrass patch (e.g. 2.4m)	# shoots / 0.25m^2	Distance to next eelgrass patch

Mean # shoots/0.25m^2 (within patches): ....

4. Leaf Area Index (LAI): Levels 3 and 4

sample	length	width
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		
21.		
22.		
23.		
24.		
25.		
26.		
27.		
28.		
29.		
30.		
Ó (total)		
x̄ (Ó ÷ 30)		

Mean leaf length (x̄): ………… ....Mean leaf width (x̄): ……………

Leaf Area Index (mean leaf length x mean leaf width x mean shoot density): …………….

5. Turbidity: Levels 3 and 4

Turbidity (secchi depth reading): ....

Time that reading was taken: ....

6. Salinity, Total Suspended Solids, Chlorophyll A: Level 4

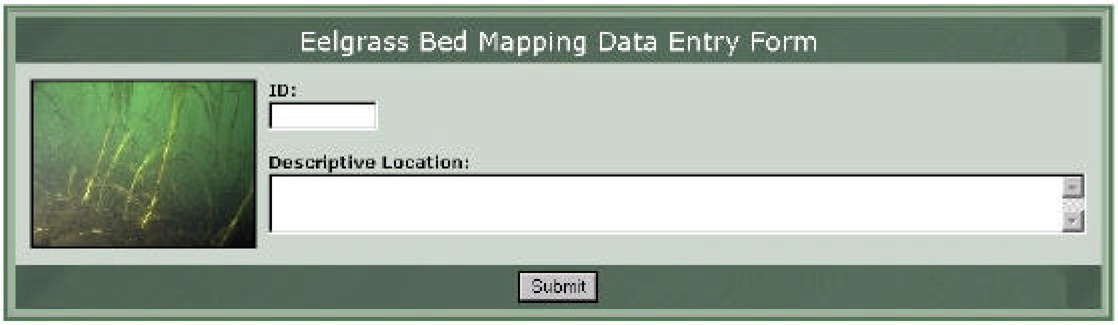
Salinity: ....

Total Suspended Solids: ....

Chlorophyll A: ....

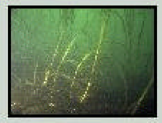
Time that samples were collected: ....

Form 1:



Form 2 (Main form):

Eelgrass Bed Mapping Data Entry Form



Unique id for eelgrass bed: 23222

Descriptive Location: Test

LOCATION OF INTERTIDAL BEDS ALONG SHORE (All Levels)

Is there any other spatial data with this report? Please comment: [ ]

To what level of accuracy to which eelgrass bed is mapped? [0 - N/A]

What method used to georeference and describe eelgrass bed? [0 - N/A]

What platform was used to survey eelgrass bed in the field? [0 - N/A]

If samples were taken, how were they taken? [0 - N/A]

Was GPS used? ☐ Make and Model of GPS: [ ]

Reference map type: [0 - N/A]

Reference map name or reference #: [ ]

Reference map scale: [ ]

Geographic (Lat/Long) or Projection: [N/A]

Specifics of projection (UTM, Albers etc including Zone and other details): [ ]

Is eelgrass represented as a line (shoreline) or polygon (bed)?: Point

# of reference points collected to delimit eelgrass bed edge: [ ]

Form of eelgrass bed: [Select One]

Tidal range of eelgrass bed: [Select one]

Eelgrass species present: [Select One]

Comments specific to polygon (health, adjacent backshore land use, backshore structures, threats): [ ]

Primary Source of Information: [Select One]

Assistant field surveyer: [Select One]

Date when eelgrass bed was surveyed (format: March 16, 2002): [ ]

Date when data was mapped or last updated (format: March 16, 2002): [ ]

Person compiling the information: [Select One]

Time Start: [ ] Time Finish: [ ]

Tide Height Start: [ ] Tide Height Finish: [ ]

Reference used to calculate tide height: [ ]

Eelgrass Bed Data Entry Form

OVERVIEW OF INTERTIDAL HABITAT

Distribution of eelgrass bed: [Select one]

Percent Cover Eelgrass:

Primary [Select one] | Secondary (optional) [Select one] | Tertiary (optional) [Select one]

Substrate Type:

Primary [Select one] | Secondary (optional) [Select one] | Tertiary (optional) [Select one]

OVERVIEW OF SUBTIDAL HABITAT (Level 2)

Distribution of eelgrass bed: [Select one]

Primary [Select one] | Secondary (optional) [Select one] | Tertiary (optional) [Select one]

Substrate Type:

Primary [Select one] | Secondary (optional) [Select one] | Tertiary (optional) [Select one]

DEPTH (Level 3-4)

	MAXIMUM DEPTH	MINIMUM DEPTH
Depth Reading:		
Actual depth:		
Time measurement was taken:		
Tide height at this time:		
Method used to determine depth:	Diver with depth gauge	Diver with depth gauge
Other method:		

LEAF AREA INDEX (Level 3 and 4)

ZONE 1:

Leaf length and width [Enter Measurements] Mean leaf length:

Leaf Area Index Mean leaf width:

ZONE 2:

Leaf length and width [Enter Measurements] Mean leaf length:

Leaf Area Index Mean leaf width:

ZONE 3:

Leaf length and width [Enter Measurements] Mean leaf length:

Leaf Area Index Mean leaf width:

DISTRIBUTION AND DENSITY
(Level 3 and 4)

Distribution of eelgrass bed: [Select One ▾]

ZONE 1: [Enter Measurements]

Length of Transect: [ ]

Direction of Transect (eg.0m at north end) [ ]

Mean # shoots/0.25m^2 [ ]

Mean # flowering shoots/0.25m^2 [ ]

ZONE 2: [Enter Measurements]

Length of Transect: [ ]

Direction of Transect (eg.0m at north end) [ ]

Mean # shoots/0.25m^2 [ ]

Mean # flowering shoots/0.25m^2 [ ]

ZONE 3: [Enter Measurements]

Length of Transect: [ ]

Direction of Transect (eg.0m at north end) [ ]

Mean # shoots/0.25m^2 [ ]

Mean # flowering shoots/0.25m^2 [ ]

Turbidity
(Level 3 and 4)

Turbidity (secchi depth reading): [ ]

Time that reading was taken: [ ]

Salinity, Total Suspended Solids, Chlorophyll A
(Level 4)

Salinity: [ ]   Chlorophyll A: [ ]

Total Suspended Solids: [ ]   Time that Sample were collected: [ ]

[Submit]

Eelgrass Bed Data Entry Form

LAI Form:

ZONE 1 - Leaf Area Index			
Existing Measurements:			
No measurements available			
Enter records one at a time and hit submit every time:			
Measurement No	Width	Length	Feature ID
			90
Submit and Next	Done		

Distribution and Density Form:

ZONE 1 - Distribution and Density					
Existing Measurements:					
No measurements available					
Enter records one at a time and hit submit every time:					
Measurement No	No of shoots (patchy / continuous)	No of flowering shoots (patchy / continuous)	Distance across eelgrass patches (patchy only)	Distance between eelgrass patches (patchy only)	Feature ID
					90
Submit and Next	Done				

Appendix 6 – Patchy vs. Continuous Eelgrass Distribution

The following illustrations are provided to demonstrate the difference between patchy and continuous eelgrass cover. The term Continuous is used to indicate that eelgrass is distributed over most of the area within the bed (Figure 1). There may be some areas without eelgrass within the bed (Figure 2).

Eelgrass is described as patchy when the bed or meadow is composed of many patches or islands of eelgrass, most of which are surrounded by areas without eelgrass (Figure 3). The area between patches is usually either exposed substrate or macroalgae.

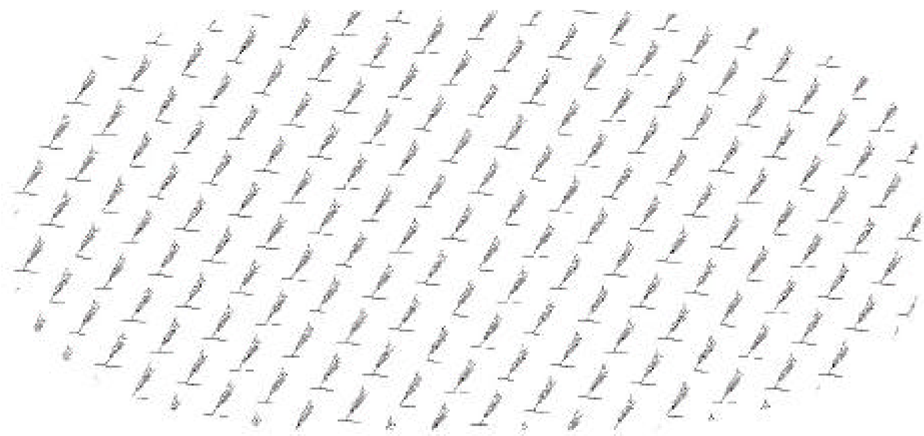


Figure 1. Continous Cover

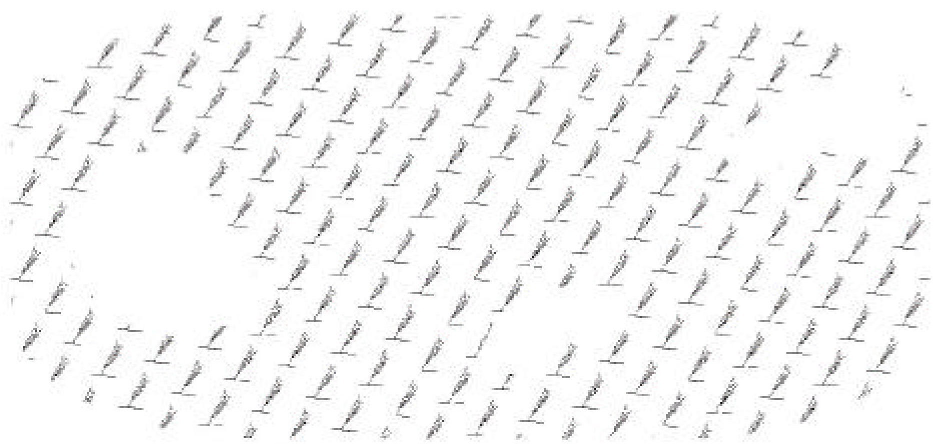


Figure 2. Continous cover with bare patches

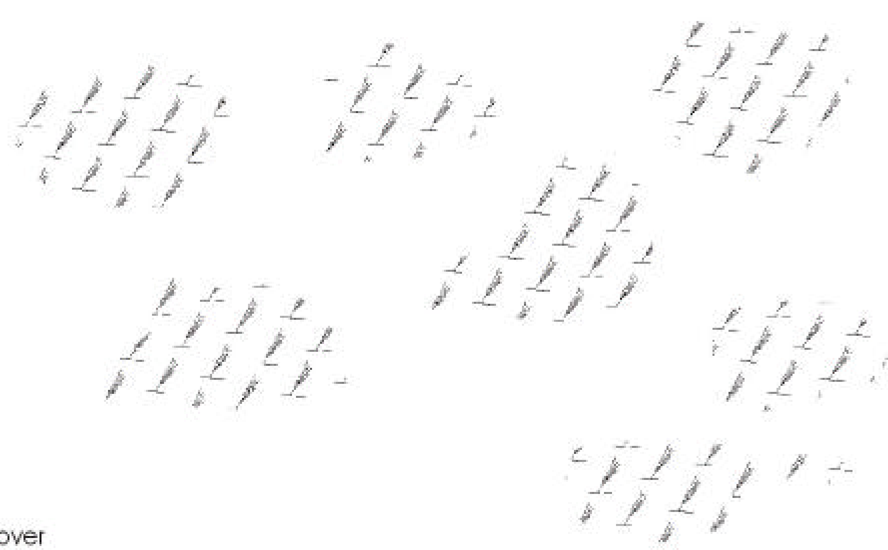


Figure 3. Patchy Cover

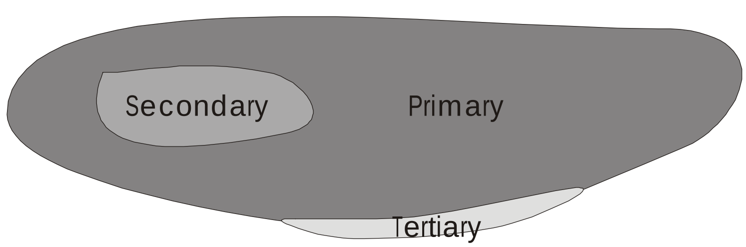
Appendix 7 – Percent Cover

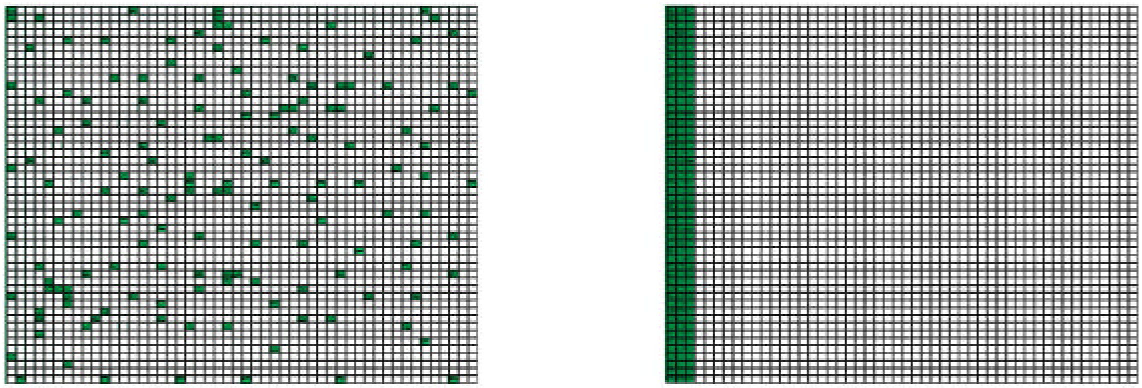
Percent cover is a quantitative assessment of the area covered by plants. For example, when the leaves and shoots form a dense blanket over the substrate (ground) such that it is impossible to see the substrate below the plants the percent cover is 100%. If you can see the substrate between the plants then the percent cover is less than 100%. The following figures are provided to illustrate this concept.

Imagine that the grey squares represent cover by eelgrass; the white squares represent exposed substrate (no eelgrass). Some people find it helpful to mentally move all the plants together in order to estimate the percent cover. Figure 7.1a represents a sparse eelgrass bed where only 6% of the area is covered by eelgrass. Figure 7.1b contains the same number of grey squares but they have been moved together. Accurately estimating precise percent cover requires training and experience. A way to circumvent this problem is to estimate percent cover within ranges. The datasheet provides a series of ranges that can be used to evaluate percent cover. By looking at the area covered by eelgrass, and perhaps mentally shifting all the plants together, you can determine which range best reflects the percent cover of eelgrass in the bed. For example, the diagram shown in Figure 7.1a would fall between 1% and 10%. The ranges that are used in this study are listed below.

Primary	1 to 10%	....	Secondary	1 to 10%	....	Tertiary	1 to 10%	....
	11 to 25	....	(optional)	11 to 25%	....	(optional)	11 to 25%	....
	26 to 50%	....		26 to 50%	....		26 to 50%	....
	51 to 75%	....		51 to 75%	....		51 to 75%	....
	> 75%	....		> 75%	....		> 75%	....

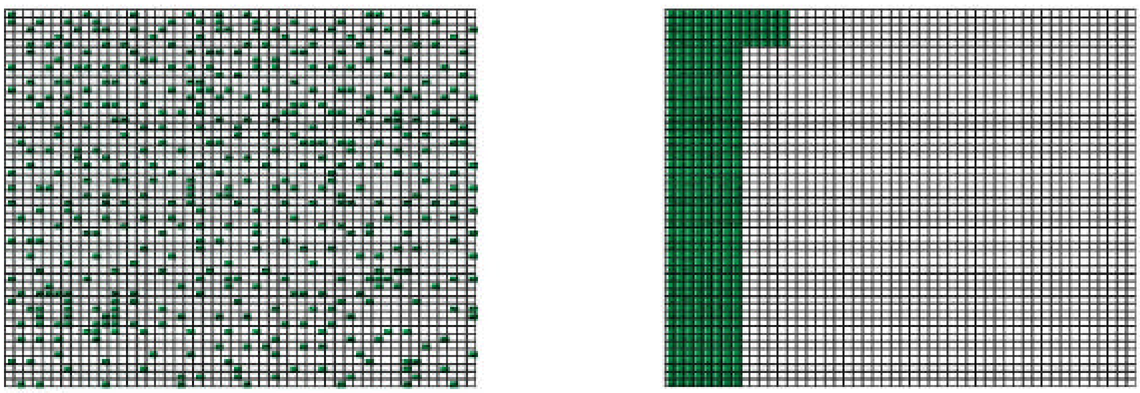
There are often differences in percent cover within a bed due to variations in physical variables such as depth or substrate. The following diagram provides a graphic representation of a bed that is composed of three areas with distinctly different percent covers. The dark area represent very dense eelgrass (>75%), the light area represents an area with low percent cover (1-10%), and the mid shade an area with intermediate cover (26 – 50%). Since most of the area falls into the >75% range this would be the primary percent cover. The secondary and tertiary percent covers would be 1-10% and 26-50% respectively. The secondary and tertiary percent cover estimates are considered optional as many beds are relatively uniform within the broad ranges that are provided. An area should represent at least 10% of the total area before it is considered significant enough to note on the datasheet.





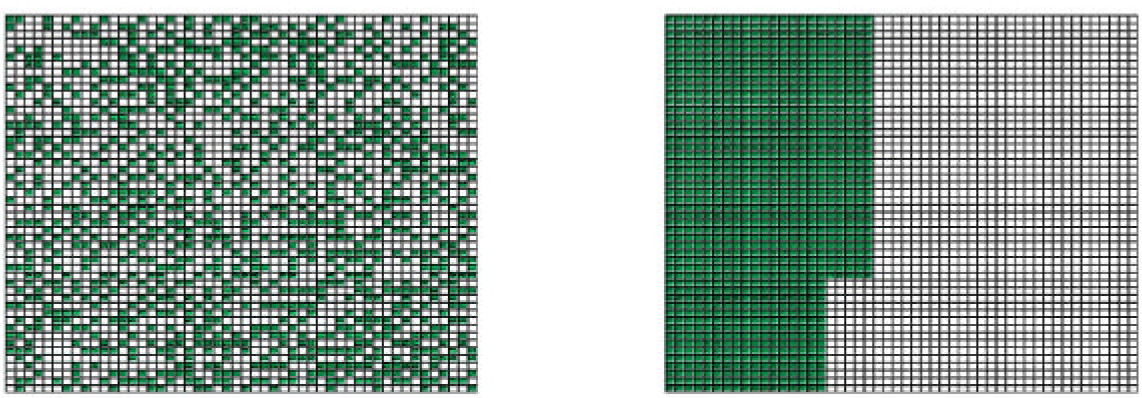
6%

Figure 7.1 Six percent of the squares are shaded. The squares are randomly located in the first diagram (a) and are grouped in the second (b). This represents an area that would be classified as 1-10% cover on the datasheet.



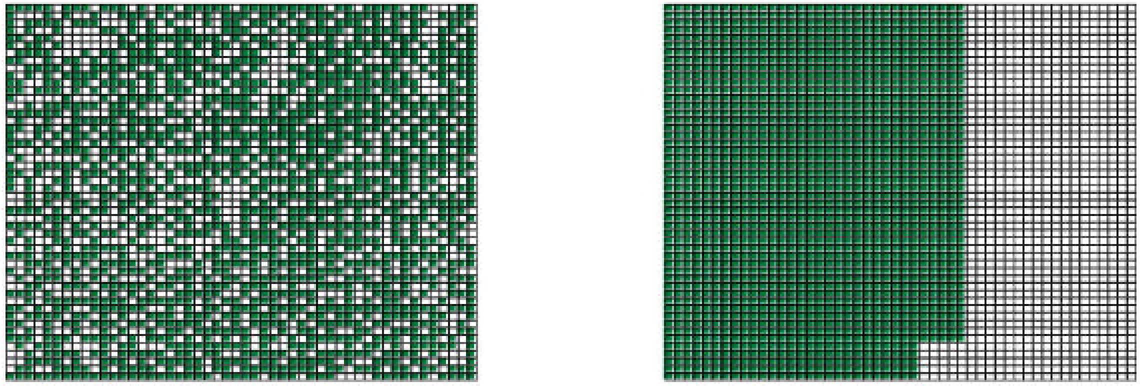
18%

Figure 7.2 Eighteen percent of the squares are shaded. The squares are randomly located in the first diagram (a) and are grouped in the second (b). This represents an area that would be classified as 11-25% cover on the datasheet.



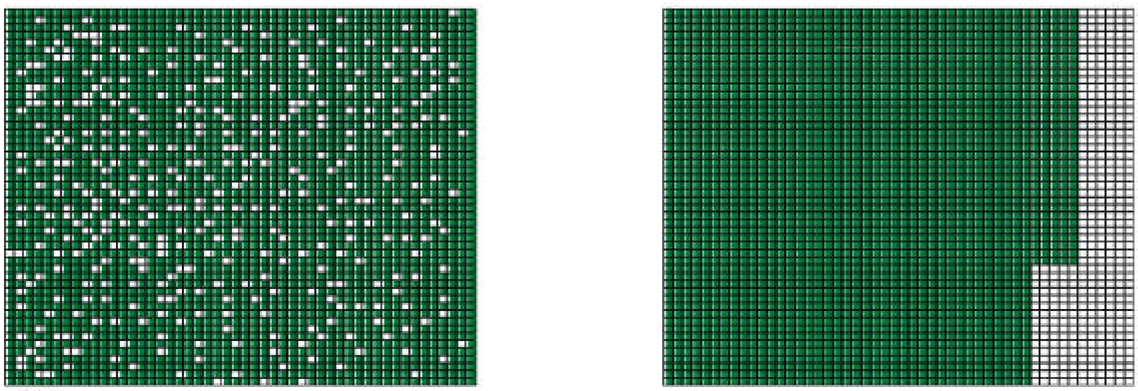
41%

Figure 7.3 Forty-one percent of the squares are shaded. The squares are randomly located in the first diagram (a) and are grouped in the second (b). This represents an area that would be classified as 26-50% cover on the datasheet.



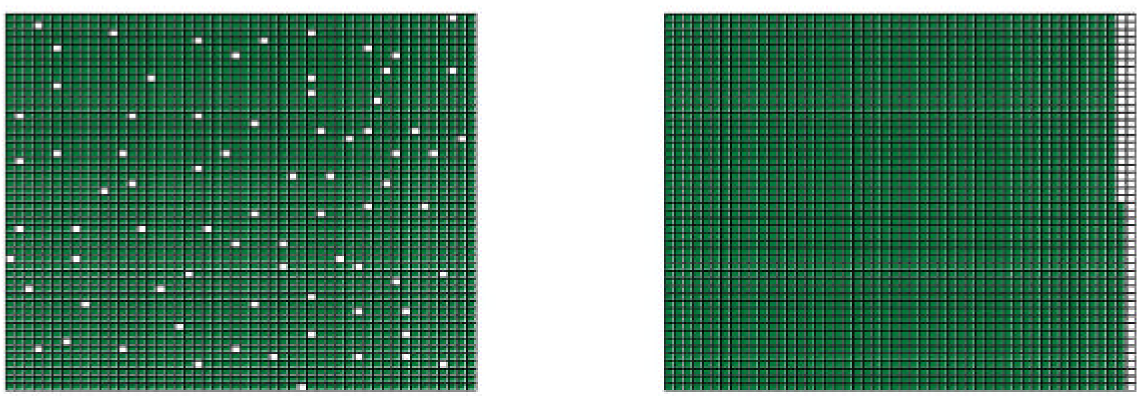
63%

Figure 7.4 Sixty-three percent of the squares are shaded. The squares are randomly located in the first diagram (a) and are grouped in the second (b). This represents an area that would be classified as 51-75% cover on the datasheet.



85%

Figure 7.5 Eighty-five percent of the squares are shaded. The squares are randomly located in the first diagram (a) and are grouped in the second (b). This represents an area that would be classified as >75% cover on the datasheet.



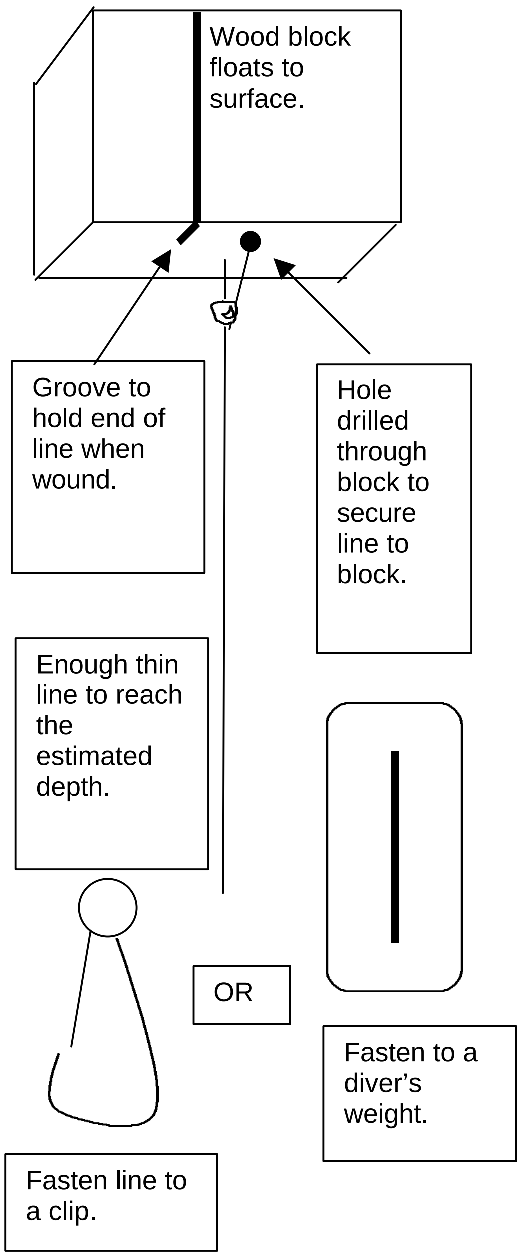
97%

Figure 7.6 Ninety-seven percent of the squares are shaded. The squares are randomly located in the first diagram (a) and are grouped in the second (b). This represents an area that would be classified as >75% cover on the datasheet.

Appendix 8 – Marker Floats

The following float design was developed by Sarah Verstegen of SeaChange to mark the perimeter of eelgrass beds.

If you need to mark the location of eelgrass under water so that you can find it from the surface, try these for short-term use. The line is wound around the block and notched into the groove. A diver can carry a few in a goody bag. When the diver finds a location to mark for people at the surface, she or he sets the marker weight on the bottom. (Clips work when there is something to fasten to.) Then, s/he un-notches the line from the groove. The line will unreel itself from the block as it floats to the surface. It helps divers avoid that nasty tangle of line when working under water.



Use either a 2 x 4 or 2 x 3 inch piece of lumber. It's easier to make notches in a long piece before it's cut into the smaller blocks. Plastic clips are ligher than lead weights and cheaper than brass.