PACIFIC SALMON FOUNDATION

EELGRASS MAPPING AND MONITORING HANDBOOK

FOR THE SALISH SEA AND WEST COAST VANCOUVER ISLAND REGION

Cynthia Durance and Nikki Wright

2026

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Illustration:Delaney Cox of Drawing it Out

PREFACE

Estuaries and nearshore ecosystems provide vital support to juvenile and adult Pacific salmon, as well as the larger food web they depend upon. There is increasing interest in protecting and restoring the interconnected nearshore habitats of kelp, tidal marshes, and eelgrass habitats within these critical salmon systems.

However, the success of nearshore recovery projects is hampered by a number of factors: a paucity of open-access information about nearshore habitat restoration and monitoring methodologies, a lack of knowledge about priority areas and suitable site selections for restoration, and a need for knowledge based approaches to conservation strategies under worsening climate change scenarios.

With funding from Fisheries and Oceans Canada's Aquatic Ecosystem Restoration Fund (AERF), the Pacific Salmon Foundation has created a Restoration Resource Hub of open-access informative resources and decision-support tools. The purpose is to guide adaptive nearshore habitat restoration and monitoring approaches to kelp, tidal marsh, and eelgrass habitats.

This Eelgrass Mapping and Monitoring Handbook is one of the components of this Hub. Other documents can be found through this link.


Unless otherwise noted, photos were provided by Cynthia Durance.

EXECUTIVE SUMMARY

This Eelgrass Mapping and Monitoring Practitioners' Handbook provides coastal communities with a standardized set of methods to map, classify, and monitor native eelgrass habitat (*Zostera marina L*) on a local level in the Salish Sea and the West Coast Vancouver Island Region. Community members will be able to enter consistent and reliable data into a central database (e.g., https://marinedata.psf.ca/data/data-submission-form).

The methodologies included in this Handbook were developed in 2002 following a review of many protocols, including SeagrassNet, European Union Special Areas of Conservation, and the Puget Sound Submerged Vegetation Monitoring Program. There are four levels of study, starting with Level 1, which is the most basic, and building in complexity to Level 4.

Since its inception, the methods described in this Handbook have been used to map subtidal eelgrass habitats within BC. Locations surrounding the Salish Sea and West Coast Vancouver Island (WVI) include the Islands Trust Area, Howe Sound, Sechelt Inlet, Cowichan Bay, Parksville, and Port Alberni, and intertidally in many areas from Boundary Bay to Haida Gwaii. The methods were integrated into the Indigenous Guardians Toolkit.

- Chapter 1 provides the reader with an understanding of basic eelgrass ecology.
- Chapter 2 examines the parameters frequently used in mapping and monitoring eelgrass habitat and offers a rationale for the specific selection applied for a particular goal.
- Chapter 3 aims to help community groups determine what type of study they should organize.
- Chapter 4 details the methodology for each level.

A series of Appendices, including data sheets, equipment lists, and additional information to assist in conducting surveys in a safe and efficient manner, is provided.

For more information on eelgrass ecology, the threats to the habitat within the Salish Sea and WVI, and a summary of some of the strategies for its conservation, please consult the Eelgrass State of Knowledge for the Salish Sea and West Coast Vancouver Island Region and the Eelgrass Restoration Practitioners' Handbook.

Recommended citation:

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CONTENTS

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Credit: Coastal Photography Studio

ABOUT THE AUTHORS

The author's first winter studying eelgrass in 1982 (top) and still learning about eelgrass 43 years later.

CYNTHIA DURANCE, R.P.BIO., PRINCIPAL OF PRECISION IDENTIFICATION

My interest in eelgrass ecology and restoration began while working in Dr. P.G. Harrison's UBC soft-bottom ecology lab from 1982 to 1989, where I planned and implemented numerous field studies with the assistance of many summer and graduate students and published in peer-reviewed journals. My seagrass knowledge has expanded by attending international seagrass conferences, the most exotic being Zanzibar and Australia.

Environment Canada commissioned me to develop a methodology and write a manual for BC stewardship groups in 2002 to promote conservation and monitor changes over time. The standardized methods enabled groups to contribute to a central database for BC on the Community Mapping Network. Since then, I have been contacted many times for clarification about the classifications. This updated manual provides additional detail and diagrams in response to those queries. Nikki's vast experience working with community groups has been integrated into this version of the manual.

I have been privileged and enriched by working with many First Nations from Tsawwassen to Haida Gwaii and travelling to remote locations throughout BC. My career has been extremely rewarding; I don't ever plan to retire and strongly encourage anyone with similar interests to follow the same career path.

NIKKI WRIGHT, FORMER EXECUTIVE DIRECTOR OF SEACHANGE MARINE CONSERVATION SOCIETY

Nikki Wright served as Executive Director of SeaChange Marine Conservation Society from 1998 to January 2023. SeaChange is a non-profit charitable society working with community partners on marine education, conservation, and restoration in the Salish Sea and BC.

In 1999, under the direction of Cynthia Durance, SeaChange staff and volunteers transplanted 1800 eelgrass (*Zostera marina*) shoots into the muddy seabed of Tod Inlet, a small inlet of Saanich Inlet within W̱SÁNEĆ Territory, north of Victoria, BC. From that success was born the Seagrass Conservation Working Group in 2001 (www.seagrassconservation.org) and over 60 community-based eelgrass restoration projects within the Salish Sea.

Ms. Wright has published two articles related to native eelgrass in BC and environmental education and is the co-author of the Eelgrass Restoration Practitioners' Handbook with Cynthia Durance, with the support of the Pacific Salmon Foundation and the Department of Fisheries and Oceans Canada.

Following the methods described in the 2002 Eelgrass Mapping Manual, Nikki guided many coastal communities to map intertidal eelgrass habitats near their communities.

Credit: Coastal Photography Studio

HOW TO USE THIS EELGRASS MAPPING HANDBOOK

This Handbook is a practical training tool to enable First Nations, stewardship community groups, and non-profit groups to map and monitor native eelgrass habitats in BC both intertidally and subtidally, with minimal expense or training.

It provides an outline of the steps required for mapping and monitoring native eelgrass in BC and includes data forms to accurately record data. We cover everything from the most basic methods to more complex methods, and guide users through what is appropriate for the purpose of your survey and the capacity of the mappers or the group undertaking the work. As you peruse the chapters, there are a few guideposts to lead you to greater detail on the subjects introduced in the text.

This image in the margin indicates that Eelgrass State of Knowledge Report (Eriksson & Clowater-Eriksson, 2026) provides more detailed information on a specific reference or statement.

A star indicates a suggestion or "tip" related to the text beside it.

This raised hand indicates a Frequently Asked Questions section found at the end of each Chapter.

Bold words are defined in a Glossary at the end of the Handbook.

A Field Reference Guide (Appendix A) can be waterproofed and used as a quick reference guide in the field, to remind you of the classification details.

If data is allowed to be shared, it can be stored within the PSF Marine Data Centre (https://marinedata.psf.ca/data/data-submission-form).

A Table of Locations of Areas Mapped in the Salish Sea and the west coast of Vancouver Island (1970-present) can be found in the State of Knowledge Report.

Data sheets for use in the field are included in Appendix E.

INTRODUCTION

> Eelgrass (*Zostera marina*) originated in the Pacific Ocean between ten to five million years ago and spread to the Atlantic Ocean starting around 3.5 million years ago before the most recent ice age hit and ice sheets separated the two oceans (Dzombak, 2022).

Eelgrass provides critical habitat for numerous marine species in BC, including out-migrating juvenile salmon (*Oncorhynchus* spp.), Pacific herring (*Clupea pallasii*), 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 (Dejong & Dejong, 1992; 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 reduces erosion (Phillips, 1984). The plants produce large amounts of oxygen, providing a vital source for marine ecosystems, sequester carbon, which can lead to a buffering of pH, and may kill pathogens (Lamd et al., 2017). A study by Short et al. in 2016 estimated that BC eelgrass habitat covered a total 1004.4 km^2 and has the potential to sequester 23,402 tons of CO_2 annually.

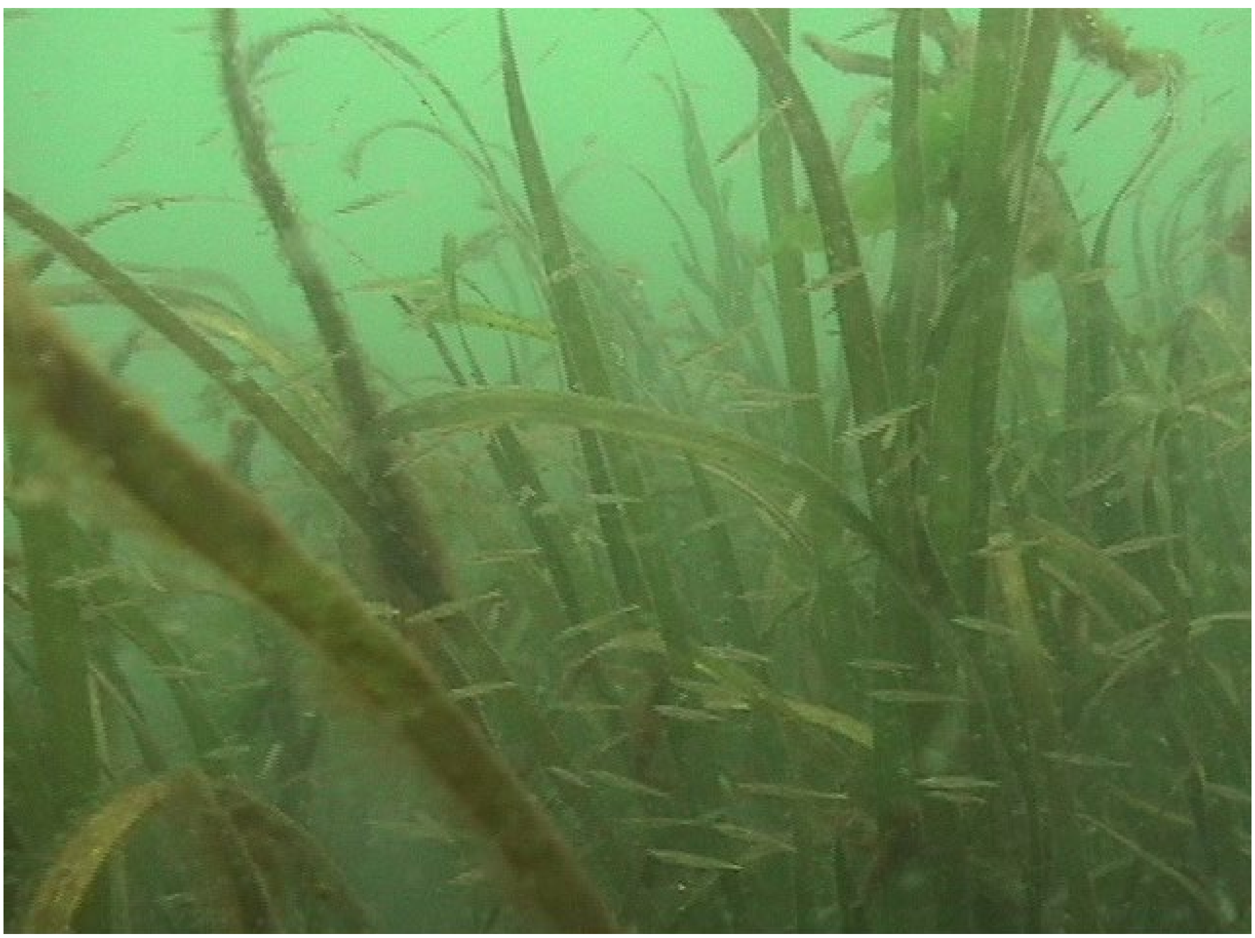
Bubbles of oxygen produced by eelgrass photosynthesizing.

Eelgrass, a species of seagrass, grows where land meets the sea, an area inhabited by about one-fifth of the world's population. It faces threats from human activities such as shoreline development, agriculture, aquaculture, dredging, and anchoring, as well as ongoing stress from climate change, including rising temperatures, higher sea levels, and changing marine conditions (Seagrass Net, 2021).

> Seagrass meadows are declining at a rate equivalent to losing a soccer field every thirty minutes since 1980. The annual loss rate has accelerated from less than 1% before 1940 to 7% since 1990. This alarming decline is a direct signal that coastal human activity is undermining the ocean's most critical nursery and carbon storage (Ferris-Olsen, 2023).

In these challenging times, it is essential to identify, classify, and quantify eelgrass through mapping exercises to take stock and understand where and potentially why eelgrass habitats are changing. Only with this information can we collectively create scientifically sound management strategies to protect them.

> It has been estimated that 80% of commercially, culturally, and recreationally important finfish and shellfish species rely on eelgrass for some part their life cycle.



Fish congregating in an eelgrass bed, finding shelter and food.

The governments of many countries, including the United States, Australia, New Zealand, South Africa, and Britain, have recognized the value of seagrass habitats 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. In BC, there is no such broad-scale government initiative. Eelgrass mapping relies heavily on Indigenous and stewardship community groups to fill this gap.

This Eelgrass Mapping and Monitoring Practitioners' Handbook is designed to ensure that standardized, easily understood methods are available to all groups in order for them to locate and track changes to native eelgrass habitats (*Zostera marina*) in their areas. Monitoring goals may include tracking changes from disturbances (e.g., dock or backshore development), mapping clam harvesting sites, or observing changes due to climate over time.

Another reason for mapping and monitoring is to assess the success of recovery and restoration efforts. The text and diagrams included in the chapters ahead provide a clearly delineated step-by-step process for both intertidal and subtidal surveys. Each chapter will describe attributes of eelgrass habitats that are important to record, especially if change over time is a goal of the survey.

A more detailed survey is required if you are collecting data for a *Fisheries Act Authorization*. The method required for this type of survey is described in Components of a Complete Eelgrass Delineation and Characterization Report, written by the Army Corps of Engineers, Seattle District, 2018.

Community volunteers mapping eelgrass during low tide in Boundary Bay.

CHAPTER 1:
EELGRASS ECOLOGY

Eelgrass meadows are dynamic systems that can change annually or seasonally in response to environmental factors. Recognizing the natural variability of these ecosystems is necessary for making accurate assessments of changes over time. This chapter provides a brief overview of eelgrass ecology and an appreciation for the inherent natural variability both within and between meadows. More information can be found in the Eelgrass State of Knowledge Report.

Emmett Duffy, director of the Marine Global Earth Observatories at the Smithsonian, puts eelgrass' value in monetary terms: "A single hectare (about 2.5 acres) is conservatively estimated to be worth over US $19,000 a year", based on the value of fish populations it supports and the carbon and nitrogen it sequesters (Ferris-Olsen, 2023).

1.1 REPRODUCTION

Eelgrass grows differently than any terrestrial plants. Its **shoots** travel through the substrate, producing more new shoots as they move. A leaf is short-lived; when it starts to die, it falls off the stem, and new roots form at the point where the leaf broke away from the shoot. The roots grow longer, reaching the sediment where they pull the stem downward. The section of stem that is pulled into the sediment develops into a **rhizome** (Figure 1.1). New shoots form at the base of the parent shoot. The rhizome branches, allowing the new shoot to grow away from the parent shoot (Figure 1.1). A single plant may have numerous shoots connected via a single branched rhizome. As time passes, older rhizomes decay, so a single plant eventually becomes two or more plants. A few other related seagrasses share this way of growing. This can be see in this animation.

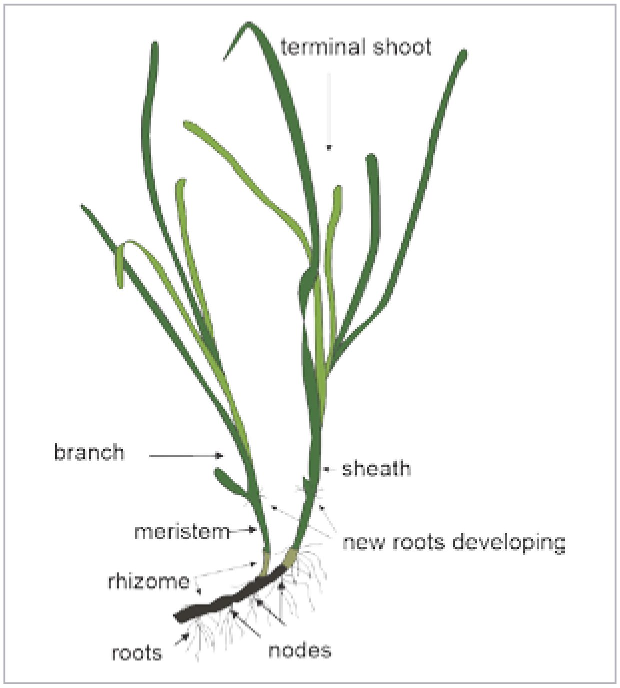


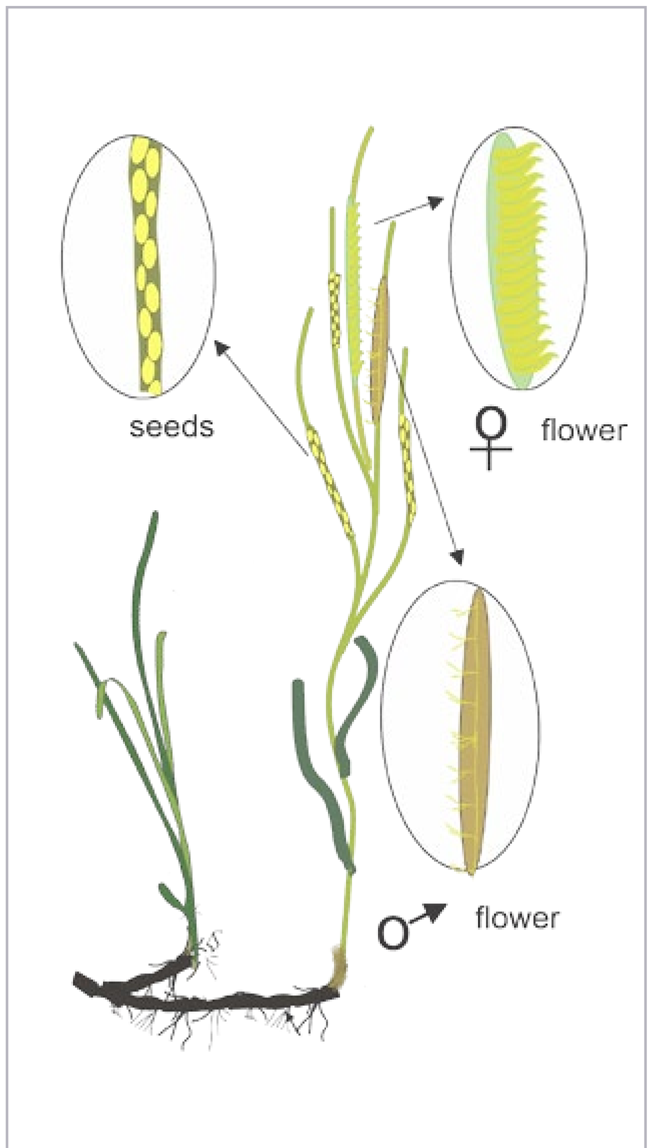
Figure 1.1 Eelgrass anatomy.

Studies in the Salish Sea with the *Z. marina* **ecotype** *phillipsii* found that a shoot typically travels 0.5 metre per year through the sediment. Transplants of the larger *Z. marina* ecotype *latifolia* grew >1 m in the first year. The growth rate of *Z. marina ecotype typica* hasn't been studied, but it is likely less due to its smaller size. The *Z. marina ecotype izembekensis* might be similar to, or slightly less than, *Z. marina ecotype phillipsii* based on its **morphology** (see Table 1.1).

Eelgrass also reproduces sexually (flowers and seeds). Some 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 (Figure 1.2). Once the seeds have matured, the shoot begins to **senesce**, breaks free from the rhizome, and drifts 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.

An eelgrass meadow could, in theory, be composed of millions of shoots that have originated from a single individual. A seagrass meadow spanning 92,000 sq km was identified in 2022 as the world's largest organism (Guinness World Record, 2022).

Figure 1.2 The flowering shoots are paler and longer than the vegetative ones. Unlike the vegetative shoots the stems are branched and round in cross-section.



1.2 SPECIES AND ECOTYPES

There are two species of eelgrass in BC: 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). There have been several recent reports of *Z. japonica* in Alaska, which may, however, suggest it arrived naturally. *Zostera nana* and *Z. americana* have not been documented in the Pacific Northwest; however, early collections of *Z. japonica* were mistakenly identified as these species (Harrison, & Bigley, 1982).

Z. japonica **morphology** is smaller than most *Z. marina*, so it can tolerate being out of water at low tide, better than most of the native species. The introduced species cannot compete with the native species due to its typically smaller size; thus it is not a threat to the native eelgrass. *Z. japonica* is often found adjacent to, or intermixed with, *Z. marina* in the intertidal (Figure 1.3).

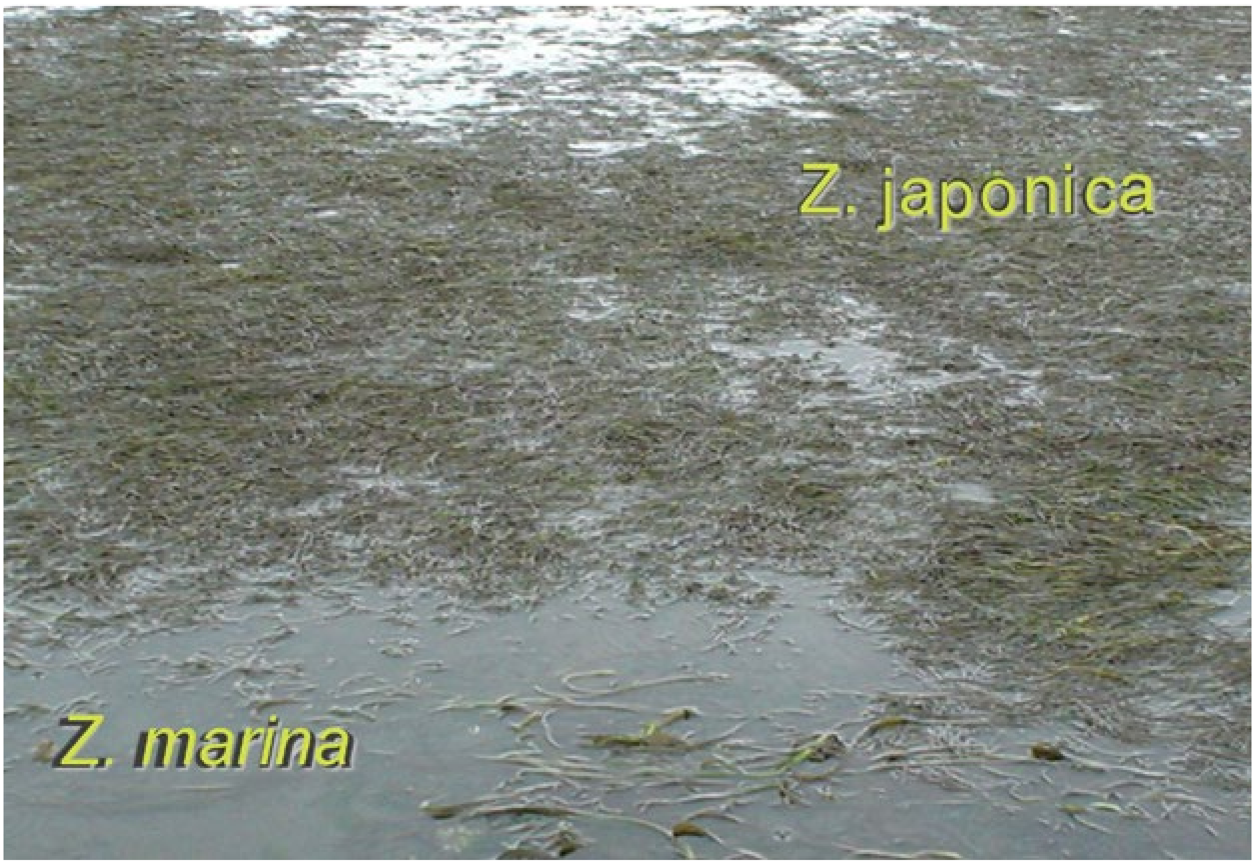


Figure 1.3 Slight variations in elevation can influence the survival of *Z. marina*. *Z. japonica* can survive in higher elevations than the *Z. marina*.

Dense populations of *Z. japonica* accrete fine sediment and have been responsible for converting sand-flats to mudflats, and consequently changing the species composition of **infauna**. The Canadian Wildlife Service has reported this causing a decline of foraging habitat for western sandpipers in the intertidal zone at Roberts Bank. On a positive note, the dense *Z. japonica* shoots ponded water during low tides enabling *Z. marina* to expand further up the tidal flats (Tarbotton & Harrison, 1996).

Z. japonica has value to fisheries during higher tides when they are submerged, providing cover and foraging opportunities for juvenile salmonids. Unlike *Z. marina*, *Z. japonica* is an annual or sometimes a short-lived perennial. Typically, it dies back completely in winter and regenerates from seed the following spring. Some shoots may persist through the winter; these die the following summer.

The information provided in this document relates specifically to *Z. marina*. A mapping handbook focusing on *Z. japonica* is available on the Community Mapping Network website (Precision Identification, 2004).

The leaf length and width of both species vary with depth. As depth increases, leaf length and width increase because more surface area is needed at depth to capture sunlight. The leaf length and width of intertidal *Z. marina* are sometimes within the range of *Z. japonica.* Fortunately, the two species have a few morphological differences (Figures 1.4 and 1.5). *Z. marina* has an entire **sheath**, which 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 so the sheath parts rather than tears when stress is applied. *Z. marina* usually has six or more roots at each node of the **rhizome**; *Z. japonica* has four. The **meristematic** cells of *Z. marina* are located only in the sheath of terminal shoots, whereas the meristematic cells of *Z. japonica* are located at each node along the rhizome. Therefore, all *Z. marina* shoots are located at the end of a rhizome, whereas *Z. japonica* produces shoots at nodes along the rhizome.

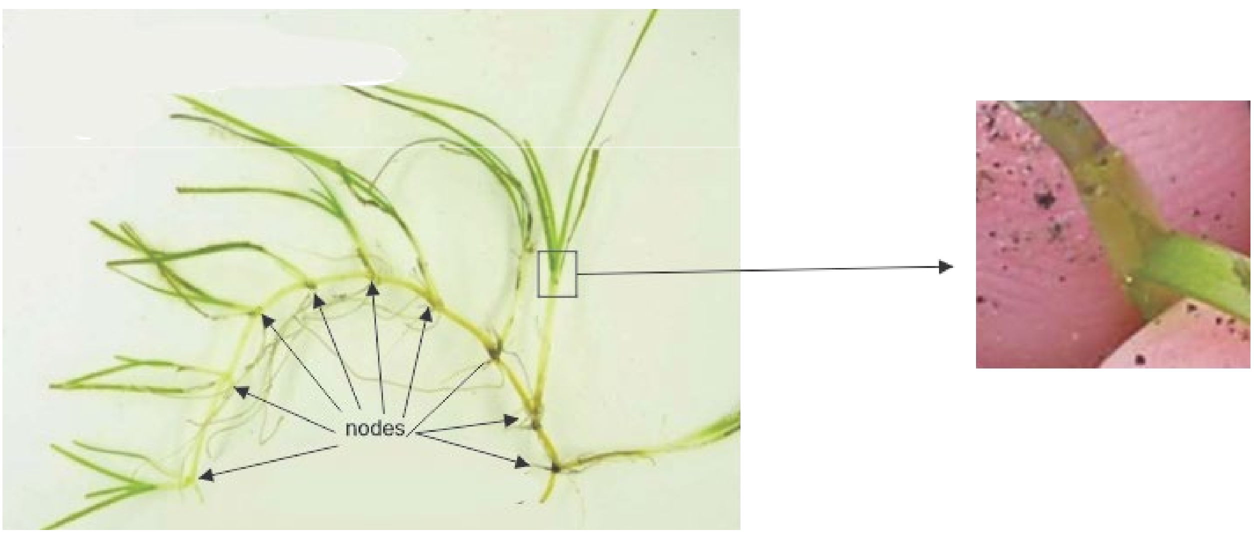


Figure 1.4 *Z. japonica* showing the location of nodes, shoots, and sheaths (square) and a close-up of the overlapping flaps of the sheath that separate cleanly with no tearing. A shoot is produced at each node along the rhizome.

Figure 1.5 *Z. marina* showing the location of nodes, shoots, and sheaths (square) and a close-up of the sheath tearing. Each shoot is growing at the end of a rhizome.

There are **ecotypes** or "races" of *Z. marina* that account for part of the morphological variation (Backman, 1991). Five ecotypes are known in the Eastern Pacific, four of which occur in BC. Each ecotype has adapted to a specific depth range. The attributes associated with each ecotype are summarized in Table 1.1.

Table 1.1 The habitat and morphological attributes associated with the four ecotypes of *Zostera marina* common in British Columbia (adapted from Backman, 1991).

Ecotype	Mature shoot length (cm)	Leaf width (mm)	Typical depth range CD (m)**	Seasonal variation in size	Current tolerance
typica	<30	2 to 5	Primarily intertidal	Small variation	Low
phillipsii	40 to 210	4 to 9	Intertidal to 4	Large, plant length reduced in winter	Moderate
latifolia	100 to 300	12 to 20	0.5 to 10	Minimal variation	Strongest
izembekensis	40 to 106	2 to 5	0 to 3*	Large, plant length reduced in winter	Moderate

* based on few observations in B.C. ** Canadian chart datum (CD) is measured relative to lowest normal tide. 0 metres is the lowest normal tide, datum measurements are the depth below 0, therefore they don't require a – sign. Tides that are lower than the lowest normal tide are negative. The US chart datum differs because it is based on the Mean Lower Low Water (MLLW).

An eelgrass meadow may contain one or more ecotypes.

The 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 ecotype *typica*, may have a density of 2000 shoots per square metre, while the adjacent subtidal habitat supports 120 shoots per square metre (Figure 1.6). The **biomass** (weight of plant tissue) 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 needs to be taken into consideration when making comparisons.

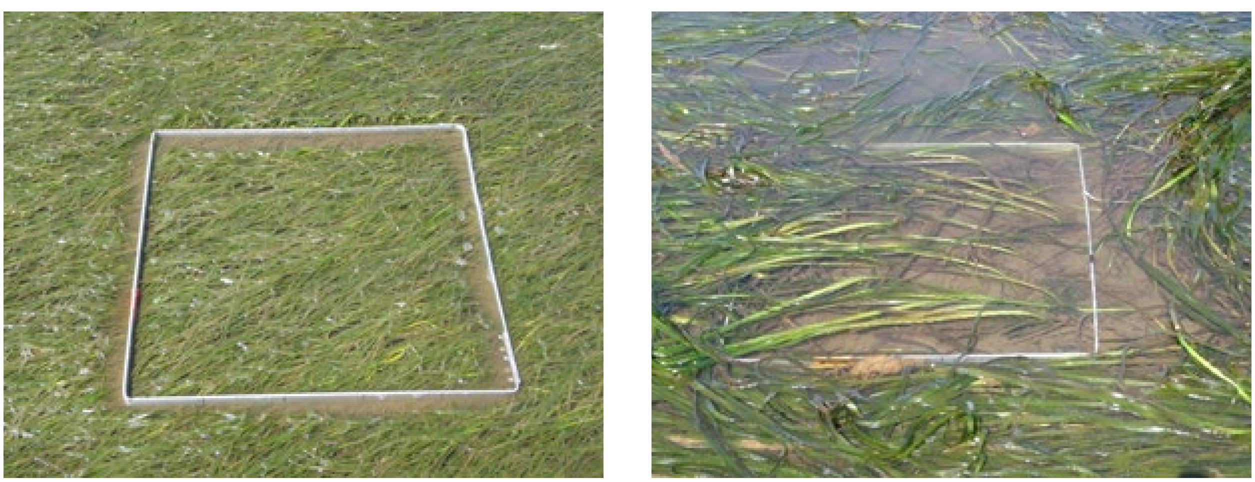


Figure 1.6 Intertidal eelgrass (*Z. marina* ecotype *typica* left) and shallow subtidal eelgrass (*Z. marina* ecotype *phillipsii* right).

1.3 COVER

The area covered by eelgrass within an eelgrass meadow is a reflection of the interaction between the substrate, depth, and **hydrodynamic regime**. A quiescent environment with a sandy mud substrate generally supports a dense, continuous eelgrass bed with virtually 100 percent cover. The cover of eelgrass in areas subjected to strong currents or waves is typically patchy. Areas with **heterogeneous** substrate (mixture of fine and coarse sediments) also tend to be patchy or sparse (Figure 1.7).

Figure 1.7 Examples of a quiescent environment supporting a continuous eelgrass bed (left), a patchy bed due to wave exposure (centre), and habitat with sparse eelgrass due to currents and sediment composition.

Eelgrass meadows shift in size due to environmental factors. Storms, extreme temperatures, and shifting sediment can damage or kill eelgrass. A 20% annual loss is not worrisome unless it becomes a trend.

1.4 DENSITY

The density of shoots within an eelgrass bed may be consistent throughout the bed, or it may vary in response to biophysical parameters within the bed (i.e., 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. This variation leads to 'zones' within the bed (Figures 1.8, 1.9).

Figure 1.8 An eelgrass bed that ranges from the intertidal zone into the narrow shallow subtidal zone.

To determine the **mean** density of shoots within the bed, 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 that can smother eelgrass and often result in sediment scour.

Figure 1.9 An example of an eelgrass bed with three zones in Tofino. The upper intertidal, Zone 1 was colonized by a continuous population of the *Z. marina* ecotype *typica* (left). Zone 2, the mid and low intertidal supported continuous population of the *Z. marina* ecotype *phillipsii* (centre) and a patchy bed of the *Z. marina* ecotype *latifolia* was located in Zone 3 in the shallow subtidal (right).

1.5 ENVIRONMENTAL REQUIREMENTS

The growth and distribution of eelgrass is influenced by salinity, sediment type, current velocity, light availability, temperature, and pH. Temperature, salinity, and pH are not usually restrictive along coastal BC. A summary of the range and optimal levels for each of these parameters is provided in Table 1.2.

Table 1.2 Environmental requirements for vegetative growth of eelgrass and optimum conditions in the Pacific Northwest (Phillips, 1974; Thom et al., 2014).

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 –10 m	MLLW to – 4.4 m
Temperature	-6 °C to 40.5 °C	6 °C to 17 °C
pH	7.3 to 9.0	7.3 to 9.0
Nutrients		Moderate soil nutrients; low in water column

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 BC. There are two known areas where eelgrass has adapted to grow over hard substrate, one on and between rocks in Port McNeill, and one on cement blocks near Victoria (Austin, pers. comm. 2006). It is possible that the eelgrass in these locations has crossed with surfgrass, another genus of seagrass that lives on hard substrate along our coasts. This has been pondered at several seagrass conferences; recent advances in genetic testing will be able to determine whether this happens occasionally.

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.

FREQUENTLY ASKED QUESTIONS:

1. **What is the difference between seagrass and eelgrass?**
   Seagrasses are vascular plants that evolved from terrestrial plants. Eelgrass is one of 60 species of seagrass.
2. **What is the geographical range of eelgrass?**
   It is a temperate species. It grows on the west coast of North America from Alaska to Baja.
3. **Why is eelgrass not considered algae?**
   Algae are primitive plants without specialized cells or a vascular system. Seagrasses are highly evolved plants with a vascular system and specialized cells.
4. **What is the difference between an eelgrass bed and meadow?**
   There is no technical distinction, although the term meadow is often reserved for large beds.
5. **What are the most unusual animals you've seen in eelgrass beds?**
   A skate, an octopus, a huge spiny dogfish, shiner perch giving birth to live young, and cows!

CHAPTER 2: MAPPING AND MONITORING PARAMETERS

Eelgrass meadows possess many attributes that can be mapped and monitored over time to assess changes and track ecosystem health. The parameters that are selected for study depend on the objectives or goals of the study and the resources available. Monitoring specific beds, using scientific sampling methods, can provide the data required to detect and assess environmental changes. Many variables are commonly measured to detect changes in eelgrass populations or beds and the environment.

The following section defines the parameters that are frequently used to study eelgrass, and the value associated with monitoring each. Chapter 4 explains how to assess each of the parameters selected for this community mapping and monitoring program.

2.1 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 and Indigenous Protected and Conserved Areas (IPCAs). The *Fisheries Act* prohibits the death of fish and the harmful alteration, disruption or destruction (HADD) of fish habitat. While eelgrass is not explicitly mentioned in the *Fisheries Act*, it is protected under fish habitat protection provisions, which prevent the HADD of fish habitat without prior authorization by the Minister. Where a HADD cannot be avoided, proponents are required to apply for a *Fisheries Act* Authorization prior to carrying out their work (Fisheries and Oceans Canada DFO, 2025).

Fisheries and Oceans Canada has a '**habitat offsetting**' policy that requires that fish habitat, including eelgrass, that is lost or damaged by authorized development projects be effectively replaced and ecologically functional over the long term, after all measures to avoid or mitigate damage are taken (DFO, 2025). Knowing the location of eelgrass beds, therefore, assists in eelgrass conservation.

2.2 FORM

In the Pacific Northwest, eelgrass beds are classified according to their **geomorphology** as either *"flat"* — broad areas in shallow embayments usually near river mouths with little slope — or *"fringe"* which are narrow, depth-defined bands. In BC, a third *"channel"* type refers to eelgrass growing in tidal channels (Figure 2.1).

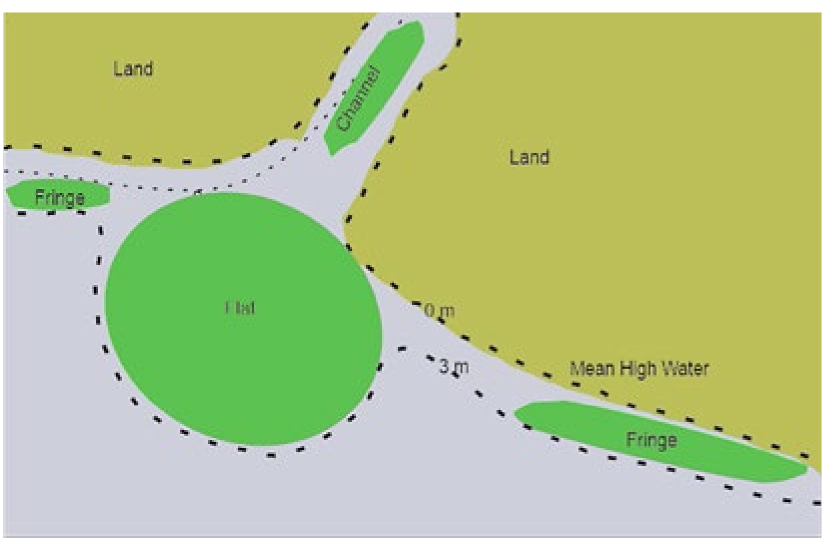


Figure 2.1 An An aerial view of the eelgrass forms. Most eelgrass beds in the Salish Sea and WCVI are situated between 0 m and 3 m chart datum (CD), although some extend to 10 m CD.

2.3 GEOREFERENCING LOCATION

Delineating the boundaries of an eelgrass bed with a GPS (georeferencing) enables the detection of habitat losses or gains over time. Losses may be caused by environmental change or anthropogenic impacts. Early identification of a loss may assist in developing mitigation plans to prevent further degradation. In addition, any industry or development that can be shown to impact eelgrass habitat may be directed by Fisheries and Oceans Canada or the Province to provide mitigation, restoration, or habitat offsetting.

2.4 DEPTH DISTRIBUTION

The distribution of eelgrass across a bathymetric gradient is limited at the upper boundary by the degree of exposure during low tides (desiccation in the summer or freezing during the winter) and by light limitations at the lower subtidal boundary. In some cases, substrate characteristics change with depth, and this may also limit eelgrass distribution. Degradation of water quality that results in increased turbidity (e.g., suspended solids, high chlorophyll A) leads to a decrease in light penetration and thus 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., 1993).


Credit: Coastal Photography Studio

2.5 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; Olsen et al., 1994). The number of flowering shoots (Figure 2.2) 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.

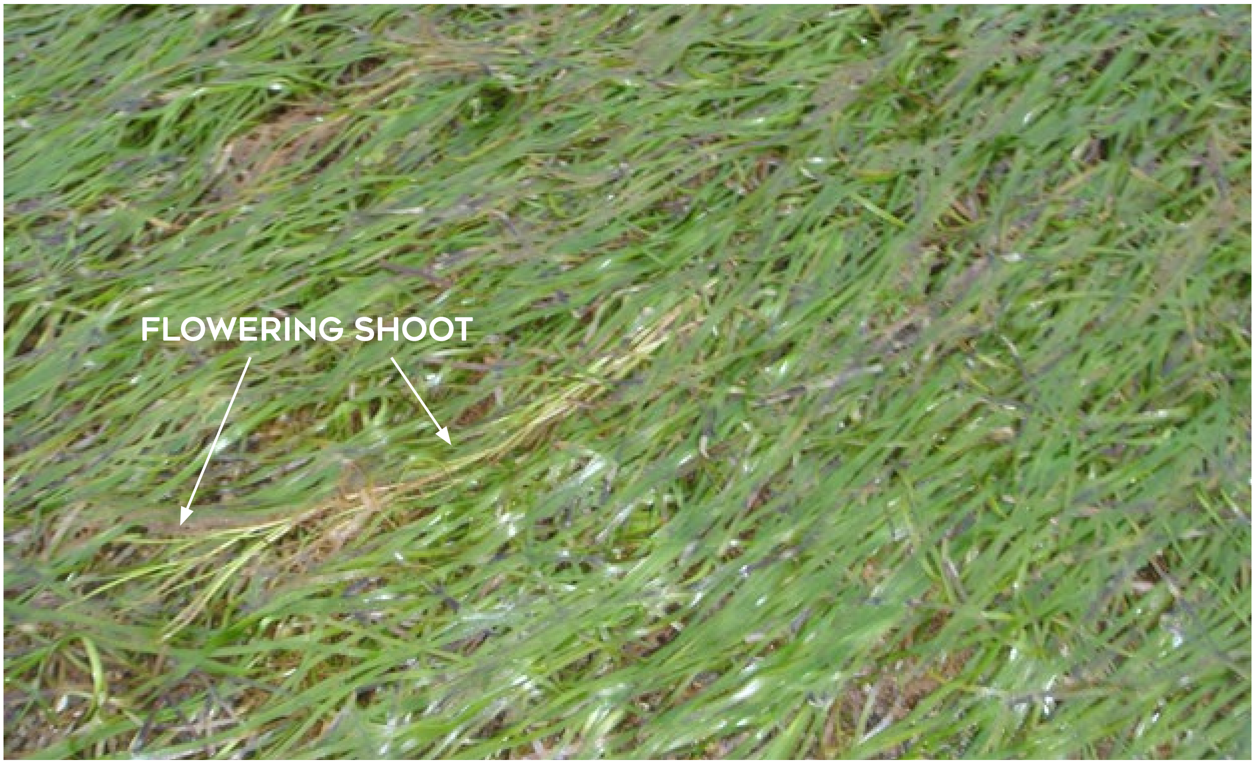


Figure 2.2 A flowering shoot (pale and branched) surrounded by vegetative shoots.

An example of inter-annual variation in density is provided in Table 2.1. The data was collected from a natural, undisturbed meadow in late July from 2006 to 2014. The **means** are based on a sample of twenty 0.25 m^2 **quadrats**. The data shows that the density in 2010 was almost double that recorded in 2006. The variability in the averages can be due to many environmental factors, including seasonal temperature fluctuations, timing of daylight low low tides, water temperature, etc.

Table 2.1 The mean number of shoots in twenty 0.25 m^2 quadrats in a natural meadow demonstrating how natural eelgrass shoot density variations over time.

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
#/0.25 m^2	23.9	26.5	32.8	25.8	42.4	35	28.2	26.2	35

2.6 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, wave action, or active seabed movement tend to have a patchy eelgrass distribution (Figure 2.3). The homogeneity of an eelgrass bed can also be reduced by **anthropogenic** disturbances (shellfish harvesting, boat anchoring, dredging activity, continuous foot traffic, etc.)

Figure 2.3 Seabed movement has exposed the rhizomes; if this continues, the patch will be washed away.

The integrity of an eelgrass bed may be threatened by fragmentation. The plants within established eelgrass beds reduce currents, leading to increased sediment and **detritus** deposition. The dense rhizome and root matrix of the plants, in conjunction with the enhanced deposition rate, assist 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 (Figure 2.4).

Figure 2.4 Adjacent to a marina, eelgrass has a continuous distribution of eelgrass but becomes patchy near the water line where it's exposed to wave action (top). The continuous and patchy areas need to be surveyed separately. The lower left photo shows a bed that would be classified as continuous with bare areas. The photo on the right would be classified as patchy habitat in the foreground becoming continuous near shore.

2.7 PERCENT COVER

The percent cover of eelgrass is useful for assessing ecosystem health and changes over time. It is a visual estimate of the eelgrass cover, a bird's-eye view of how much of the water's surface, or sediment during low tide, is covered by eelgrass at a point in time. Visual estimation of percent cover is quick but is susceptible to observer bias. Most people have no trouble distinguishing between 1% cover and 100% cover, but have difficulty assigning a precise percentage.

To minimize variations in percent cover estimates made by mappers, the percent cover may be estimated within ranges: very sparse (<10%), sparse (11 to 25%), moderate (25 to 50%), dense (51 to 75%), and very dense (75 to 100%) (Figure 2.5). It is a good idea to practice with the other members of the crew, by comparing your estimates.

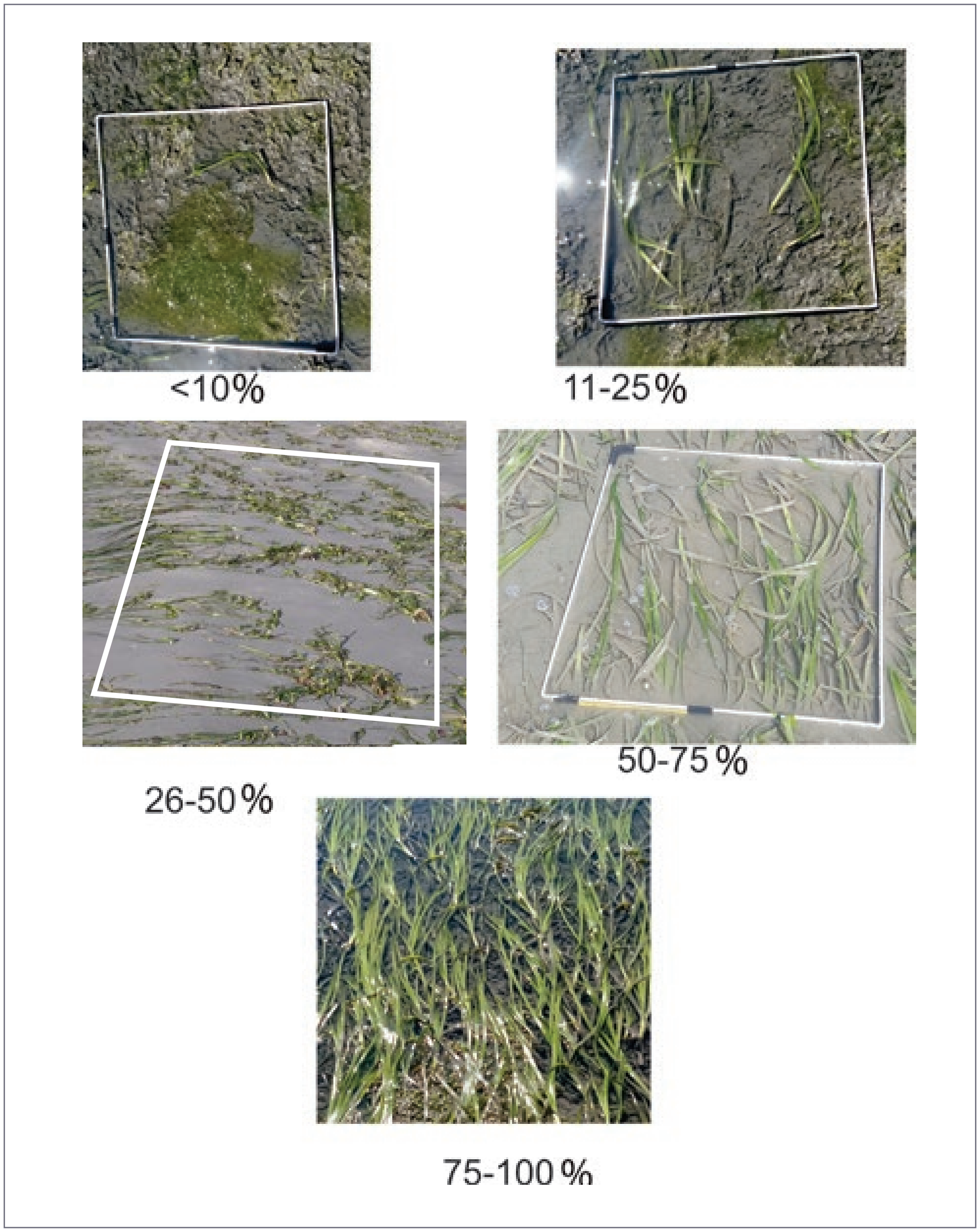


Figure 2.5 Close up photos of percent cover ranges.

Estimates of percent cover of eelgrass in intertidal eelgrass habitats viewed at low tide are more replicable than surveys of subtidal eelgrass, where cover appears to vary with tidal stage. The percent cover of subtidal eelgrass appears greater during a flood or ebb tide when the currents move the leaves in the direction of the tide, versus slack tide when the leaves are vertical and the gaps between them are visible.

If the percent cover of subtidal eelgrass seems to vary considerably over time, consider the tide level at the time the estimates were made. It is important to remember percent cover is a snapshot of a moment in time.

2.8 LEAF AREA INDEX (LAI)

Leaf area indices are often used to estimate the **productivity** of eelgrass. The greater the productivity the greater the amount of habitat available for colonization by **epifauna** and **epiphytes**, the amount of carbon sequestered, and the amount of oxygen produced. The LAI is calculated according to the following formula (note: shoot length and width are measured in centimetres (cm) and millimetres (mm) and need to be converted to metres (m) to calculate the LAI.):

LAI = mean shoot length (m) x mean shoot width (m) x mean # shoots/m^2

For example, if the mean shoot length was 98 cm (0.98 m), the mean leaf width was 7 mm (0.07 m) and the mean density was 48 shoots/m^2, the LAI would be:

0.98m x 0.07m x 48 shoots/m^2= 3.29. Note that the units cancel each other out.

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

2.9 SHOOT BIOMASS

Shoot **biomass** (weight of plant material per unit area) and dry weight 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 communities (ovens and scales). For these reasons, it isn't part of the methodology included in this handbook.

Credit: Sharon Jeffery

2.10 WATER QUALITY

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

The environmental parameters that are included in several large-scale eelgrass monitoring projects are listed in Table 2.2.

Table 2.2 Environmental variables included in several large-scale eelgrass monitoring projects.

Parameter	Puget Sound Submerged Vegetation Monitoring Project	*SeagrassNet*	European Directorate Special Areas of Conservation
Temperature	★	★	–
Salinity	★	★	–
Dissolved oxygen	★	–	–
Turbidity	★	★	★
Photosynthetically active radiation	★	–	–
Light parameters, back scatter, florescence	★	–	–
Surface sediment character	–	★	–
Nutrient levels	–	–	★

FREQUENTLY ASKED QUESTIONS:

1. **What is the benefit of calculating the productivity of an eelgrass bed?**

   Calculating productivity of an eelgrass bed is a way to compare ecosystem health between beds. For example, a sparse bed with large shoots may be as productive as a very dense bed with smaller shoots.

2. **Our community group is small with low capacity and not much money. What are the minimum parameters that we should measure?**

   See Chapter 3.

CHAPTER 3: STRATEGY

3.1 LOCATION

The flow chart below (Figure 3.1) outlines four levels of surveys to enable all interested parties to participate in an eelgrass mapping or monitoring project according to their capacity (budget, time, and personnel).

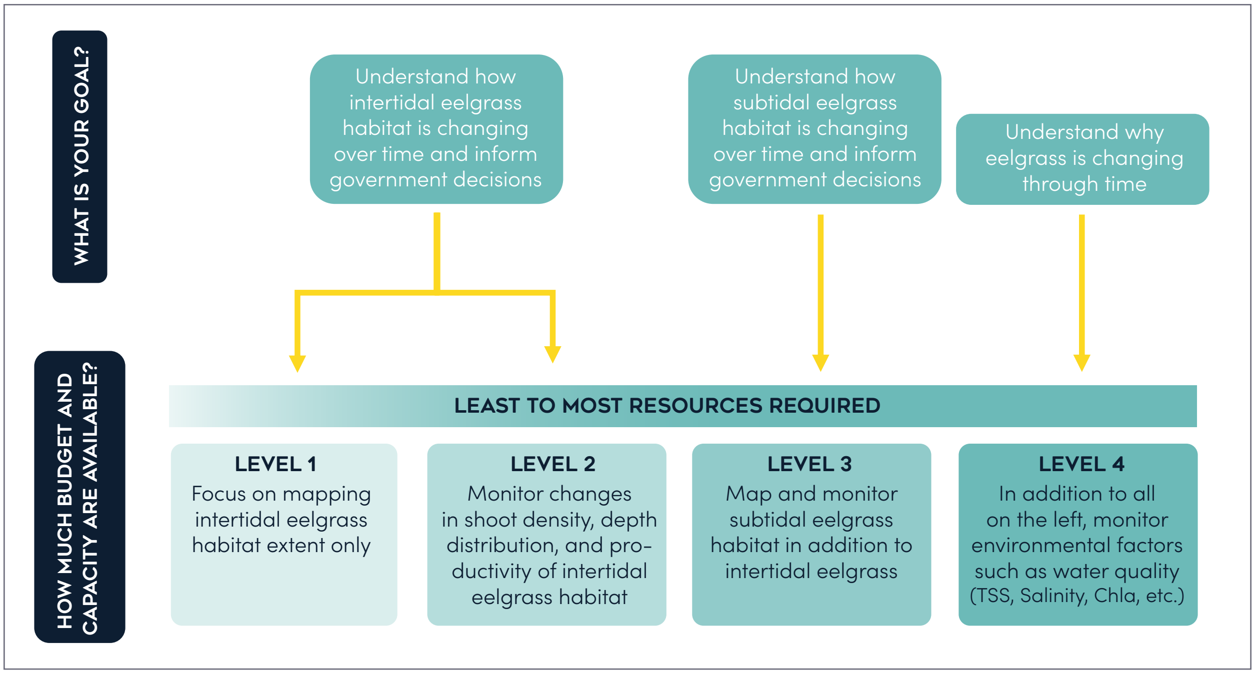


Figure 3.1 Survey goals and capacities required to meet them with each survey level.

The mapping level you choose will depend on your group's objectives and resources. Table 3.1 lists the parameters associated with each level.

Table 3.1 Parameters included with each level of survey.

Parameter	Level 1	Level 2	Level 3	Level 4
Location of eelgrass meadows	★	★	★	★
Overview of habitat	★	★	★	★
Georeference intertidal habitat	★	★	★	★
Georeference subtidal habitat	–	–	★	★
Depth range	–	–	★	★
Shoot density, including reproductive status	–	★	★	★
Leaf Area Index (LAI)	–	★	★	★
Turbidity	–	–	–	★
Salinity	–	–	–	★
Total Suspended Solids (TSS)	–	–	–	★
Chlorophyll A	–	–	–	★

3.2 MONITORING SCHEDULE

The frequency of monitoring depends on the resources of the study team. Monitoring programs may collect data annually, biannually, or seasonally.

★ Multi-year 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, whenever possible, to avoid seasonal differences.

There is a minimum set of parameters associated with each level. However, any of the parameters from higher levels may be added to a lower-level survey. For example, a group may elect to complete a Level 1 survey but decide to collect LAI data for the intertidal area with the methods used for a Level 2 survey. Strategies may be developed to suit the requirements of each sampling team by using a combination of Levels.

★ A recommended strategy is to map all eelgrass within a geographical area at Level 1, then select several meadows of interest to monitor at a higher level on a regular basis. The beds that are selected for monitoring can be in areas of potential environmental concern (e.g. new shoreline development or marina), and in this case, at least one should be monitored in a relatively protected area to use as a reference site.

FREQUENTLY ASKED QUESTIONS:

1. **How does providing eelgrass maps to the government aid conservation?**

   Any proposed development with potential impacts on fish habitat necessitates a *Fisheries Act* Authorization (FAA). The proponent is responsible for reporting the presence of eelgrass; however, in cases where the eelgrass is subtidal, its existence may be overlooked. Access to accurate maps helps proponents identify eelgrass locations, which contributes to their conservation.

CHAPTER 4: METHODS

The following methods are based on protocols that have been used to map and monitor eelgrass communities globally. The methods described here enable groups or agencies to map eelgrass in a consistent manner and contribute to a central database using standardized data entry forms.

Mapping and monitoring can be performed at any time of year, but if you plan to survey intertidal beds on foot, the survey should be conducted during the lowest spring and summer tides for optimal access, exposure, and comfort.

The author has spent many winter low low tide periods surveying eelgrass, even on a New Year's Eve. I've always enjoyed the experience, but realize that many folks wouldn't.

> ★ A list of the equipment required for each level of study is provided in Appendix B. Safety considerations for working in intertidal and subtidal eelgrass beds are provided in Appendix C.

The field data sheets in Appendix E provide a series of fields and categories to describe each eelgrass bed.

The following steps outline the tasks required to complete the fields in the Data Field Forms for each Level.

4.1 SURVEY STEPS

Step 1: Locate eelgrass beds – All Levels

Identifying the location of local eelgrass beds can take years in some areas, depending on the time and resources available.

Indigenous peoples on the BC coast have always known where eelgrass grows in their Territories. Consulting Indigenous Knowledge Holders about locations of past and present eelgrass beds is a good place to start when embarking on locating and mapping eelgrass habitats. Traditional or Local Ecological Knowledge (TEK or LED) is increasingly recognized as a valuable source of information, synthesized with other data, to establish historical baseline conditions and assess long-term ecosystem change (Beaudreau & Levin, 2014).

There are many publicly available sources of information that may assist in identifying the location of intertidal and subtidal eelgrass beds. Sources that should be reviewed include:

- the BC ShoreZone Maps (www.shorezone.org/shorezone-maps/bc-shorezone),
- Islands Trust eelgrass habitat mapping (islandstrust.bc.ca/programs/ecosystem-inventories),
- the Marine Conservation Atlas (BCMCA) (https://bcmca.ca/),
- Eelgrass Mapping Bed Atlas on the Community Mapping Network website (https://www.cmnbc.ca/),
- Eelgrass Habitat Suitability Maps (under development),
- Eelgrass habitats are often visible on Google Earth imagery if the images were taken during a relatively low tide.

Methods of locating intertidal and subtidal eelgrass habitats in your area are explained on the next page.

Intertidal eelgrass habitat locations — All Levels

A survey of the mid and low intertidal zone conducted during the lowest daytime tides of the year can identify the location of many intertidal eelgrass meadows. Surveying with a drone at low tide is an excellent way to cover a long distance of shoreline in a small amount of time. Information about drone survey methods and regulations is available in a series of excellent videos that were produced by the Hakai Institute with the Marine Plan Partnership North Pacific Coast (https://youtu.be/fcDSX0Zd-Ko4?si=IR-lETFOXmBg2OdR).

Subtidal eelgrass locations — Levels 3 and 4

Mapping subtidal eelgrass beds requires diver surveys (SCUBA or **freedivers**), and/or the use of a towed underwater video camera. If the bed is located in the very shallow subtidal, it may be possible to survey by foot or kayak during an extreme low tide. A short video is available on YouTube about the methods used by freedivers working with the Mayne Island Conservancy (https://youtu.be/c7pIxzlw2N-Q?si=Y_J8c7ChUzep_6tV).

Surveying a shallow subtidal eelgrass bed during an extremely low tide.

SCUBA divers, snorkelers, remotely operated vehicles (**ROV**), or a drop camera from a boat can be used to identify subtidal eelgrass beds. Underwater cameras feed information into an above water video recorder. A description of this method is in Appendix H. It is suggested that when searching for subtidal eelgrass, the habitat at a depth between 1 m and 3 m (**chart datum**, CD) be investigated, as most subtidal eelgrass beds in BC will extend across this depth range.

Step 2: Plan field surveys

Examine your list of sites identified in Step 1 and determine the number of surveys that are feasible given your available resources and time. Select which beds should be given priority for mapping and/or monitoring.

Step 3: Collect overview data — All levels

Determine form and distribution

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

Estimate percent cover of eelgrass

If the bed extends into the intertidal, the percent cover of the eelgrass can be estimated during low tide. Wander back and forth across the bed, assessing the percent cover of the eelgrass and the substate types. A copy of the Field Reference Guide (Appendix A) can aid you in your decisions. If your survey is going to include subtidal areas, then the tide doesn't matter, and the intertidal portion may be surveyed at the same time as the subtidal. Have a diver, snorkeler, or drop camera hover over the tips of the eelgrass leaves and move back and forth over the bed with the diver or snorkeler estimating the percent cover of eelgrass. If you use a drop camera, watch the monitor to assess the percent cover. If the cover varies significantly, then the primary, secondary, and, if present, tertiary percent covers should be recorded. Examples of each range are provided in Figure 2.5.

Determine substrate type

The substrate(s) should be estimated by eye and recorded in order of dominance. If more than one substrate type is present, then the percentage that is occupied by each type should be recorded according to the categories provided on the datasheet.

Diver hovering over eelgrass to assess percent cover. Credit: Danielle LaCasse.

Step 4: Georeferencing

Delineate the perimeter

The boundaries 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. An accepted international standard is that areas which support a minimum density of one (1) shoot per m^2 are included in the bed. We have adopted the same criteria.

The edge of the bed shall be defined as the point at which the density decreases below 1 shoot per 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 (Figure 4.1) or if the patches are large you may choose to map each patch as a small continuous bed.

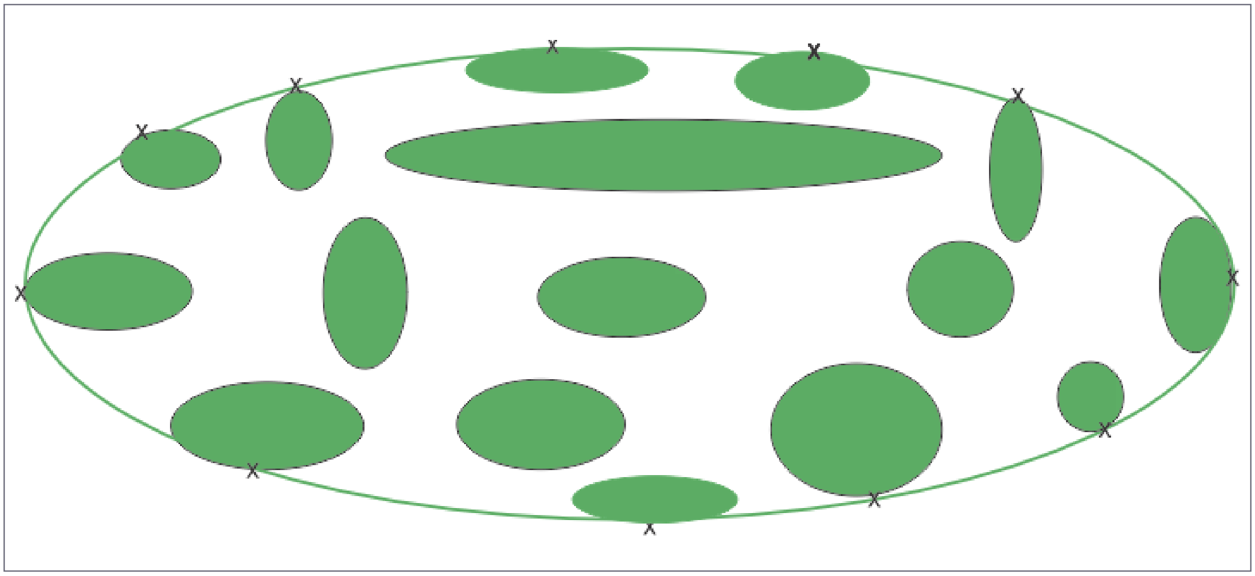


Figure 4.1 Graphic representation of a patchy eelgrass bed. Xs indicate perimeter way points.

A Global Positioning System (GPS) unit and most smart phones are accurate and inexpensive tools for recording the location and perimeter of a bed. A GPS track around the perimeter can be used to create a polygon, which can be used to calculate the area covered by eelgrass. Alternatively, waypoints can be used to create the polygon. The boundaries of a subtidal bed may be determined using an aqua viewer, ROV, a towed underwater camera, or a diver or snorkeler with weighted floats Appendix H. The depth to which the aqua viewer or snorkeler may be used successfully will depend on the turbidity of the water and the depth range of the eelgrass.

GPS readings should be recorded at roughly 5 to 10 metre intervals around the perimeter of large beds. Smaller beds, <30 m in any direction, need a minimum of three waypoints along both the deep and the shallow edges. The accuracy of mapping will increase with the number of points recorded.

An intertidal survey should include a track line along the exposed portion of the bed. A subtidal survey needs to collect waypoints around the perimeter (Figure 4.2). An example of how to survey the perimeter is provided in a series of graphics in Appendix H.

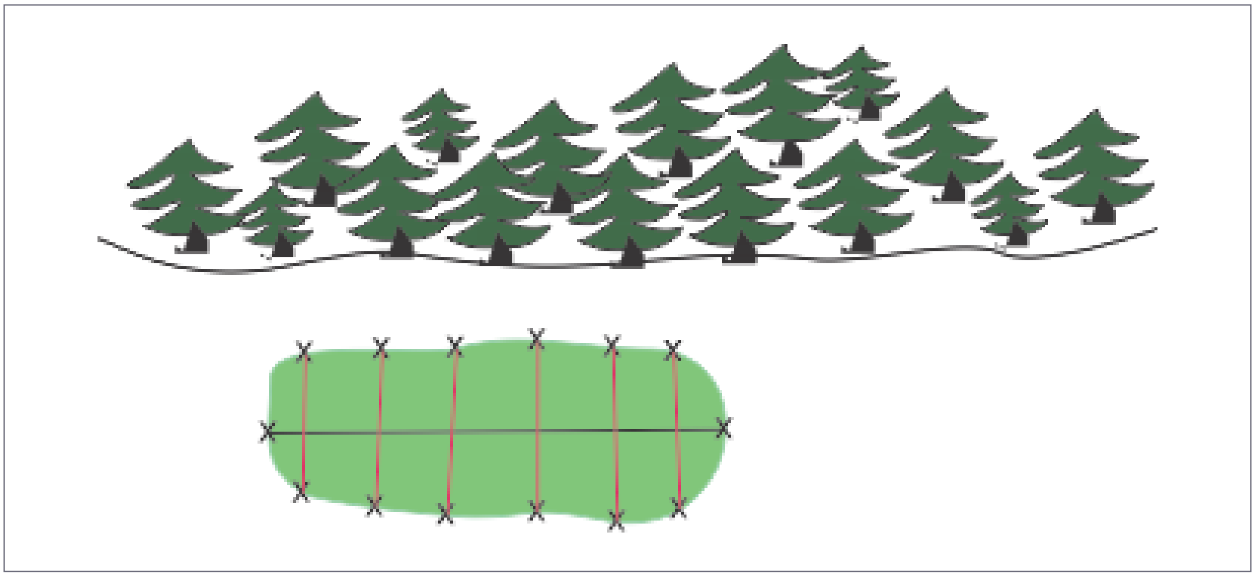


Figure 4.2 Graphic showing where waypoints (x) should be collected around the perimeter of an eelgrass bed

The free Gaia GPS app is available for both Android and iPhone and is very reliable.

If you are conducting a Level 1 survey, it is now complete, and you have contributed to eelgrass conservation.

Step 5: Record maximum and minimum depth

The minimum depth can be determined during intertidal surveys. Watch the tide come in and record the time that seawater covers the uppermost part of the bed. Later, reference the relevant tide tables to calculate the chart datum height.

The maximum and minimum depths for beds that extend into the subtidal should be determined when the bed is submerged. Diver's depth gauges may only be used if they are known to be accurate to within 0.2 metres. One method is to attach a weight to the end of a metre tape, which is then lowered to a diver at the deepest 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 taut and vertical, then records the measurement. The procedure is then repeated at the most shallow edge of the bed.

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 (e.g., https://www.tides.gc.ca/).

To calculate the depth, subtract the tide height given in a tide table for the time the measurement was taken. Subtract your depth measurement. For example, if the maximum depth during your survey was 5 m, and the tide height at that time was 2 m, then the actual depth (chart datum) was 5 m – 2 m = 3 m.

Step 6: Determine zonation, shoot density, and size — Levels 3 and 4

The density and shoot size of eelgrass shoots (length and width) 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 into the next, often by several metres; these areas are referred to as 'Transition areas'. The zones may all be the same ecotype, or each zone may be a different ecotype.

The density and size of the shoots are significantly different between zones; therefore, each zone must be sampled individually.

Monitoring must be conducted outside of the transition areas (Figure 4.3). The zones should be classified numerically, starting with the uppermost zone. Zones that are less than 4 m in width do not need to be assessed.

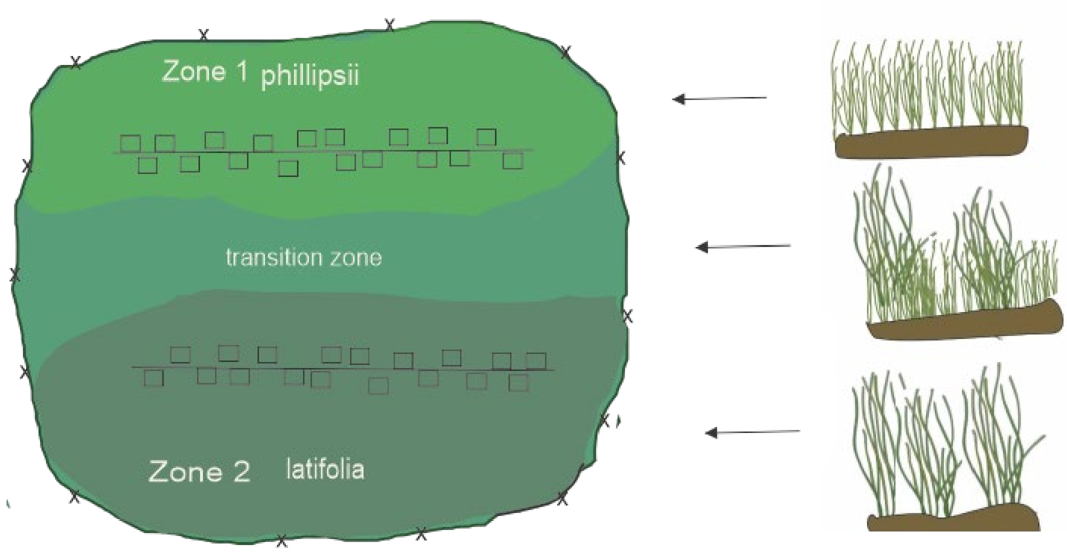


Figure 4.3 A graphic representation of an eelgrass bed with two zones; one supporting a population of the ecotype *phillipsii* and a deeper one dominated by the larger ecotype *latifolia*. A narrow transition zone supports both ecotypes. The Xs indicate GPS locations, the squares represent quadrat sampling locations (not to scale).

The width of each zone does not need to be recorded as the exact boundaries are difficult, if not impossible, to determine and may vary between years.

The following example of a zonation is intended to provide an understanding of the zonation typical in BC:

Zone 1 is a band 20 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 38 shoots/m^2). Zone 1 blends into Zone 2, at a slightly lower elevation.

The plants in Zone 2 are larger and denser (80 cm, 112 shoots/m^2) than 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 measuring 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 (50 cm x 50 cm) (Figure 4.4) should be used to assess density in most cases. This represents a quarter of a square metre.

Intertidal eelgrass may reach densities in excess of 500 shoots per quarter metre squared (#/0.25 m^2). It is recommended that a smaller quadrat (25 cm x 25 cm) be used to monitor density once the number of shoots /0.25 m^2 exceeds 100. A quadrat of this size represents 1/16 of a metre squared (0.0625 m^2) (Figure 4.5).

Figure 4.4 A 0.25 m^2 quadrat.

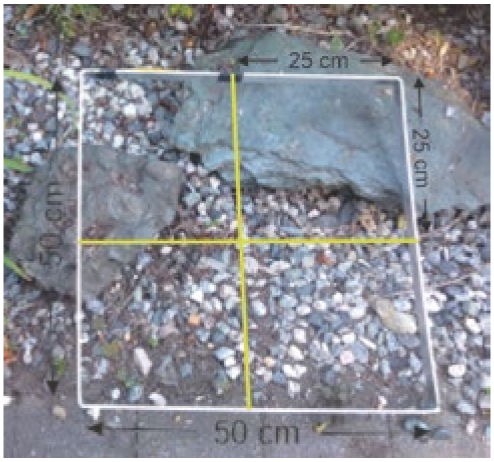


Figure 4.5 A 0.25 m^2 quadrat can be modified to create a 0.16 m^2 quadrat by tying strings across it 25 cm from each corner.

The number of quadrats assessed will vary depending on the length of the transect. Avoid sampling at the edge of the bed as this is often not representative of the conditions within the bed.

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 can be calculated by subtracting the number of reproductive shoots from the total number of shoots. This is easier than keeping track of vegetative and reproductive shoots separately. The Hakai video webpage has a video showing quadrats and counting (https://youtu.be/fcDSX0ZdKo4?si=lR-IETFOXmBg2OdR).

Continuous eelgrass beds

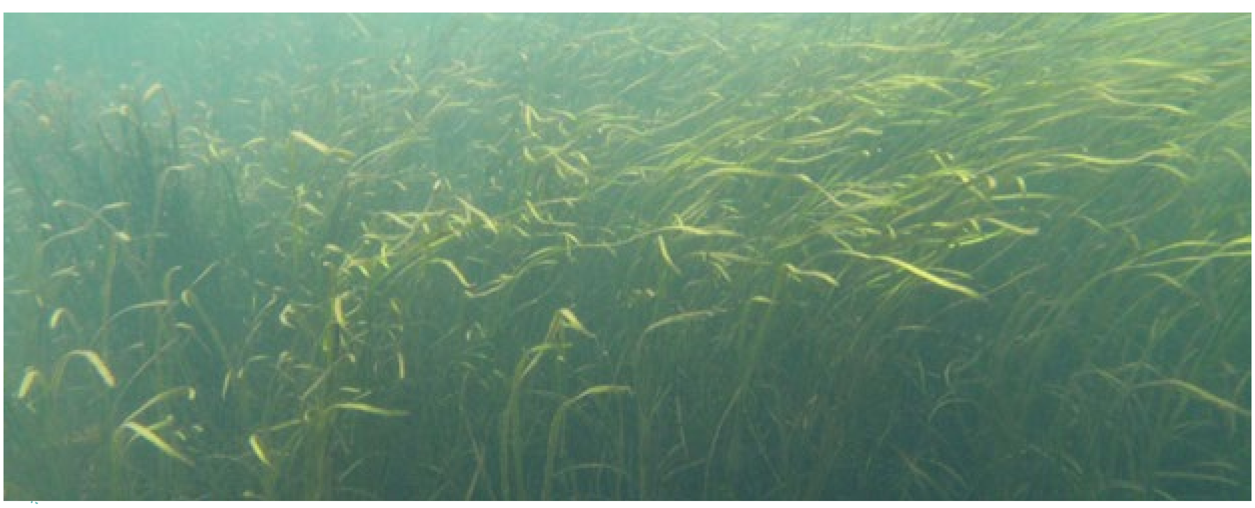
A temporary transect using a metre tape or marked line should be established in each zone, roughly parallel to the shore, along a depth continuum. The length of each transect should be roughly 60% of the bed width. The transects should be centred in the bed to avoid edge effects. A sample of 30 quadrats is usually adequate in a continuous bed. Sample within zones, avoiding transition areas whenever possible.

To avoid observer bias, use predetermined random numbers to establish the location along either side of the transect where quadrats will be placed. It will be necessary to determine the number of quadrats (or replicates) required to estimate the mean density of shoots on a site-specific basis due to the natural variability within eelgrass communities. Initially, a minimum of 30 quadrats should be assessed for density within each zone. Use this data to calculate the **running mean**.

Random number generators are available free of charge on the internet.
For example: https://www.calculator.net/random-number-generator.html.

The running mean is an accepted method by which to determine the number of quadrats to sample. Sample size is adequate once the variation between samples, which decreases as the number of samples increases, is reduced to 5%. A sample of 30 quadrats should be enough to calculate the running mean for the number of quadrats to assess in future surveys. It is likely that the number of replicates required in the future will be less. The running mean can be easily calculated in a spreadsheet (e.g. Mircosoft Excel) (Appendix J).

Diver measuring the width of a shoot and recording data. Credit: Coastal Photography Studio



Patchy eelgrass beds

It is challenging to design a sampling method for patchy (fragmented) beds, since the size and distribution of patches varies between and within sites. You may need to adapt the following method to what you encounter in the field:

1. Establish a temporary transect line parallel to the 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 1 m^2, use a quadrat to determine the density (total number of shoots rooted within the quadrat and number of reproductive shoots) within 0.25 m^2, avoiding the edges of the patch.
2. If the patch is greater than 6 m^2, place 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 substrate, and sample wherever it lands.
3. Follow the transect line recording the distance that it travels over each patch, the distance between each patch, and the density within patches >1 m^2 (Figure 4.6).

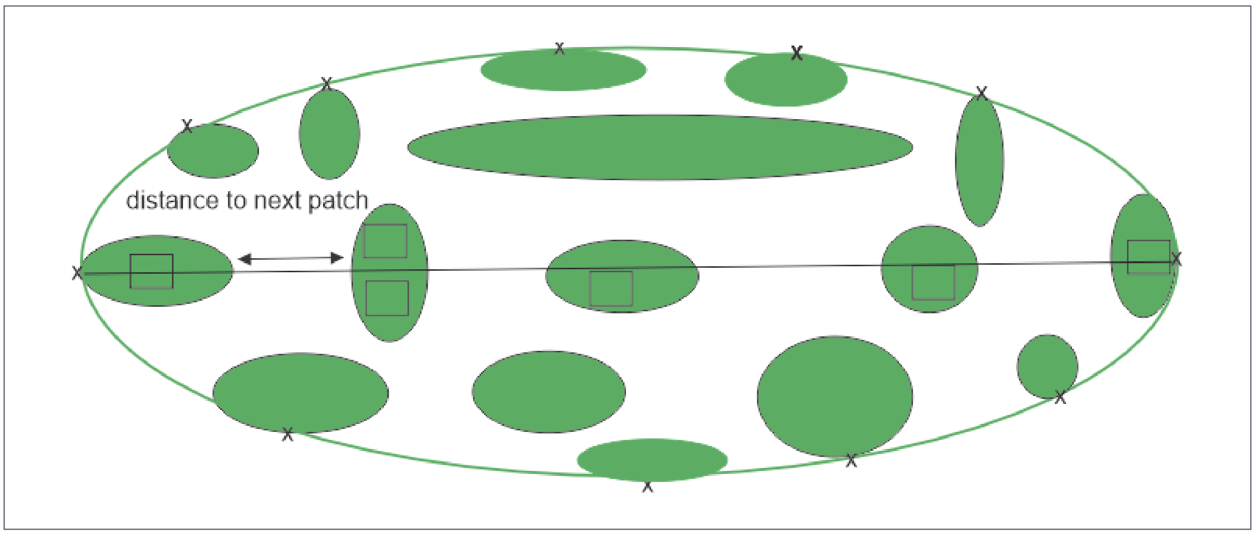


Figure 4.6 The green oval represents the perimeter of the bed, each 'x' indicates a GPS point that was taken to define the perimeter of the bed. Squares represent quadrat sampling locations (not to scale).

Step 7: Calculate Leaf Area Index (LAI) — Levels 2, 3, and 4

The mean leaf length and width can be determined from a random sample of 30 shoots within a zone. The data may be collected at the same time as the density is assessed.

To avoid sampling only the largest shoots, measure a mature shoot located nearest to a predetermined corner of the quadrat (i.e., bottom left corner). Measure the leaf length (cm) from the sediment surface to tip of the second oldest (unbroken) leaf and the width (mm) near the middle of the leaf.

The LAI is calculated according to the following formula: (note: shoot length and width are measured in cm and mm units and need to be converted to m to calculate LAI.

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

For example, if the mean shoot length was 98 cm (0.98 m), mean leaf width 7 mm (0.07 m) and the mean density 48 shoots/m^2. The LAI would be 0.98 m x 0.07 m x 48/m^2 = 3.29

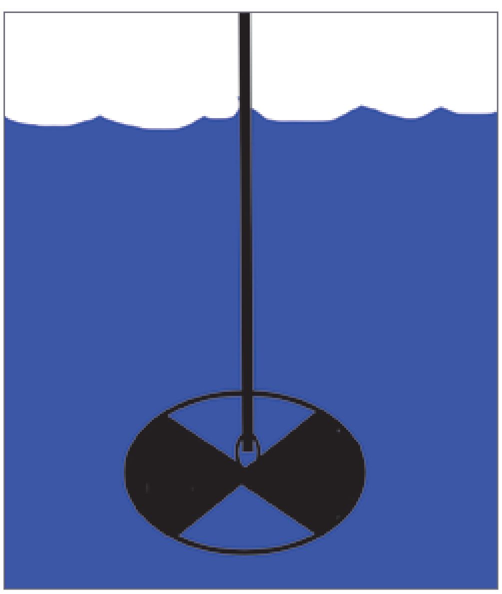
There are variations in the way that researchers measure LAI; some include the sheath, and others measure each leaf. The above method was selected, as it requires the least amount of time and can be used to provide a relative estimate of biomass.

If you are conducting a Level 2 or 3 survey, it is now complete and you have contributed to eelgrass conservation.

Step 8: Measure water quality attributes – Level 4

Turbidity

A Secchi depth reading is the easiest way to assess turbidity.



How it works:

1. Descent: The Secchi disk is attached to a rope or pole with depth markings and slowly lowered into the water.
2. Disappearance: The observer notes the depth at which the disk is no longer visible from the surface.
3. Secchi depth: This recorded depth is the Secchi depth, which is a direct indicator of the water's transparency or turbidity at a given time.

Figure 4.7 A Secchi disk is a circular tool, usually divided into black and white sections, used to measure water clarity. It is lowered into the water until it disappears; this depth, called the Secchi depth, indicates transparency: deeper means clearer water, while shallower suggests more suspended particles.

Salinity

The salinity along the BC coast is almost always within the range suitable for eelgrass, however if you want to assess it you can measure it in either Practical Salinity Units (PSU) or parts per thousand (ppt). Recently, Practical Salinity Units (PSU) have become the acceptable way to measure salinity. It uses a digital meter that measures the water's **electrical conductivity (EC)**, temperature, and pressure, then applies the Practical Salinity Scale 1978 (PSS-78) or the newer TEOS-10 standard equations to convert these readings into a dimensionless ratio, reported as PSU, which is nearly equivalent to parts per thousand (ppt).

A salinometer can be used to determine salinity in parts per thousand (ppt). Salinometers are available online and can range in price from $16 to $250 (Appendix B).

Total Suspended Solids (TSS)

Water samples need to 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 samples

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

If you are conducting a Level 4 survey, it is now complete and you have contributed to eelgrass conservation.

FREQUENTLY ASKED QUESTIONS:

1. **If the patches are large, should we map each patch as a small continuous bed or group them together as a larger patchy bed?**
   It doesn't matter; the results are valid either way.

2. **Why don't we set up permanent plots to monitor?**
   The objective of monitoring is to assess the overall mean density of shoots, not the density at specific points.

3. **Why do we need to keep track of the number of shoots that are flowering?**
   The flowering shoots break off and drift away once the seeds are mature. This can affect the density between monitoring events.

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GLOSSARY OF TERMS

The following definitions were adapted from Dunster and Dunster (1996), unless otherwise noted.

Aerial coverage	Area covered as viewed from above. (C. Durance)
Anthropogenic	Modified by human activities. (C. Durance)
Aqua viewer	The science of mapping the contours of the ocean floor or lake bed.
Bathymetry	The science of mapping the contours of the ocean floor or lake bed.
Biomass	The total mass at any given time of living organisms per unit of space.
Desiccation	To dry up.
Chart datum	Canadian chart datum (CD) is measured relative to lowest normal tide. (Government of Canada website). The lowest normal tide is zero metres CD, datum measurements refer to the depth below zero metres, therefore they don't require a negative sign. A negative sign is used to denote tides below the lowest normal tide. (C. Durance)
Ecotype	A subdivision of a species with distinct morphological or physiological that has adapted **to local or regional** conditions and that has resulted from genetic selection in response to local environmental factors.
Ephemeral	Lasting for a brief period of time.
Epifauna	An animal living on the outside of a plant in a non-parasitic relationship.
Epiphyte	A plant growing on the outside of another plant in a non-parasitic relationship.
Detritus	Freshly dead or partially decomposed plant or animal matter.
Freediving	A mode of underwater diving that relies on breath-holding (apnea) until resurfacing rather than the use of breathing apparatus such as scuba gear.
Geomorphology	The study of landforms, the process whereby they are formed, and the materials of which they consist.
Georeference	A navigational system and poisoning system with which the three-dimensional geodetic and velocity of a user at a point on the earth can be determined in real time.
Habitat offsetting	Offsetting measures are the actions taken by a proponent to counterbalance the residual effects to fish and fish habitat that are caused by their project after avoidance and mitigation measures have been applied. (DFO)
Heterogeneous	A system whose composition or structure is not uniform.
Hydrodynamic regime	A state of fluid motion characterized by the specific way a fluid flows, in environmental science, it refers to flow patterns that influence everything from microbial communities to sediment distribution. (AI)
Infauna	Fauna that lives in the substrate.
Mean	The arithmetic average of the observations in a data set.
Meristematic	The tissue or cells that are actively dividing to form new growth of various plant parts.
Mitigation	Mitigation measures include on-site remediation for the purpose of returning the project site to a natural form after construction activities. (DFO)

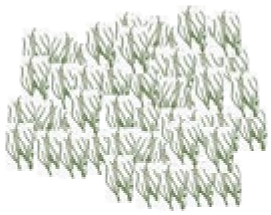
Morphology	The form and structure of living organisms.
pH	A measure of the concentration of hydrogen ions indicating neutrality (pH 7), acidity (less than pH 7) or alkalinity (greater than pH 7).
Polygon	A stream of digitized way points approximating the delineation (perimeter) of an area on a map.
Productivity	The rate at which biomass accumulates over a given area in a period of time.
Quadrat	A small, clearly defined plot or sampling area of known size, used as a part of a sampling scheme to ascertain characteristics of a larger ecosystem.
Rhizome	A root-like stem growing horizontally below the ground surface. A rhizome is used for storage of food materials.
ROV	A remotely operated underwater vehicle is a free-swimming submersible craft.
Running mean	A running mean is a series of averages of different subsets of a larger dataset, calculated by moving a "window" of a fixed size across the data. Each new average is calculated by dropping the oldest data point from the previous window and adding the next new data point, which helps to smooth out short-term fluctuations and highlight longer-term trends. This is also known as a known as a moving average or rolling average. (Appendix J)
Senesce	The process of aging towards the end of an organism's life.
Shoot	The above ground part of a plant, with eelgrass this includes the sheath and leaves. (C. Durance)
Sheath	A tubular covering such as part of a grass leaf surrounding the stem.
Transect	A straight line across a landscape along which surveys are conducted.
Turbidity	A measure of water quality, or the degree to which water is opaque due to suspended silt or other sediments.
#/0.25m²	Number per quarter metre squared, in this manual number of eelgrass shoots. (C. Durance)


Credit: Sharon Jeffery

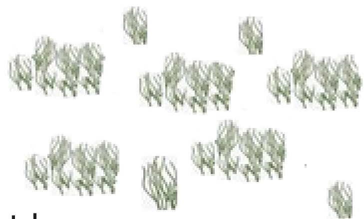
APPENDIX A: QUICK REFERENCE FIELD GUIDE

Distribution:

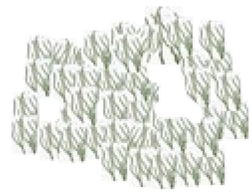
Continuous: Eelgrass is in one bed rather than isolated patches; there may be some bare patches within the bed.
Patchy: Area contains isolated groups or patches of eelgrass.



Continuous



Patchy



Continuous with bare patches

Form:

Fringe: A narrow band in a narrow depth range, like a necklace along the shore.
Flat: A more expansive bed that covers a wide area outwards from the shore.

Tidal range:

Intertidal = eelgrass area located between the high and low water mark, exposed at low tide
Subtidal = eelgrass always under water, even during low tides it's below the water
Tide height: The height of the tide at a given time.

Substrate type:

Mud = fine, mucky
Mud/Sand = mixture of mud and sand
Sand = coarse grainy
Gravel = thumb sized rocks
Cobble = fist sized rocks
Boulder = large, heavy rocks
Bedrock = solid rock base, not broken into boulders
Shell hash = broken shells
Unknown: difficult to say with confidence

Percent cover of eelgrass:

<10% not much eelgrass, mostly bare sediment (mud, sand etc.)
11 – 25% more eelgrass, still more bare sediment than leaves covering the ground
25 – 50% almost as much eelgrass as bare sediment
51 – 75% more than half the area of the bed covered by eelgrass
>75% very little or no bare sediment

The images below show percent cover within a 0.25 m^2 area. The percent cover you record is for the entire bed, if it's all the same then record only the primary, if it varies record secondary (next most common range) and if present tertiary.

<10%

11 – 25%

26 – 50%

51 – 75%

>76%

APPENDIX B: EQUIPMENT

The basic equipment that is required for each level of survey:

Equipment	Level 1	Level 2	Level 3	Level 4
Eelgrass Field Datasheets, pencils, notebook, or tablet	★	★	★	★
Maps or orthophotos at an appropriate scale	★	★	★	★
Tide tables https://tides.gc.ca/eng/data/predictions/	★	★	★	★
Camera	★	★	★	★
Watch	★	★	★	★
Cell phone	★	★	★	★
GPS, phone, or tablet with mapping software	★	★	★	★
50 or 100 metre measuring tape or line	–	★	★	★
50 cm x 50 cm quadrat	–	★	★	★
25 cm x 25 cm quadrat (optional)	–	★	★	★
Boat (motor or paddle)	–	–	★	★
Metre stick or measuring tape	–	–	★	★
Dive gear, snorkel gear, aquaviewer, ROV, or underwater camera	–	–	★	★
Secchi disk	–	–	–	★
Salinometer	–	–	–	★
Water quality sampling equipment	–	–	–	★
Safety				
Level 1 First Aid kit	★	★	★	★
Satellite phone/SPOT Worksafe BC requirement*	★	★	★	★
Check in and out procedure	★	★	★	★
Safety plan	★	★	★	★
Personal				
Neoprene booties, old running shoes, or rubber boots**	★	★	★	★
Sunscreen, drinking water	★	★	★	★
Raingear (optional)	★	★	★	★

*not required if you are volunteering ** for low tide surveys

Data may be recorded in waterproof notebooks, paper, or a tablet in a waterproof case. Waterproof notebooks and paper are available from stores that sell surveying equipment, some marine supply shops, and online.

Quadrats may be constructed from any waterproof material. Local metal shops can usually make them out of aluminum for about $30. Aluminum quadrats are formed by a thin piece of 1" wide metal 2 metres in length that is bent to form a square and welded. Aluminum 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, have a larger footprint, and a tendency to float (see Figures 4.4 and 4.5 for an example).

A plastic-coated surveyor's measuring tape works well for laying out transects. Alternatively, a thick nylon rope with labelled flagging tape to mark each metre may be constructed. Rope 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.

A Secchi disk may be purchased from a scientific supply company or hand-made (www.fizzicseducation.com.au/150-science-experiments/biology-environmental-science- projects/make-a-secchi-disc/).

Tide tables are necessary for planning the survey. Tide tables may be downloaded from https://www.tides.gc.ca/en/stations or https://tide.arthroinfo.org/.

APPENDIX C: 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 and falling. 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 lose 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 to prevent sand chafes) work well.

The author's feet and legs after crawling out of a muddy eelgrass bed.

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 with first aid certification in each crew. 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 Giardia (beaver fever) are 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 requires a boat operator licence (www.boaterexam.com/canada/britishcolumbia/) for anyone operating a power boat less than 4 metres in length.

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 a hand 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, online at http://www.boatsafe.com/.

SCUBA

Anyone participating in a SCUBA survey must be certified, if they are paid they must be commercially certified and follow all Worksafe BC rules. 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.

Divers and boat operators must be aware of each other's actions and the danger associated with spinning propellers.


Credit: Coastal Photography Studio

APPENDIX D: 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, air photo, ortho-photo, 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 are easiest to survey on foot during a good low tide.
However, they can also be mapped by SCUBA divers or snorkelers during a higher tide.

1. Map as much of the perimeter as is visible.
2. Complete the overview of intertidal habitat data sheet.
3. Determine the number of zones and lay out a transect in each as described in Chapter 4.
4. Lay a quadrat at pre-selected random distance along the transect and count the total number of shoots, number of flowering shoots and the shoot length and width of a shoot nearest a pre-selected corner.
5. Calculate the LAI.

Credit: Sharon Jeffery

Level 3 Survey

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. Complete tasks of the Level 2 Survey, then complete tasks 1-3 below.

1. Determine maximum and minimum depths.
2. Determine the number of zones and select locations for transects.
3. Establish transects, collect shoot density data, and leaf length and width data.

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 after the field survey.

Level 4 Survey

While completing a Level 3 Survey, the water samples can be collected. Follow the instructions provided by the lab that will be doing the analysis, and remember to record the time of collection on the datasheet.

Turbidity (Secchi depth) readings may be taken at any time during the survey.

Credit: Coastal Photography Studio

APPENDIX E: FIELD DATA FORM AND DATA ENTRY FORMS

The 'Eelgrass Field Data Sheet' may be photocopied onto waterproof paper for use during fieldwork. In order to enter data into the Community Mapping Network database (https://cmnmaps.ca/eelgrassbc/), 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 website.

Alternatively, you can contribute your data to the PSF Marine Data Centre. (https://marinedata.psf.ca/data/data-submission-form).

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: ______________ **Tide range of eelgrass bed** (subtidal, intertidal, both)**:** __________

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

Reference 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

EELGRASS BED DATA ENTRY FORM

1. Overview of intertidal habitat: All Levels
2. Overview of subtidal habitats: Levels 3 and 4

Form	☐ Fringing	☐ Flat	☐ Channel
Distribution	☐ Continuous	☐ Patchy	
Location	☐ Intertidal	☐ Subtidal	

Percent cover of eelgrass (circle)

Primary	1 to 10%	**Secondary**	0%	**Tertiary**	0%
	11 to 25%		1 to 10%		1 to 10%
	26 to 50%		11 to 25%		11 to 25%
	51 to 75%		26 to 50%		26 to 50%
	> 75%		51 to 75%		

Area occupied by: (circle)

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

Substrate type: (circle)

Primary	mud	**Secondary** (optional)	mud	**Tertiary** (optional)	mud
	mud/sand		mud/sand		mud/sand
	sand		sand		sand
	gravel		gravel		gravel
	cobble		cobble		cobble
	boulder		boulder		boulder
	bedrock		bedrock		bedrock
	shell hash		shell hash		shell hash
	unknown				

Area occupied by: (circle)

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

A sample data sheet is provided below. The data refers to a flat, continuous bed with mostly dense eelgrass (>75%) and a few (<10%) bare (0%) areas. The substrate was mostly (>75%) a mixture of mud and sand with some cobble (<10%) and a boulder (<10%).

1. Overview of intertidal habitat: All Levels
2. Overview of subtidal habitats: Levels 3 and 4

Form	☐ Fringing	☑ Flat	☐ Channel
Distribution	☑ Continuous	☐ Patchy	
Location	☑ Intertidal	☐ Subtidal	

Percent cover of eelgrass (circle)

Primary	1 to 10%	**Secondary**	**0%**	**Tertiary**	0%
	11 to 25%		1 to 10%		1 to 10%
	26 to 50%		11 to 25%		11 to 25%
	51 to 75%		26 to 50%		26 to 50%
	> 75%		51 to 75%		

Area occupied by: (circle)

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

Substrate type: (circle)

Primary	mud	**Secondary** (optional)	mud	**Tertiary** (optional)	mud
	mud/sand		mud/sand		mud/sand
	sand		sand		sand
	gravel		gravel		gravel
	cobble		**cobble**		cobble
	boulder		boulder		**boulder**
	bedrock		bedrock		bedrock
	shell hash		shell hash		shell hash
	unknown				

Area occupied by: (circle)

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

3. Distribution and density: Levels 2, 3, and 4

Distribution: ☐ Continuous eelgrass ☐ Patchy eelgrass

Survey type: ☐ On foot ☐ SCUBA ☐ Snorkeler ☐ Drop camera

Number of zones (complete one form for each zone)**:** ______________________________

Direction of transect (e.g., 0 m at north end):______________________________

Zone #:					
Length of transect:			**# of quadrats sampled:**		
Raw data (#/0.25 m²):					
Total	**Reproductive**	**Total**	**Reproductive**	**Total**	**Reproductive**
Mean # total:			**Mean # reproductive:**		

Mean # shoots/0.25 m² (within patches): ______________________________

4. Leaf Area Index (LAI): Levels 2, 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.		
Σ (total)		
ξ (Σ ÷ 30)		

Mean leaf length (ξ): ______________________________ **Mean leaf width (ξ):** ______________________________

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

5. Depth: Levels 3 and 4

Method used to determine minimum and maximum depth
(diver with depth gauge, diver with boat and metre tape or rod, survey rod without diver, other — explain)

____

____

____

____

____

Time measurement was taken: ________________________

Minimum depth reading (metres e.g. 8.2 m): ________________________

Tide height at this time: ________________________

Actual depth: ________________________

Maximum depth reading: ________________________

Tide height at this time: ________________________

Actual depth: ________________________

6. Turbidity: Level 4

Turbidity (Secchi depth reading)**:** ____

Time that reading was taken: ____

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

Salinity: ____

Total Suspended Solids: ____

Chlorophyll A: ____

Time and date that samples were collected: ________________________________

APPENDIX F: 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 F.1); it may be sparse. There may be some areas without eelgrass within the bed (Figure F.2).

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

Figure F.1 Continuous eelgrass distribution without bare patches.

Figure F.2 Continuous eelgrass distribution without bare patches.

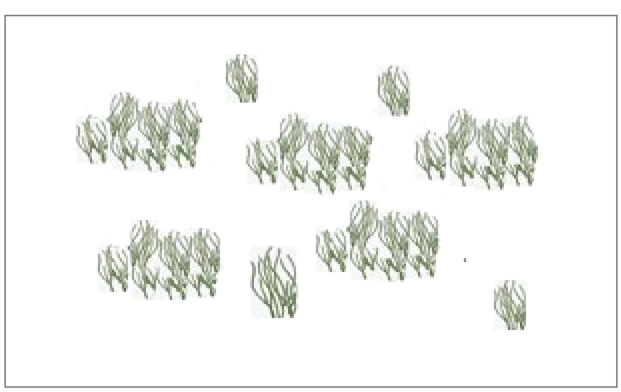


Figure F.3 Patchy eelgrass distribution.

APPENDIX G: 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%.

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 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.

The ranges that are used in this study for a Level 1 or Level 2 survey are listed below.

Percent cover of intertidal eelgrass (circle)					
Primary	1 to 10%	**Secondary**	0%	**Tertiary**	0%
	11 to 25%		1 to 10%		1 to 10%
	26 to 50%		11 to 25%		11 to 25%
	51 to 75%		26 to 50%		26 to 50%
	> 75%		51 to 75%		

The following photographs (Figure G.1) are examples of percent cover with each range.

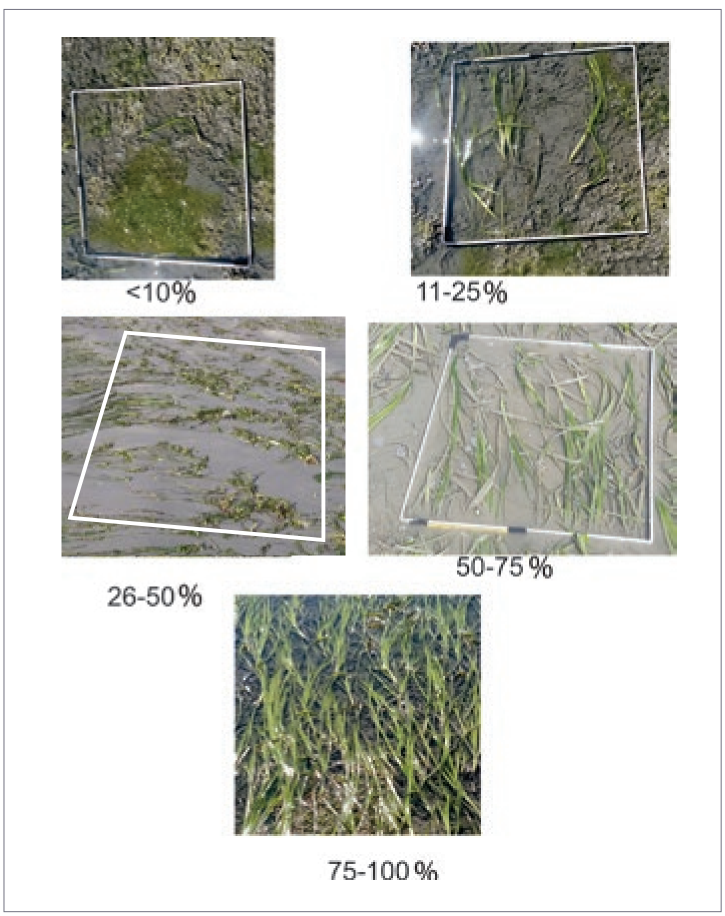


Figure G.1 Level 1 or 2. The entire eelgrass bed may fall into one range, in which case you would only record the primary percent cover. There are often differences in percent cover within a bed due to variations in physical variables such as depth or substrate.

The following diagram (Figure G.2) provides a graphic representation of a bed that is composed of three areas with distinctly different percent covers.

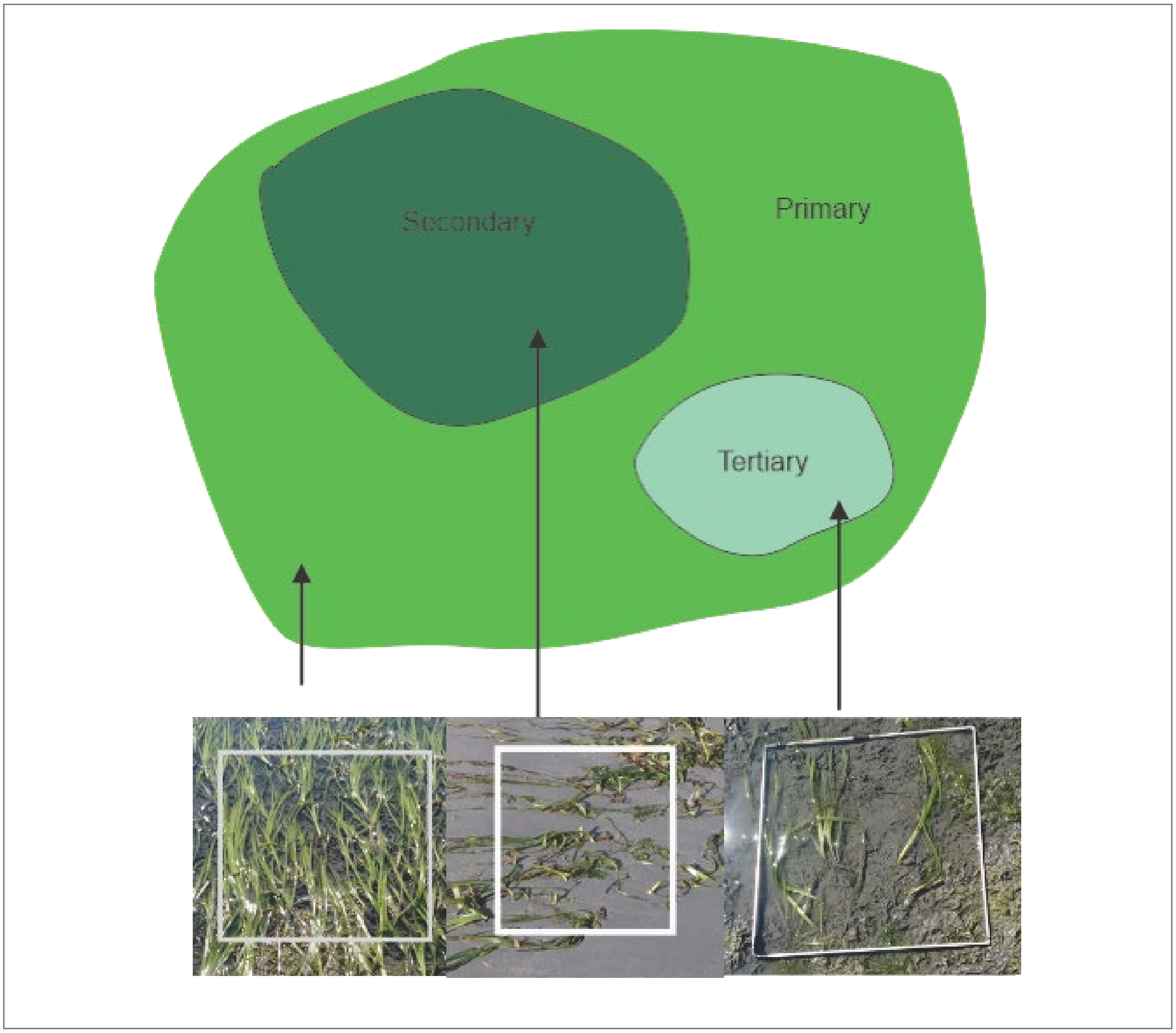


Figure G.2 The dark area represents a very dense eelgrass (>75%), the light area represents an area with low percent cover (1-10%), and the mid shade an area with intermediate cover (26 – 50%).

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 26-50% and <10%, respectively. The secondary and tertiary 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.

Estimates of percent cover may be easier if you imagine all the plants grouped together. The graphics below illustrate this concept (Figures G.3-G.5).

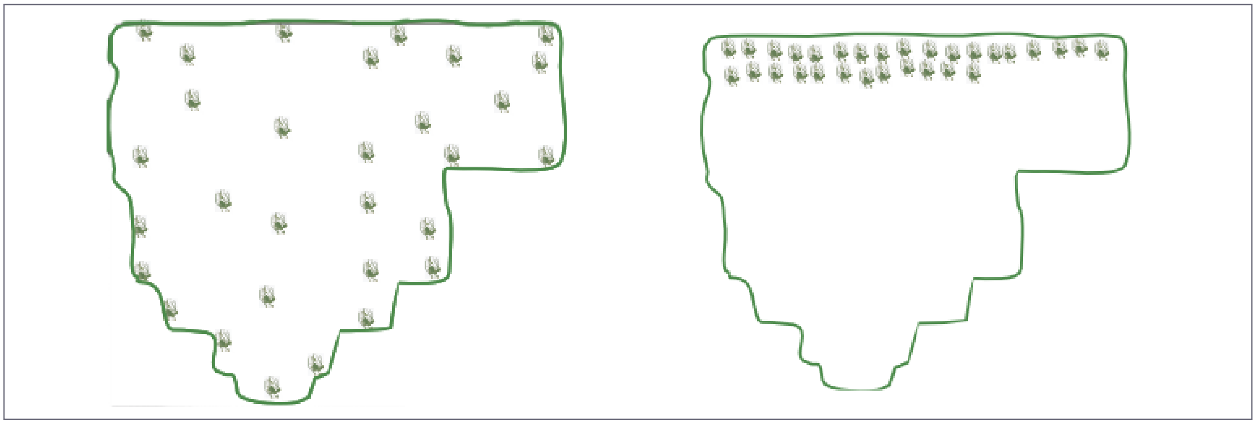


Figure G.3 15% cover as seen in the field (left) and the same icons grouped together (right).

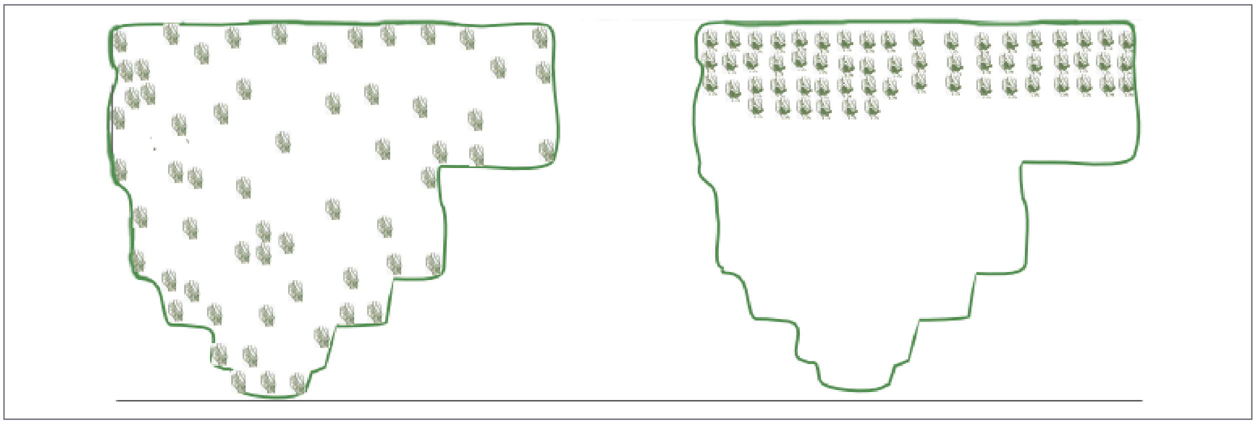


Figure G.4 30% cover as seen in the field (left) and the same icons grouped together (right).

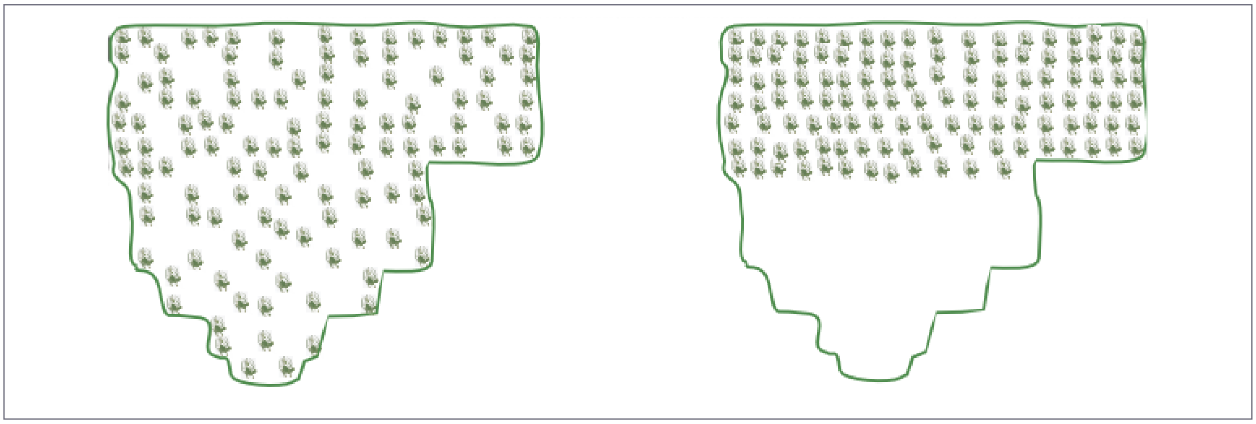


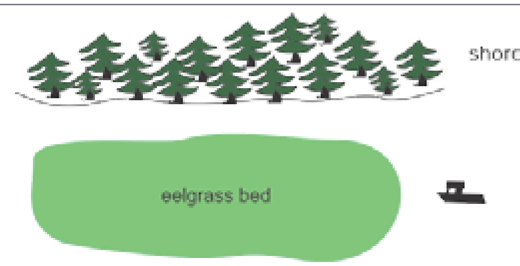
Figure G.4 60% cover as seen in the field (left) and the same icons grouped together (right).

APPENDIX H: METHOD TO SURVEY THE PERIMETER OF AN EELGRASS BED

Overview of habitat with a drop camera and boat.

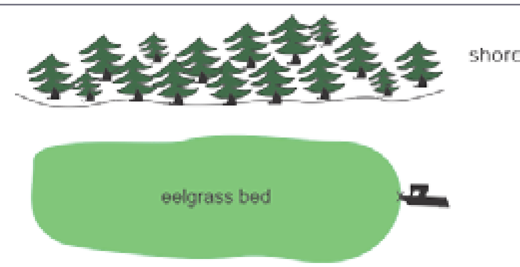
Step One

Approach the bed from a longshore direction.



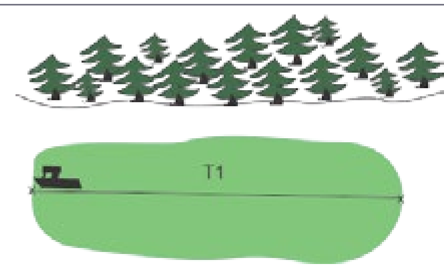
Step Two

Record a way point (x) as soon as eelgrass shoots more than about 1/m² are encountered, measure and record depth, time, and tide height if available.



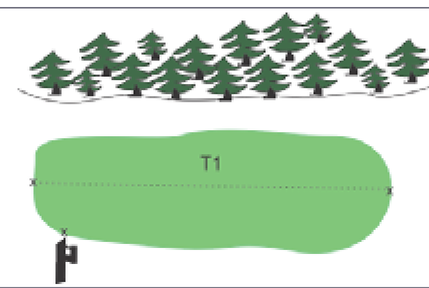
Step Three

Travel across the bed until you reach the opposite edge <1 shoot/m², record a GPS point, measure and record depth, time, and tide height if available. This completes your first transect T1.



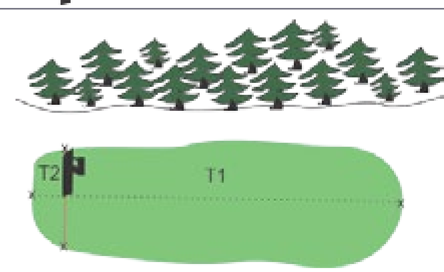
Step Four

Head into deeper water and locate eelgrass bed edge near the end of T1, record waypoint. measure and record depth, time, and tide height if available.



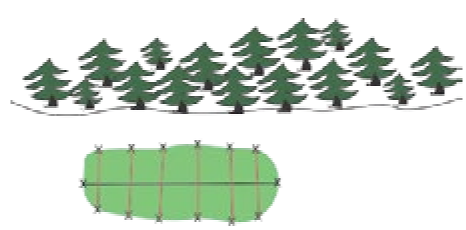
Step Five

Travel towards the shore and record a waypoint once shoot density is <1shoot/m², measure and record depth, time, and tide height if available.



Step Six

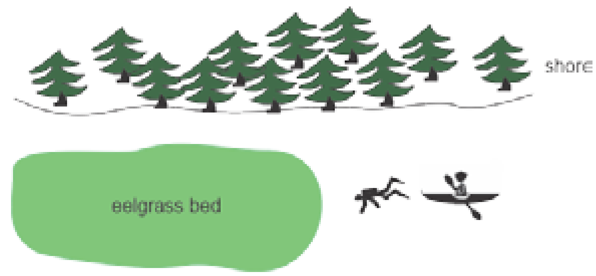
Continue running transects across the bed until you reach the other side. The accuracy of your map will increase with the number of transects you survey.



Overview of eelgrass habitat with snorkeler, SCUBA diver, or free diver and kayak.

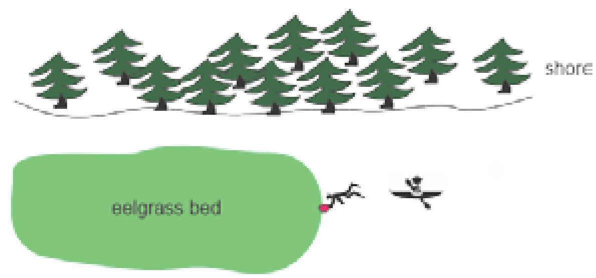
Step One

Snorkeler or free diver and kayak approach eelgrass between at about 1 and 2 m CD.



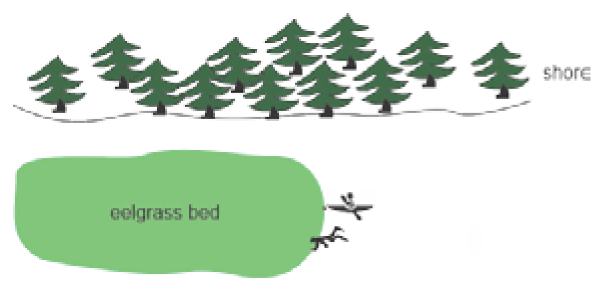
Step Two

Snorkeler or free diver drops a weighted float when eelgrass is first seen (>1 shoot/m^2).



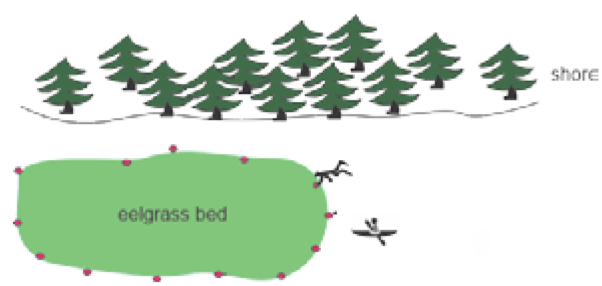
Step Three

Snorkeler or free diver follows edge of bed and drops a weighted float when direction changes. Kayaker moves to first float and takes a GPS point directly over the float.



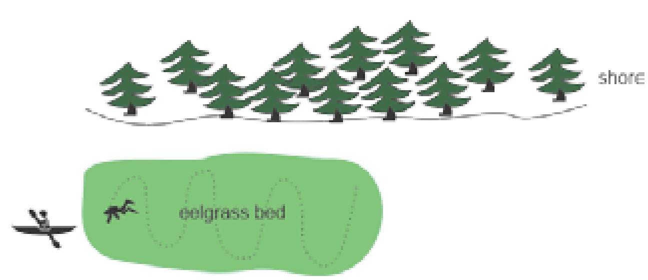
Step Four

Snorkeler or free diver continues to follow edge of bed and drops a weighted float when direction changes, until they reach the first float. The accuracy of your map will increase with the number of points you record. Kayaker follow the person in the water recording a point at each float.



Step Five

Snorkeler or free diver swims throughout the bed slightly above eelgrass leaves checking percent cover and substrate composition.

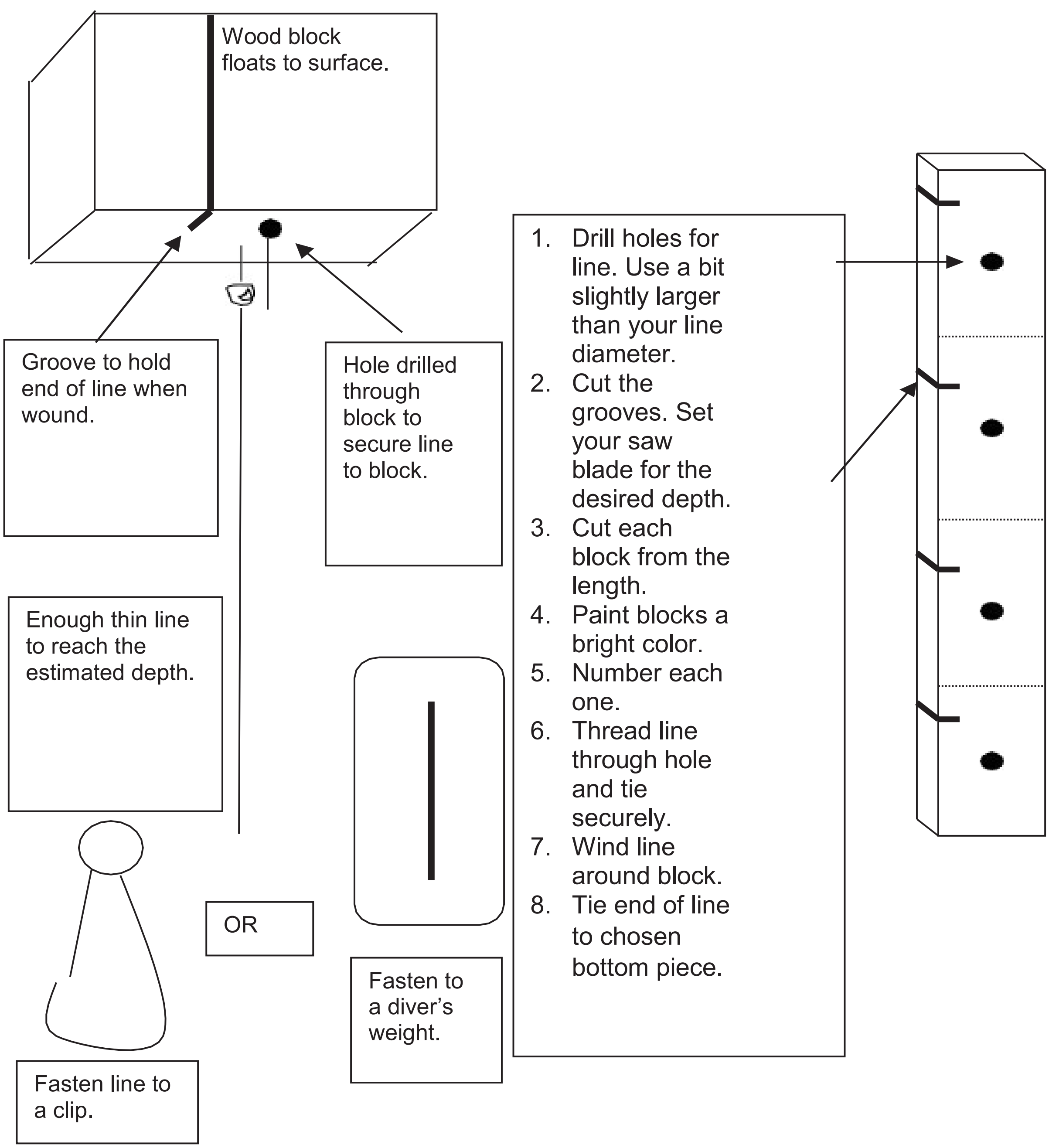


APPENDIX I: MARKER FLOATS

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

If you need to mark the location of eelgrass underwater 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, the diver 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.

Used plastic bottles with caps can also be used to make marker floats.



APPENDIX J: RUNNING MEAN CALCULATIONS

Using a simple formula in Excel

This method uses a combination of absolute and relative cell references with the AVERAGE function, allowing the range to expand as you copy the formula down a column.

1. **Enter your data** in a column (e.g., Column B, starting from cell B2).

2. In the cell where you want the first running mean (e.g., C2), enter the following formula: =AVERAGE($B$2:B2)
   - $B$2 is an **absolute reference** which keeps the starting cell of the range fixed.
   - B2 is a relative reference that changes as you copy the formula to other cells.

- **Drag the fill handle** (the small square in the bottom-right corner of the selected cell) down the column to apply the formula to the rest of your data.

3. The formula in cell C3 will become =AVERAGE($B$2:B3), in C4 it will be =AVERAGE($B$2:B4), and so on, calculating the cumulative average up to the current row.

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Pêches et Océans Canada