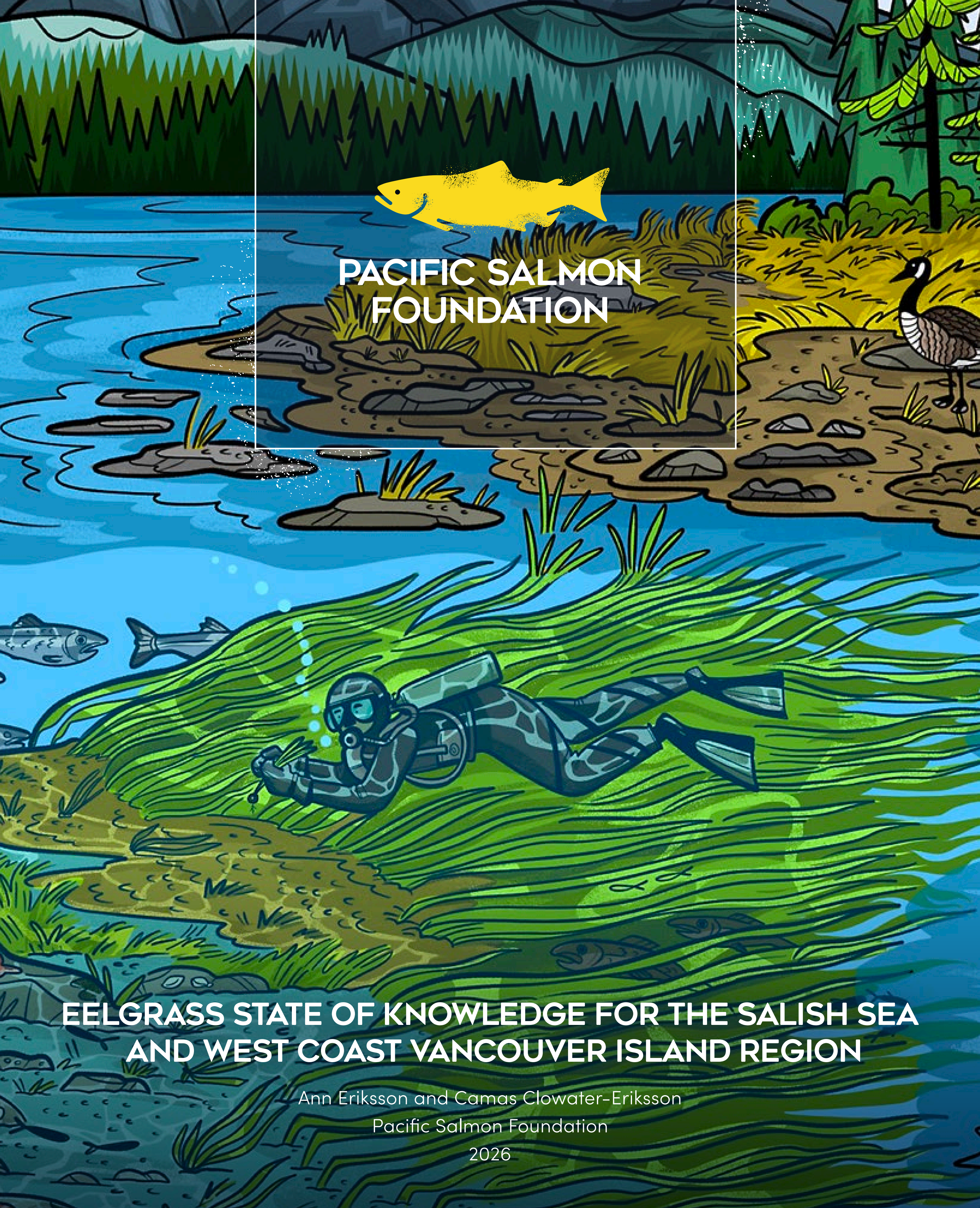

PACIFIC SALMON FOUNDATION

EELGRASS STATE OF KNOWLEDGE FOR THE SALISH SEA AND WEST COAST VANCOUVER ISLAND REGION

Ann Eriksson and Camas Clowater-Eriksson
Pacific Salmon Foundation
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psf.ca


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, salt 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 Research 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, salt marsh, and eelgrass habitats.

This Eelgrass State of Knowledge document is one of the components of this Hub.
Other documents can be found through this link.


Credit: Jillian Lynn-Lawson

EXECUTIVE SUMMARY

Zostera marina L. (Zosteraceae), a species of seagrass, is a perennial flowering marine plant that grows in 'beds' or 'meadows' in unconsolidated soft sediments (mud and sand) in coastal estuaries and protected bays. Commonly referred to as eelgrass, *Z. marina* is recognized as a 'keystone' species, both ecologically and culturally, as it provides nearshore habitat for a myriad of invertebrates, fish, and birds. Long considered to be an important nursery and feeding habitat for juvenile Pacific salmon and the forage fish which salmon feed on, such as herring and Pacific sand lance, eelgrass also provides ecosystem services such as coastal protection from erosion, pollution mitigation, carbon sequestration, and oxygen production, many of which are beneficial to salmon. Eelgrass has declined in many areas of the world, including along the British Columbia coast, as a result of cumulative impacts from coastal development, industrial processes, and climate change. The need for protection and restoration of this vital ecosystem is great.

This report focuses on eelgrass ecosystems in the British Columbia portion of the transboundary Salish Sea and the west coast of Vancouver Island (referred to in this report as the 'Salish Sea and WCVI region' or 'the region'). The area is home to three broad Indigenous groups — the Coast Salish, Nuu-chah-nulth, and Kwakwaka'wakw — and over fifty First Nations, together who hold a wealth of Traditional Ecological Knowledge (TEK). It is increasingly recognized that Indigenous Traditional Ecological Knowledge (TEK) and Western science are complementary, the combination of the two improving the knowledge base and providing a more complete and long-term understanding of a particular system. This report, wherever possible, strives to integrate these worldviews into what is referred to as 'Two-eyed Seeing.' The region is also home to dozens of coastal communities, sources of valuable Local Ecological Knowledge (LEK).

The Eelgrass State of Knowledge report is based on an extensive literature search focused primarily on research and restoration work conducted in the Pacific Northwest region since 2014 plus foundational papers as far back as 1984; the summary report from the eelgrass symposium held in Campbell River on October 15–17, 2024; and interviews with Indigenous Knowledge Holders, scientists, restoration practitioners, and community groups involved in eelgrass restoration. The following chapters provide, within the context of eelgrass importance to Pacific salmon, current information about eelgrass ecology and distribution in the region, monitoring and mapping protocols, stressors to eelgrass habitats, an assessment of restoration methodologies, strategies for protection, and an identification of knowledge and data gaps. We make recommendations for actions to better steward these critical ecosystems, including charting a path toward a seagrass network within British Columbia and beyond.

Credit: Rebecca Benjamin-Carey

This report is a companion to the PSF documents Eelgrass Restoration Practitioners' Handbook (Wright et al., 2026) and the Eelgrass Mapping and Monitoring Practitioners' Handbook (Durance & Wright, 2026).

These documents are cross-referenced throughout the Eelgrass State of Knowledge Report with the symbols:

RH = Restoration Handbook

MH = Mapping Handbook

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ACKNOWLEDGEMENTS

The authors of this Eelgrass State of Knowledge Report are deeply grateful to the Coast Salish, Nuu-chah-nulth, and Kwakwakaw'akw Peoples who, for millennia, have stewarded the lands and waters of the Salish Sea and the west coast of Vancouver Island.

We thank the Department of Fisheries and Oceans Canada for financial support of the Aquatic Ecosystem Research Fund (AERF). In addition, we would like to acknowledge, with gratitude, the speakers and participants of the Eelgrass Symposium held in October 2024 in Campbell River, as well as interviewees, reviewers of the manuscript, and those who provided photos and graphics for use in the report. Special appreciation to Nicole Christiansen and the rest of the Greening the Salish Sea team at PSF, for their comradeship during the writing process, and whose knowledge of nearshore ecosystems greatly informed this report.

Credit: Greenways Land Trust

ABOUT THE AUTHORS

Mother-daughter team Ann Eriksson and Camas Clowater-Eriksson worked together to produce the Eelgrass State of Knowledge Report.

Ann, the lead author, is a biologist and professional writer who lives on Thetis Island, BC. Ann was the Gulf Islands Regional Coordinator for the Salish Sea Nearshore Habitat Recovery Project, a five-year restoration initiative for eelgrass habitat, funded by the federal Coastal Restoration Fund under Canada's Oceans Protection Plan. Ann has previously worked on State of Environment reports at the federal and provincial level, and co-authored Taking Nature's Pulse: The Status of Biodiversity in BC and the BC Biodiversity Atlas, projects of the multiagency Biodiversity BC. Ann is currently the Executive Director of the Thetis Island Nature Conservancy, which has collaborated with SeaChange Marine Conservation Society on nearshore restoration projects. Ann also writes ecologically-themed novels for adults and ecological literacy books for younger readers. www.anneriksson.ca

Camas has a Masters degree in Public History from Carleton University and a double major in History and Environmental Studies from the University of Victoria. She specializes in translating academic writing into publicly accessible information. Camas conducted the literature search, wrote the draft of the Stressors chapter, and collaborated on the final draft compilation. She has volunteered tying shoots at eelgrass restorations in the Salish Sea. She also loves hanging off cliffs in Scotland, where she currently lives.

The authors would like to extend a special thank you to Nikki Wright and Cynthia Durance, who provided expert guidance and feedback on several drafts of the document. Nikki Wright also conducted the interviews. The Eelgrass State of Knowledge report would not have been possible without Nikki and Cynthia who between them hold an encyclopedic knowledge about eelgrass in BC.

Ann Eriksson at Hope Bay eelgrass restoration on Pender Island. Credit Camas Clowater-Eriksson

Ann & Camas at Wilcox Pass in the Rocky Mountains.
Credit: Richard Abel

Camas Clowater-Eriksson climbing in the UK.
Credit: Richard Abel

CHAPTER ONE
NATIVE EELGRASS IN THE SALISH SEA AND WEST COAST VANCOUVER ISLAND REGION AND IMPORTANCE TO SALMON ECOLOGY

Explore an Eelgrass Meadow: Watch
Seagrass: Life in the Underwater Meadows
(2:51 min) Credit: Hakai Institute

INTRODUCTION

The seagrass *Zostera marina* L. (Zosteraceae) is a perennial flowering marine plant. Commonly known as eelgrass, it forms fringing beds along coastal shorelines or extensive flat meadows in more sheltered bays and estuaries, in unconsolidated soft sediments (mud and sand) (Phillips, 1984; Precision Identification Biological Consultants, 2002; Nelson, 2018). The only native eelgrass species in British Columbia, it is found in suitable habitat throughout the Salish Sea and WCVI region and along the central and north coast (see Chapter 2 for distribution mapping).

Eelgrass is recognized as a **foundational**[1] marine species (Sherman & Debruyckere, 2018, and references within), as well as an **ecological and cultural keystone**[2] species (Turner, 2001; Garibaldi & Turner, 2004). It provides nearshore habitat for a myriad of invertebrates, birds, and fish, (Figure 1.1) and many cultural services valued by Indigenous Peoples. It also provides a number of ecosystem services which are important to the health of Pacific salmon (Figure 1.2) (Sherman & DeBruyckere, 2018).

Figure 1.1 An eelgrass bed provides habitat for many species of fish, birds, and invertebrates, and supports the marine food web. Credit: Sylvia Heredia

1. A species that structures communities of organisms.
2. Ecological keystone species: A species that has a disproportionately large effect on its natural environment relative to its abundance; Cultural keystone species: A species that shapes in a major way the cultural identity of a people, as reflected in the fundamental roles it has in diet, materials, medicine, and/or spiritual practices.

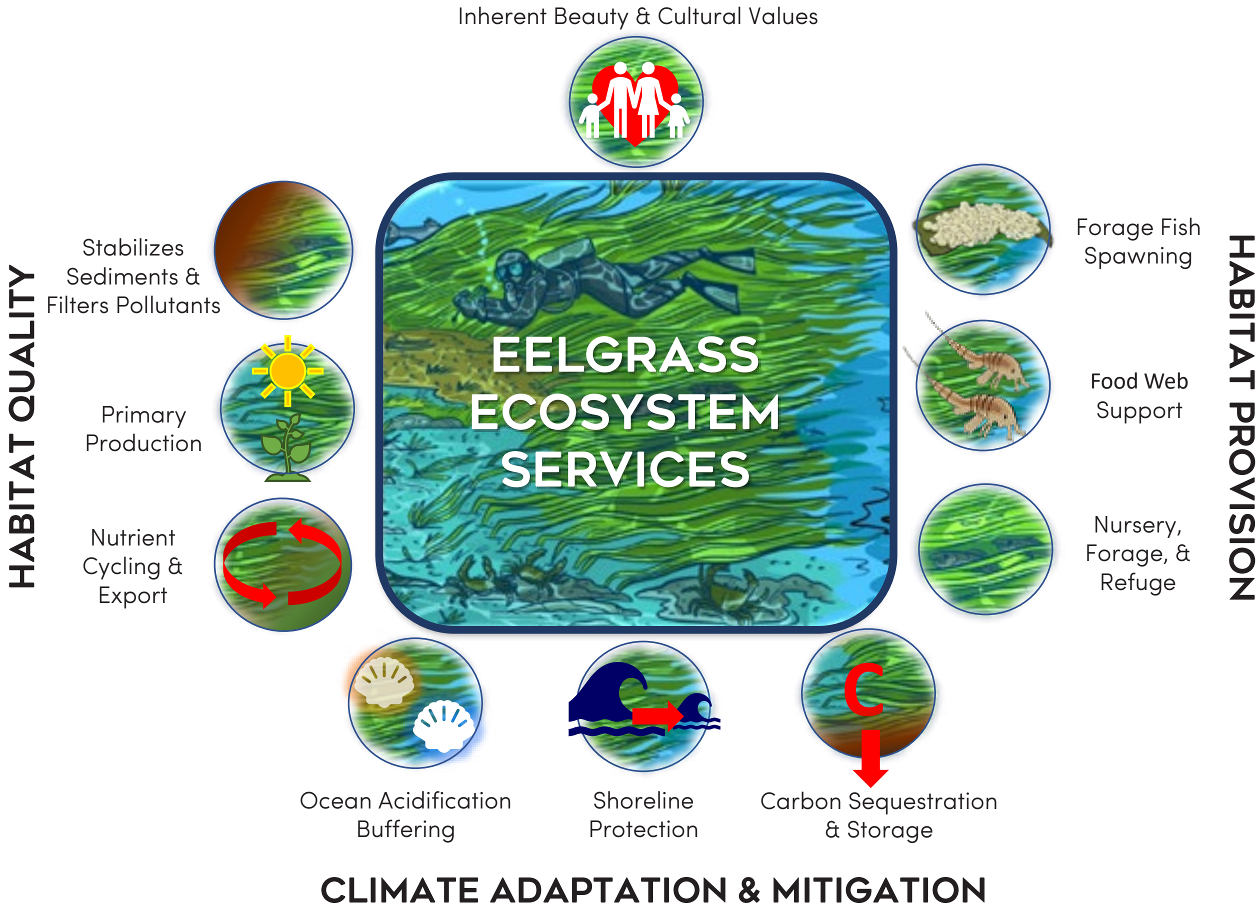


Figure 1.2 Eelgrass ecosystem services. Credit: Delaney Cox and Nicole Christiansen

10,000 YEARS OF EELGRASS STEWARDSHIP

For thousands of years Indigenous Peoples have valued native eelgrass, evident in their language, cultural traditions and oral histories (Figure 1.3) (Cullis-Suzuki, 2007, 2015; Uu-a-thluk, 2010; Turner, 1995, 2001). The practice of naming signifies a level of importance, and each group has one or many names for eelgrass (Table 1.1). Indigenous Peoples of the region often refer to eelgrass as the 'candy of the sea' because the leaf bases and rhizomes were harvested in the spring, often in May and generally by women, and eaten as a source of sugar and carbohydrates after a winter of preserved foods (Uu-a-thluk, 2010; Turner, 1995, 2001). The Nuu-chah-nulth, who believe eelgrass is the food of the mythical ancestors, enjoyed the roots, wrapped in leaves and dipped in eulachon grease (Turner, 1995).

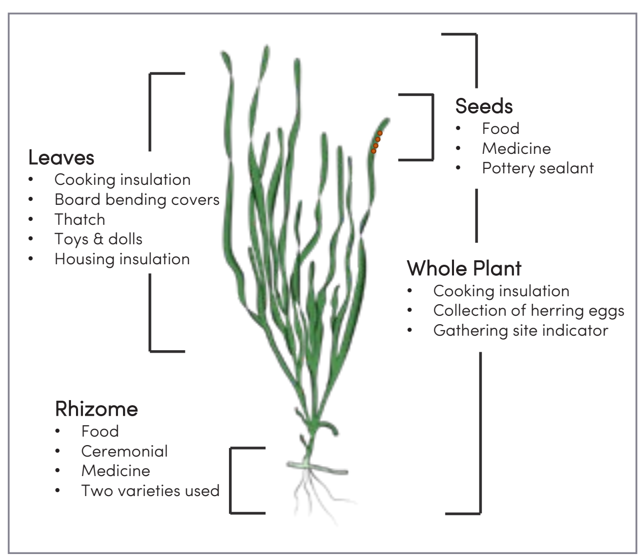


Figure 1.3 Traditonal uses of eelgrass by coastal Indigenous Peoples (Turner 1995). Credit: Anisha Parekh and Nicole Christiansen

Table 1.1 A selection of Indigenous traditional words for eelgrass (Nuu-chah-nuth and Kwakwaka'wakw terms are from Cullis-Suzuki, 2007, and references within; Uu-a-thluk , 2010; Hul'q'umi'num' terms are from https://plants.hwulmuhwqun.ca/plant/tsulum-eelgrass/).

Indigenous People	Language or Dialect	Traditional Name	Meaning
Nuu-chah-nulth	Dididaht	*taba-x*	the 'real' eelgrass
		kalkatcapt	edible rhizome
	Tla-o-qui-aht	*ts'aay'imts*	eelgrass
	Hesquiaht	*ća·ýimc*	general name for seagrass
		ča·čamasʔi·k	roots of white-rooted eelgrass
		hašqi·c	brown-rooted eelgrass, growing
		hašqi·csmapt	brown-rooted eelgrass, washed up on shore
Kwakwaka'wakw	Kwak'wala	*ts'áts'ayem*	eelgrass
		tsatsamot	dead eelgrass
Coast Salish	Hul'q'umi'num'	*tsulum' (cələm̓)*	eelgrass

The Songhees dried thin cakes for winter food. A common harvest technique in subtidal eelgrass was to use a two pronged 'twisting' stick (*k'elpaxu* in Kwa k´ wala, the language of the Kwakwaka'wakw) to carefully pull the plants from the sediment from a canoe (Cullis-Suzuki, 2007; Turner, 1995). Eelgrass leaves were used for food preparation and in pit cooking, and dried leaves were used for colour contrast in basketry and weaving (Turner, 2001).

Eelgrass is valued for its role as a spawning substrate for herring (*Clupea pallasii*) (Figure 1.4). The eggs (roe) are a choice food for coastal Indigenous Peoples (Turner, 1995), and the herring are a forage (prey) fish for salmon (Osgood et al., 2016; Phillips, 1984). As a cultural example, the Nuu-chah-nulth preserved the spawn-covered eelgrass by laying it out to dry in the sun, for later reconstitution with water (Uu-a-thluk, 2010).

Figure 1.4 Eelgrass provides a substrate for herring to lay their eggs. Credit: Jim Shortreed

> **Food sovereignty is the right to define our own healthy and culturally appropriate food systems... From the lens of food sovereignty... eelgrass meadows provide healthy ecosystems, social economic justice, food security, cultural revitalization, and more.**
>
> - Katarina (Kat) Duke, Manager of Marine Conservation and Fisheries for Ka:'yu:'k't'h' / Che:k'tles7et'h' First Nations

Healthy eelgrass plants and ecosystems contribute to the food sovereignty of Indigenous Peoples in BC. Oral histories and archeological evidence prove that Indigenous Peoples in the region have stewarded salmon and salmon habitat, as well as many other marine species, for 10,000 years or more for food, ceremonial, and social purposes and they continue to do so in the present day (Atlas et al., 2021; Efford et al., 2023; Mos et al., 2004). Oral histories describe how eelgrass beds were used as indicators of the presence of food items, with many valued resources, including salmon, herring, clams, and waterfowl harvested in and around eelgrass beds (Turner, 2001). Some traditional harvesting protocols included careful and infrequent removal of plants to ensure long-term health of the eelgrass plants and meadows (Cullis-Suzuki, 2007, 2015; Uu-a-thluk, 2010). An experimental study by Cullis-Suzuki (2007, 2015), which replicated the timing, depth, choice of meadow, and amount of eelgrass harvesting used by ancestral Kwakwaka'wakw, showed that these practices increase the growth of new shoots over the summer, resulting in larger, healthier plants, with higher nutritional value. This traditional form of 'keeping it living' ecosystem management could be applied to modern eelgrass revitalization efforts to increase productivity over time (Cullis-Suzuki, 2007, 2015).

With other sugar sources readily available today, and with pollution and habitat loss reducing the availability of healthy marine foods, including eelgrass, for consumption, few Indigenous Peoples in the Salish Sea and WCVI region harvest eelgrass anymore (Cullis-Suzuki, 2007; Mos et al., 2004). However, monitoring and restoration of eelgrass meadows is now being undertaken by many First Nations, often in partnership with Western-trained scientists (Sharpe et al., 2019). Several of these projects are profiled in Chapters 2, 4, and 5.

Credit: Crystal Norman

IMPORTANCE OF EELGRASS TO PACIFIC SALMON

EELGRASS MEADOWS AS NURSERIES AND PLACES OF REFUGE

Nearshore habitats such as eelgrass, salt marsh, and kelp forests have been well documented as 'nursery' habitats for juvenile salmon, ideally providing a range of high-quality functions such as opportunities for rearing, feeding, refuge from predators, and acclimation to increasing salinity during the migration from freshwater to open ocean (Chalifour et al., 2021; Levings, 2016; Sheaves et al., 2015; Simenstad et al., 1982). Juvenile salmon have been found to spend varying periods of time in nearshore habitats (Figure 1.5) (Arbeider et al., 2024; Chalifour et al., 2019, 2021; Chittenden et al., 2018; Munsch et al., 2016), with coho (*Oncorhynchus kisutch*), chum (*Oncorhynchus keta*) and Chinook (*Oncorhynchus tshawytscha*) showing the greatest reliance (Simenstad et al., 1982). Salmon that grow rapidly to a large size before entering the ocean have increased chances of survival at sea because they are better able to evade predators, catch prey, and withstand periods of low food availability (Pearsall et al., 2021, and references within). Therefore, the abundant foraging and protection opportunities in these nearshore stopover habitats for juvenile salmon are critical.

Numerous studies have documented Pacific salmon using eelgrass meadows as stopover nursery habitat during their juvenile phase (Archipelago Marine Research Ltd., 2014; Chalifour et al., 2019; Kennedy et al., 2018; Moore et al., 2016; Robinson & Yakimishyn, 2013) with variations in residency patterns and time (from days to over a month) between species (Chalifour et al., 2021; Moore et al., 2016). Eelgrass beds may be an especially important nursery habitat for Chinook and chum salmon (Chalifour et al., 2021; Hodgson et al., 2016). If left undisturbed, eelgrass ecosystems have proven to be very ecological efficient, stable over time, even in changing ocean conditions, and to support a diverse food web within and beyond their margins (Phillips, 1984; Robinson & Yakimishyn, 2013).

Figure 1.5 Juvenile Pacifc salmon use eelgrass as nursery habitat, and for foraging and refuge.
Credit: Campbell Photography

Eelgrass is considered one of the most productive marine ecosystems. Large amounts of **biomass**[3], in the form of leaves and **rhizomes**[4] (Phillips, 1984), support the aquatic **food web**[5] for salmon in several ways. The upright three-dimensional nature of an eelgrass plant and bed or meadow provides structural complexity compared to adjacent unstructured habitats such as sand and mud (Phillips, 1984) and have been shown to support higher species richness, higher densities, and increased growth for juvenile salmon (Chalifour et al., 2019; Lefcheck et al., 2019; McDevitt-Irwin et al., 2016; Rubin et al., 2018).

While *Z. marina* can reproduce sexually from seed, in the Salish Sea and WCVI region, where not much is known about germination rates, generally very few seeds form mature plants. More commonly, eelgrass reproduces asexually by vegetative branching from a parent shoot, which creates a genetically identical clone (Figure 1.6) (Phillips, 1984). The resulting rhizome continues to branch and produce new shoots, with the shoots over time forming new plants when the older rhizomes joining them decay. A bed or meadow can sometimes originate from a single parent plant. The rhizomes intertwine and often form dense mats within the bottom sediments. This 'rhizosphere' provides several ecosystem functions in addition to stabilizing the sediments (Figure 1.7). As a photosynthesizing vascular plant, eelgrass draws in carbon from its surroundings, uses it to build its structures, and, through the rhizomes, traps and stores the remaining carbon in the sediments. Also, during photosynthesis, eelgrass releases dissolved oxygen (DO), creating an oxygen rich environment beneficial to fish (Magel, 2020; Magel et al., 2022).

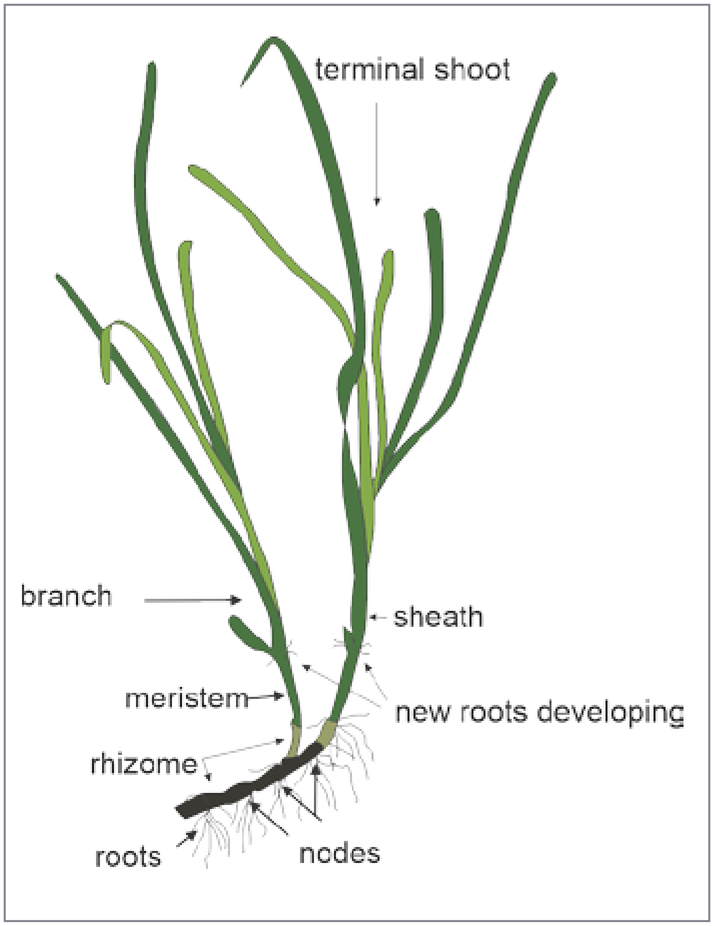


Figure 1.6 Botanical features of a *Z. marina* plant.
Credit: Cynthia Durance

3. total amount of living matter of a particular species or community of species
4. stabilizing underground stems
5. Interconnected relationships between organisms in an ecological community (e.g., what eats what)

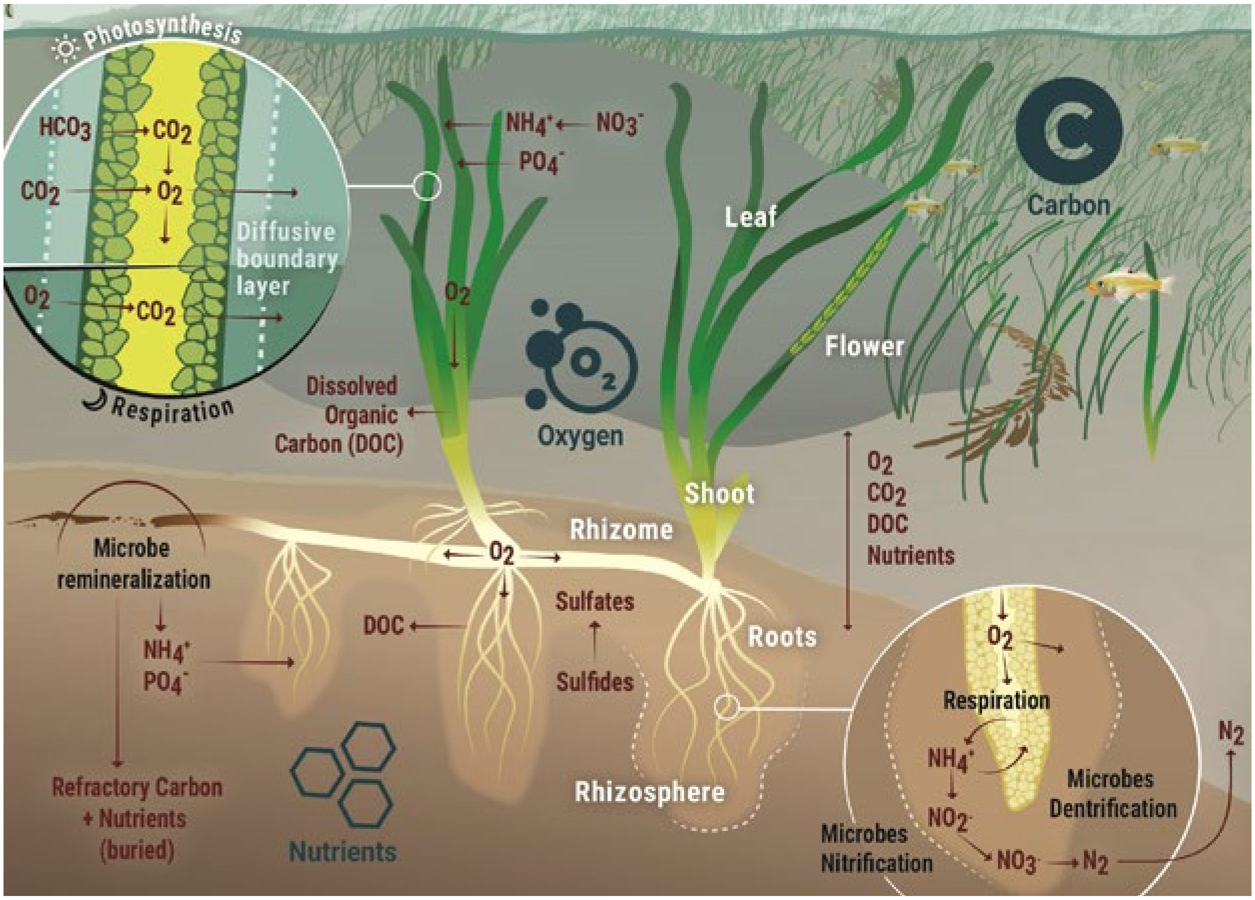
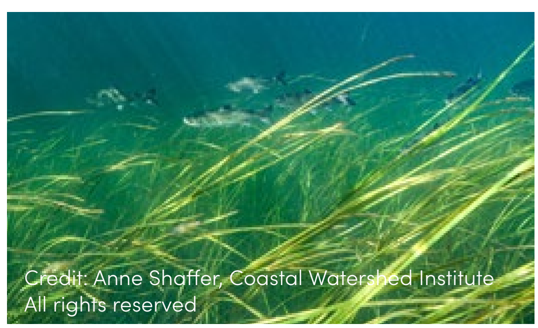


Figure 1.7 Chemical and biological interactions taking place in eelgrass plants and the rhizome/sediment/microbial complex (the rhizosphere) facilitate many processes beneficial to salmon such photosynthesis, oxygen production, nutrient cycling, sediment stabilization, and carbon sequestration and storage. Credit: Fisheries and Oceans Canada (2026)

These two characteristics, the three-dimensional upright nature and the stabilizing rhizomes, create the conditions for the growth of a rich environment that benefits salmon (Phillips, 1984). The surface area of eelgrass plants supports over 350 species of **macroalgae**[6] and 91 species of **microalgae**[7] that live on eelgrass blades. Decaying eelgrass plant material, which falls to the ocean floor where it joins other debris trapped by the leaves and rhizomes from outside the meadow, provides food for a diversity of invertebrates, some of which are favoured prey species for salmon (Phillips, 1984; Sherman & DeBruyckere, 2018). Even more importantly, the living eelgrass plant tissue develops a unique **microbiome**[8] of microscopic life, a 'brown felt' of bacteria, diatoms and algae, on the leaves and sediment surface, which adds to total primary production, increases invertebrate diversity, and supports the overall health of the eelgrass ecosystem (Levings, 1986; Phillips, 1984; Trevizan Segovia, 2021).

> **Microbiome studies of the community of microorganisms living on *Z. marina* plants have revealed that the micro-biome of the root and rhizome are different, and that the below ground microbiome is resilient to stresses resulting from transplantation.**
>
> - Mary O'Connor, 2024.



Credit: Anne Shaffer, Coastal Watershed Institute

6. multicellular algae that can be seen with the naked eye (e.g. seaweed)
7. microscopic algae (e.g. diatom)
8. a population or community of microorganisms living on a surface

Eelgrass-associated invertebrates and larval fish common in eelgrass beds have been shown to make up a majority of juvenile salmon diets (Figure 1.8) (Arbeider et al., 2019; Davis et al., 2018; Kennedy et al., 2018), 93 per cent for juvenile coho salmon and 83 per cent for juvenile Chinook). In particular, small crustaceans called harpacticoid **copepods**[9], which are found in greater numbers in eelgrass habitats than in other adjacent habitats (water column and unvegetated sediments), make up approximately 80 per cent of the diet of juvenile coho salmon and a large portion of the diet of juvenile Chinook and sockeye (Arbeider et al., 2019; Kennedy et al., 2018). The abundance of harpacticoid copepods and other eelgrass-associated invertebrates preferred by salmon increase with an increase of eelgrass density, suggesting that healthy eelgrass ecosystems play a role in improving the chances of marine survival for Pacific salmon, with implications for eelgrass restoration and protection (Kennedy et al., 2018). It is important to note that the composition of invertebrate prey preferred by salmon was found to be consistent across a range of eelgrass densities suggesting that patchy and sparse eelgrass are no less important than denser habitat for providing food for juvenile salmon (Kennedy et al., 2018). To underscore this point, juvenile salmon have been documented in both patchy beds and continuous/dense eelgrass meadows (Archipelago Marine Research Ltd, 2014).

Figure 1.8 Small crustaceans living in eelgrass, like these amphipods, are food for Pacific salmon.
Credit: Jamie Smith, Coastal Photography Studio

9. small marine crustaceans that live on the ocean floor or in the sediment

CONNECTIVITY

Eelgrass ecosystems are increasingly recognized as an important part of a mosaic or 'seascape' of mutually supportive interconnected habitats from terrestrial upland to open ocean (Figure 1.9) which can benefit a diversity of salmon life histories (Chalifour et al., 2019; Nagelkerken et al., 2015; Olson et al., 2019; Woo et al., 2019). Transfer of nutrients and energy in and out of eelgrass meadows can occur through the movement of detached leaf and other detrital material or by fish moving through the seascape (Olson et al., 2022; Whippo et al., 2018). Eelgrass meadows export large amounts of biomass as leaves and other litter dislodged by birds, storms or natural defoliation (Phillips, 1984) to adjacent ecosystems and to those sometimes hundreds of kilometres away (Stark et al., 2020). Floating eelgrass can become trapped in nearby salt marshes, also important nursery habitats for juvenile salmon, where the nutrients are recycled. Eelgrass meadows can also receive inputs from other habitats. Material from kelp forests floating into eelgrass meadows from outside the ecosystem boundaries, for instance, has been shown to be preferred food for some eelgrass-associated herbivorous invertebrates (Olson et al., 2022).

Seascape connectivity with other structurally complex habitats, such as kelp and salt marsh, and other nearby eelgrass beds, has been demonstrated to enhance the nursery function of eelgrass beds for fish through this type of nutrient and energy exchange between habitats and through increased access to a variety of habitats for predator avoidance (Olson et al., 2019). A study in the Fraser River estuary comparing fish species richness in salt marsh, eelgrass, and sand flat showed the highest number of fish species in eelgrass but more salmonids in salt marsh, with specific habitat preference varying by season and local environmental conditions, such as acidity, temperature, oxygen levels, and nutrient levels (Chalifour et al., 2019). For example, chum salmon were found in greater numbers in marsh when dissolved oxygen levels were high and higher numbers in eelgrass when **turbidity**[10] was low relative to sand flats (Chalifour et al., 2019). In other words, juvenile salmon use and move between connected habitats according to the most favourable conditions as they grow and as their needs change (Chalifour et al., 2019; Seitz et al., 2020; Stark et al., 2020).

Figure 1.9 Eelgrass is part of a seascape of interconnected habitats. Credit: Delaney Cox, Drawing It Out

10. measure of water quality, or the degree to which water is opaque due to suspended particles

HABITAT FOR JUVENILE HERRING, AN IMPORTANT FORAGE FISH FOR SALMON

As mentioned previously, Pacific herring preferentially lay their eggs on eelgrass blades (Phillips, 1984; Thom et al., 2014). Once hatched, juvenile herring use eelgrass beds as nursery and refuge habitat in much the same way as juvenile salmon, before migrating to the open ocean (Figure 1.10) (Sherman & DeBruyckere, 2018, and reference within). Herring, an abundant and energy rich food source, is an important forage (prey) fish for both young and adult Pacific salmon, particularly Chinook (30-70 per cent of diet) and chum (Osgood et al, 2016; Phillips, 1984; Salish Sea Pacific Herring Assessment and Management Strategy Team, 2018). See also Chapter 3 for information about herring population declines and implications for salmon.

Figure 1.10 Forage fish, such as Pacific herring, use eelgrass for nursery, feeding, and refuge habitat, and are an important prey for Pacific salmon. Credit: Ryan Miller

WATER POLLUTION MITIGATION

Contaminants enter rivers and the ocean from the atmosphere, from industry, stormwater and road runoff, and other **point**[11] and **nonpoint**[12] sources. Evidence suggests that these contaminants, many of which are toxic and long-lived in the environment, have the potential to affect salmon by slowing growth, increasing susceptibility to disease, changing behaviour and lowering survival at sea (Pearsall et al., 2021, and references within). Studies in the US Salish Sea have shown that contaminants are reducing or preventing the recovery of Chinook salmon (Meador et al., 2020; Pearsall et al., 2021). Contaminants may also damage or reduce important habitat. While salmon migrate through many habitats from freshwater to open ocean and back, all of which will have different contaminant characteristics, eelgrass meadows have been shown to filter particulates, including toxic pollutants such as polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) from seawater (Sherman & DeBruyckere, 2018, and reference within). In this way, eelgrass has the potential to provide a less contaminated refuge, particularly for those juvenile salmon that are resident in eelgrass meadows for extended periods of time.

11. pollution that can be traced to a specific source
12. diffuse pollution that can't be traced to a specific source

EELGRASS, SALMON, AND CLIMATE CHANGE

Climate change is one of the greatest threats to the health of wild Pacific salmon, impacting them throughout their life cycle (Pacific Salmon Foundation [PSF], 2025). Extreme weather events, warming ocean temperatures, and ocean acidification can interrupt salmon migration, destroy or impair habitat and food sources, increase risks from disease and other stressors, and reduce the fitness of salmon making them more susceptible to predation. The following subsections describe how eelgrass ecosystems, while also subject to the impacts of climate change, when healthy and intact, can help mitigate some impacts of climate change on salmon by sequestering carbon, buffering ocean acidification, maintaining dissolved oxygen levels, stabilizing shorelines, and reducing the threat of harmful algal blooms (HABs).

Estimating Rates of Carbon Sequestration by Eelgrass Habitats in the K'ómoks Estuary

The Comox Valley Project Watershed Society (CVPW) and the Squamish River Watershed Society (SRWS) wanted community-based eelgrass restoration projects to be recognized for the blue carbon that they sequester and store. Together, with funding from the North American Partnership for Environmental Community Action (NAPECA), they developed a manageable low-cost protocol for mapping eelgrass habitat and estimating both carbon stores and carbon sequestration rates. The work, which took place in the K'ómoks Estuary, and which tested several methods, estimated that the 164 ha of eelgrass growing there could store as much as 58 tonnes of carbon per year. The team estimated that carbon sequestration rates are site specific, even within an estuary, and that much of the eelgrass carbon is exported out of the estuary and deposited elsewhere, both important considerations for blue carbon and eelgrass restoration project design and interpretation. A detailed description of the project and the protocol can be found in Hodgson and Spooner (2016), available on the Project Watershed website.

Researchers extract a sediment core from an eelgrass bed to measure carbon storage.
Credit: Comox Valley Project Watershed

Credit: Rebecca Benjamin-Carey

CARBON SEQUESTRATION

The ocean absorbs about a quarter of the carbon dioxide (CO_2), a major heat-trapping gas, emitted into the atmosphere by the burning of fossil fuels (Friedlingstein et al., 2023). This 'greenhouse gas' is responsible for a large portion of the global heating that is causing climate change and its impacts (Pörtner et al., 2019), including to salmon. In effect, by absorbing atmospheric CO_2, the ocean is limiting atmospheric warming. In addition, during photosynthesis, submerged aquatic vegetation (SAV), including seagrasses, kelp, and salt marsh plants, **sequesters**[13] dissolved CO_2 out of the seawater and use it to build the organic carbon components of their biomass. Some of this organic carbon is then stored in the sediments, making SAVs effective **carbon sinks**[14] (Commission for Environmental Cooperation, 2016; Rosentreter et al., 2023; Sherman & DeBruyckere, 2018). Carbon that is sequestered and stored in the ocean is called 'blue carbon'. If left undisturbed, SAVs, such as *Z. marina*, have the potential to store blue carbon in sediments for long periods of time.

Eelgrass ecosystems contribute to blue carbon when their biomass of leaves and stems slows the movement of water and filters out additional organic material originating inside and outside of the bed to settle onto the bottom sediment, where it is trapped by the rhizomes. All of this organic carbon in the eelgrass biomass and the additional organic material, except what is lost during decomposition, is eventually incorporated deep into the sediments where oxygen is low, and decomposition is slow. Globally, seagrass ecosystems are estimated to store 15 per cent of blue carbon even though they occupy only 0.2 per cent of the ocean surface (Krause et al., 2025, and reference within; Kennedy & Bjork, 2009).

However, the ability of seagrasses to sequester and store carbon varies by species and meadow density. In comparison with global averages, organic carbon densities measured in *Z. marina* ecosystems in coastal British Columbia are consistent with values for *Z. marina* around the world but lower than the global average for all species of seagrass, suggesting that it is not as effective a carbon sink as other species (Lutz, 2018; Murray, 2017; Poppe & Rybczyk, 2018; Prentice et al., 2020; Short et al., 2016; Spooner, 2015). The reasons appear to be site specific, with the ability of a seagrass meadow to sequester carbon dependent on certain key processes, including the amount of seagrass biomass accumulation, the rate of sedimentation of organic carbon from outside the bed, and the efficiency of organic carbon burial (Mazarrasa et al., 2018). The limitations of *Z. marina* are thought to include its relatively shallow rhizome, its fairly thin flexible leaves which are less effective at filtering particles, and its inability to maintain a steady growth rate in environments with low light levels, and where high sediment organic carbon leads to the production of toxic sulphides (Lutz, 2018; Poppe & Rybczyk, 2018; Postlethwaite et al., 2018). Carbon storage rates can also decrease with other factors such low water motion, nutrient limitations during winter, and high proportions of fine sediments (Prentice et al., 2019). Estimates for some eelgrass sites show that much of the organic carbon stored in a meadow originated from outside the meadow (Prentice et al., 2020; Röhr et al., 2018; Short et al., 2017). It is thought that only a small portion of the biomass of *Z. marina* meadows is buried within the meadow (Poppe & Rybczyk, 2018), although exported material may be stored elsewhere, where it contributes to overall blue carbon totals (Duarte & Krause-Jensen, 2017).


Credit: Rebecca Benjamin-Carey

13. to absorb from the atmosphere or seawater
14. an ecosystem such as a forest or the ocean that stores carbon

Regardless of these limitations, overall, *Z. marina* ecosystems in the region do store carbon and at greater rates than un-vegetated sites, and represent an important carbon sink. If disturbed, *Z. marina* ecosystems have the potential to release large amounts of carbon dioxide back into the environment (Lutz, 2018; Postlethwaite et al., 2018). For example, the 300 Mg of organic carbon estimated to be stored in the top 50 cm of eelgrass sediments in Skagit County in the U.S. Salish Sea would, if disturbed and exposed to oxygen, potentially emit one million metric tons of CO_2 into the atmosphere (Lutz, 2018; Poppe & Rybczyk, 2018). Eelgrass meadows in coastal BC are estimated to absorb over 23,000 tons of CO_2 annually (Short et al., 2016).

> **Protecting the continuum of carbon-sequestering vegetated coastal ecosystems, including forests (both trees and understorey plants), salt marshes, understory algae, kelp forests, and eelgrass, represents an important nature-based solution to climate change (Rosentreter et al., 2023).**
>
> – Mary O'Connor, 2024.

OCEAN ACIDIFICATION BUFFERING

Acidity is the concentration of hydrogen ions in a solution. The higher the concentration of hydrogen ions, the greater the acidity. The concentration of hydrogen ions is measured on the **pH**[15] scale, with a lower pH indicating higher acidity. When CO_2 is absorbed by the ocean and reacts with seawater, hydrogen ions are released, increasing the acidity of the seawater (lowers pH), with potential impacts to marine organisms (Evans et al., 2023; Pörtner et al., 2019). Ocean acidification (OA) is predicted to reduce the productivity and availability of zooplankton prey species for salmon (Evans et al., 2023; Pearsall et al., 2021) and may also affect some salmon species physically. A recent behavioural study on ocean-phase coho salmon in the Salish Sea demonstrated that high marine CO_2 concentrations and the resultant increasing OA impairs the sense of smell in salmon (Williams et al., 2019), a sense that is central to finding prey, avoiding predators, and homing to the natal stream. Results for other salmon species are mixed (Evans et al., 2023).

Modelling for Washington State Salish Sea predicts that OA will increase by a 1.8 unit decrease in pH by 2095 relative to the year 2000 (Khangaonkar et al., 2019). The average OA increase in BC coastal waters, reported in 2023, was 40 per cent above pre-industrial levels, higher than the global average of 30 per cent. It is predicted to be 55 per cent at an atmospheric level of 468 ppm (parts per million), which is expected to be reached within 15 years at the current emissions trajectory (Evans et al., 2023).

When eelgrass removes dissolved CO_2 from the ocean during photosynthesis, it reduces the release of hydrogen ions and effectively lowers the acidity of the seawater (increases pH) (Groner et al., 2018; Magel, 2020; Magel et al., 2022; Nielsen et al., 2018). While the effect is generally expected to occur during daytime hours, and mostly in spring and summer when photosynthesis is highest (Nielsen et al., 2018), it has been shown in a California study to persist for up to 21 days (Ricart et al., 2021). While results are mixed and more research is required (Koweek et al., 2018; Tejeda, 2014), eelgrass may have the potential to reduce daily extremes of OA and the time that organisms are exposed, providing a localized extended refugia for species sensitive to increasing acidity, including salmon (Nielsen et al., 2018; Sherman & DeBruyckere, 2018; Smith, 2016). Species that also benefit from reduced OA are those with a calcium carbonate shell, such as crabs, shellfish, and zooplankton, and those species with sensitive early life histories, such as larvae and juveniles (Evans et al., 2023; Fabry et al., 2008; Nielsen et al., 2018).

Studies in Puget Sound suggest that the ability of eelgrass to buffer OA may increase with future increases in CO_2 because more carbon will be available in seawater for photosynthesis (Pacella et al., 2018; Nielsen et al., 2018, and references within).

15. a measure of the concentration of hydrogen ions indicating neutrality (pH 7), acidity (less than pH 7), or alkalinity (greater than pH 7)

MITIGATION OF HYPOXIA AND HARMFUL ALGAL BLOOMS

Globally, the ocean has absorbed most (90 per cent or more) of the excess heat in the atmosphere produced by **anthropogenic**[16] emissions of heat-trapping gases (World Meteorological Organization, 2021). The impacts of increasing ocean temperature on cold-water adapted Pacific salmon are many, for example, physiological stress, reduced prey biodiversity, interruption in food webs, reduced availability of oxygen, and an increase in harmful pathogens (Pearsall et al., 2021). Eelgrass may play a mitigating role in two of these effects: ocean hypoxia and an increase in harmful algal blooms (HABs).

In the Salish Sea (Strait of Georgia), sea surface and sea bottom temperatures have been increasing by more than 1˚C per century (Riche et al., 2014; Pearsall et al., 2021). One modelling projection based on the most reasonable high emissions scenario reported by the Intergovernmental Panel on Climate Change (IPCC) to the year 2095 is for an average increase in ocean temperatures in the Salish Sea (Washington portion) by 1.51 °C relative to the year 2000 (Khangaonkar et al., 2019, and references within). This increase will result in an average decrease in dissolved oxygen by about 0.77 mg/L, with a corresponding increase in the area of ocean experiencing hypoxia annually from the current <1 per cent to about 16 per cent. Eelgrass may play a role in mitigating hypoxia by raising daytime dissolved oxygen in the water column during photosynthesis (Magel, 2020), potentially providing a temporary refugia for salmon, which are sensitive to low oxygen.

Ocean warming has also increased the occurrence and severity of HABs in British Columbia coastal waters (Evans et al., 2025; Wells et al., 2015). The algae (diatoms and dinoflagellates) and bacteria (cyanobacteria) that form HABs can be toxic to some animals, and, in combination with other stressors, HABs have the potential to harm wild salmon (Esenkulova et al., 2021, 2022). In response to dense HAB blooms, Chinook salmon have been shown to reduce feeding, and damage to liver and gills has been documented during blooms dominated by particular algae (Esenkulova et al., 2022). Studies in Puget Sound demonstrated that eelgrass-associated bacteria can act as an algicide and inhibit the growth of the algae that produce HABs (Inaba et al., 2017). Reductions of algal abundance have been shown to reach beyond a continuous eelgrass meadow by at least 15 m, forming a protective halo around the bed (Jacobs-Palmer et al., 2020), by inference producing a temporary refuge for salmon susceptible to HABs.


Credit: Mitch Miller

16. human-caused

COASTAL PROTECTION

Global heating is increasing both the number and severity of storms (Pörtner et al., 2019). These storms have higher wave action and more intense rainfall events, both of which increase the erosion of shorelines. Resulting impacts on salmon include loss of shoreline vegetation, which provides invertebrate and insect forage for juveniles; increased turbidity, which can impact physiology, behaviour, and habitat (Bash et al., 2001); and loss of nursery and refuge habitat, including eelgrass (see Chapter 3).

Intact, healthy eelgrass can contribute to shoreline protection and prevent coastal erosion (Figure 1.11). The interwoven mat of eelgrass rhizomes and roots binds and stabilizes the sediment, while the leaf structure slows currents and wave action, allowing suspended particles to settle onto the sediment, and at the same time, preventing their re-suspension (Phillips, 1984; Sherman & DeBruyckere, 2018, and references within).

Figure 1.11 Eelgrass protects shorelines from erosion by absorbing wave energy and stabilizing sediments.
Credit: SeaChange Marine Conservation Society

CHAPTER ONE LESSONS LEARNED

- ☑ *Zostera marina* is the only native eelgrass species in the Salish Sea and WCVI region.
- ☑ Eelgrass ecosystems are important habitats for juvenile Pacific salmon.
- ☑ Eelgrass is part of a seascape of interconnected habitats from terrestrial to the open ocean, all of which contribute to the health of salmon.
- ☑ Healthy eelgrass ecosystems contribute to the food sovereignty of coastal Indigenous Peoples who also rely on healthy salmon populations.
- ☑ Eelgrass ecosystems provide many ecosystem services that benefit salmon, including mitigation for climate change impacts.

Next Chapter: Finding Eelgrass: Distribution and Extent Mapping of Eelgrass Habitats in the Salish Sea and WCVI Region

CHAPTER TWO
FINDING EELGRASS: DISTRIBUTION AND MAPPING OF EELGRASS IN THE SALISH SEA AND WCVI REGION

Explore Eelgrass Mapping: Watch
MaPP Seagrass Training: Survey Tiers
(2:33 min) Credit: Hakai Institute

INTRODUCTION

Eelgrass (*Zostera marina)* ecosystems are dynamic in time and space, and the distribution and extent of beds can vary naturally, the edges expanding or contracting, by season or from year to year as environmental conditions or anthropogenic impacts change (Precision Identification, 2002; Sherman & DeBruckyere, 2018). For example, a meadow can be completely or partially wiped out by a storm, or plants exposed at low tide during a severe winter frost or summer heat wave can die (Precision Identification, 2002). Factors, often interrelated, such as salinity, temperature, sediment type, light availability, pH, current and wave velocity, nutrients, and **hydrodynamics**[17] determine if and where an eelgrass bed might form, how dense it grows, whether the cover is patchy or continuous, and if it persists over time (Phillips, 1984).

This chapter will first explain the environmental factors that eelgrass requires for optimum health, and which determine its distribution in the nearshore landscape. Knowledge of these environmental requirements is the first step to finding and mapping eelgrass, which is the focus of the second half of the chapter.

Credit: Jillian Lynn-Lawson

17. fluid flow patterns

WHERE DOES EELGRASS GROW? FACTORS DETERMINING EELGRASS DISTRIBUTION

Zostera marina is found in relatively sheltered, gently sloping locations or on tidal flats near the shore (Phillips, 1984; Precision Identification, 2002). It can grow from the intertidal zone to the subtidal zone in narrow fringing beds that follow the shoreline, in larger flat beds in bays and estuaries (Precision Identification, 2002; Nelson, 2018) or in shallow tidal channels where it grows from one side of the channel to the other (Figure 2.1) (Cynthia Durance, personal communication, 2025). Most of the eelgrass in the region is subtidal, however extensive intertidal mud flats are found in the Fraser River Estuary and in Boundary Bay (Murphy et al., 2021, and reference within).

In the upper intertidal, *Z. marina* is sometimes intermixed with the introduced species, *Zostera japonica*, an annual or short-lived perennial (see Chapter 3 for more information about *Z. japonica*) (Harrison & Bigley, 1982; Precision Identification, 2004; Shafer et al., 2014). The two species can look very similar, differentiated only by the configuration of the roots at each rhizome node. Detailed information about the differences between *Z. marina* and *Z. japonica* can be found in the **MH** (Durance & Wright, 2026).

Along the Pacific coast, including the Salish Sea and WCVI region, the majority of *Z. marina* beds are perennial, persisting through the winter (Murphy et al., 2021, and reference within). Typically, maximum shoot density and leaf growth occurs from spring to late summer (Blok et al., 2018). Starting in the fall, reproductive shoots and some vegetative shoots release and are transported out of the bed and onto beaches during seasonal storms, reducing shoot density and aboveground biomass over the winter. Energy stored in the established rhizomes supports the shoots until the next growing season (Wong et al., 2020).

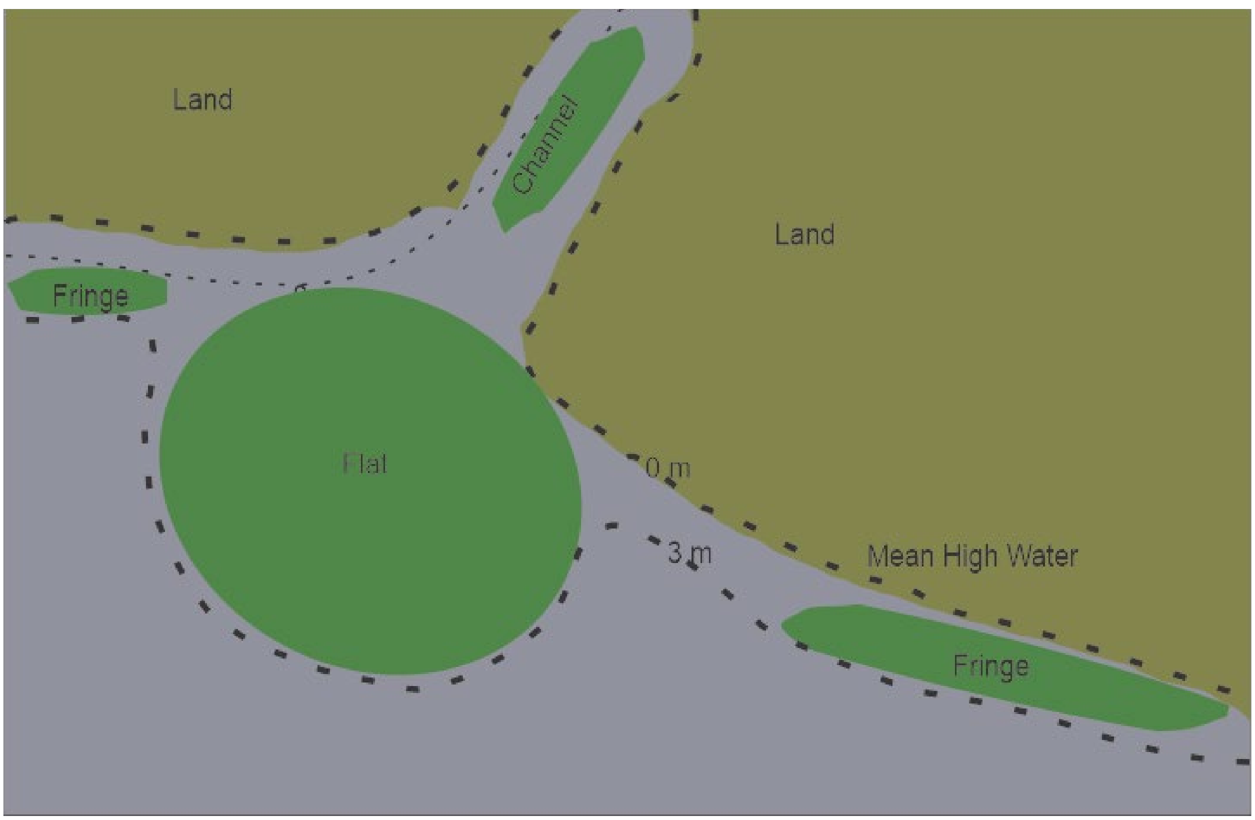


Figure 2.1 Eelgrass can grow from the intertidal zone to the subtidal zone in narrow fringing beds that follow the shoreline, in larger flat beds in bays and estuaries or in shallow tidal channels where it grows from one side of the channel to the other. Credit: Cynthia Durance

Four **ecotypes**[18] occur in the region, sometimes co-mingling: *Z. marina* ecotype *typica* which has a smaller leaf and grows primarily in the intertidal zone; *Z. marina* ecotype *latifolia*, which has a larger leaf and grows subtidally; *Z. marina* ecotype *phillipsii* which has a leaf size and depth range intermediate between the previous two ecotypes; and *Z. marina* ecotype *izembekensis*, which has habitat requirements similar to ecotype *phillipsii*, but tends to have narrower leaves (Table 2.1) (Backman, 1991; Precision Identification, 2002). Where more than one ecotype co-occurs in a bed the density of eelgrass shoots will vary (Precision Identification, 2002). Knowledge of ecotypes is important for eelgrass mapping and restoration.

The distribution of eelgrass within a bed also varies with environmental conditions such as sediment type, current velocity, wave energy, and depth (Backman, 1991; Precision Identification, 2002). Eelgrass beds are either continuous or patchy. A dense, continuous eelgrass meadow will form in sheltered bays within an optimal sand and mud bottom, while beds influenced by strong currents or with a substrate made up of sand and cobble will generally be patchy (Precision Identification, 2002). A patchy bed is characterized by isolated groups or 'patches' of plants. Note that a bed containing bare patches surrounded by eelgrass is considered continuous. A bed may be consistently dense throughout or may have zones of varying density and leaf size along a depth gradient.

Table 2.1 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 (m)	Seasonal variation in size	Current tolerance
typica	<30	1.5 to 3.5	primarily intertidal	small variation	low
phillipsii	40 to 210 cm	5 to13	+0.5 to - 4	large, plant length reduced in winter	moderate
latifolia	100 to 300 cm	12 to 20	-0.5 to -10	minimal variation	strongest
izembekensis	40 to 106 cm	2 to 5	0 to -1.5*	large, plant length reduced in winter	moderate

* based on few observations in BC.


Credit: Jamie Smith Coastal Photography Studio

18. genetic variants

ENVIRONMENTAL REQUIREMENTS FOR EELGRASS GROWTH

Eelgrass (*Z. marina*) requires certain environmental conditions for vegetative growth (Table 2.2). The most limiting factors influencing eelgrass distribution growth and persistence in the Salish Sea and WCVI region are light availability, sediment characteristics, and exposure to waves and currents. The ocean environment is complex and dynamic, with environmental factors simultaneously influencing the growth and distribution of eelgrass habitat. Effects vary by site, requiring local assessment for mapping, monitoring, and restoration.

Table 2.2 Environmental requirements for vegetative growth of *Zostera marina* in the Pacific Northwest (Phillips, 1984; Precision Identification, 2002; Thom, Southard & Borde, 2014). (ppt = parts per thousand; MLLW = mean lowest low water).

Variable	Range	Optimal
Light/depth	1.8 m above MLLW to -10 m	MLLW to -4.4 m
Surface conditions/currents	Waves to stagnant water	Little wave action, gentle currents to 3.5 knots
Temperature	-6 °C – 40.5 °C	6 °C – 17 °C
pH	7.3 – 9.0	7.3 – 9.0
Salinity	freshwater to 42 ppt	10 ppt – 30 ppt
Dissolved oxygen	5 mg/L	Unknown
Substrate	Firm sand to soft mud	Mixed sand and mud
Nutrients	Nitrogen and phosphorous	Moderate soil nutrients; low in water column

LIGHT AVAILABILITY

Eelgrass requires adequate light to photosynthesize. Eelgrass can adapt to lower light conditions by increasing or decreasing leaf length according to its photosynthetic needs (Wong et al., 2020), and has been shown to grow in a wide range of light conditions, but, generally, lower light availability reduces density, and leaf and flower production (Phillips, 1984).

Because light is absorbed as it travels through the water column, depth is a limiting factor with deeper beds receiving less light (Murphy et al., 2021, and references within; Phillips, 1984, and references within). Other factors that affect light absorption rate include latitude (day length), season, tides, cloudy weather, water clarity, and colour (absorption and scattering properties) (Murphy et al., 2021, and references within; Phillips, 1984; Thom et al., 2018). Increased turbidity can occur naturally during plankton blooms, which are occurring more frequently with climate change. Runoff from land also increases turbidity from increased sediments in the water column, a growing problem resulting from shoreline development and more intense and frequent storms with climate change (Murphy et al., 2021, and references within) (see also Chapter 3).

In the Salish Sea and WCVI region, *Z. marina* grows year-round, with the most productive season during spring and summer when low tides occur during the longer daylight hours, bringing more light to plants. In sheltered nearshore areas of the region, such as the Strait of Georgia, where turbidity may generally be higher than in open ocean areas because of runoff from the Fraser River and other coastal rivers and streams, depth limits are thought to be shallower than some other regions (Murphy et al., 2021). In a blue carbon mapping study for Canada and the US, average maximum depth at the eelgrass deep edge was determined to be 3 m in the Strait of Georgia and 5 m for the rest of the BC coast (Short et al., 2016). Light levels below a depth of 10 m to 12 m are inadequate to support photosynthesis, as evidenced by reduced shoot density (Precision Identification, 2002).

TEMPERATURE AND PH

Temperature and pH are not restrictive for eelgrass growth in the region, with a wide range in suitable parameters (Precision identification, 2002). However, this may change with factors related to climate change, such as ocean acidification and marine heat waves (see Chapter 3). The optimal pH range for *Z. marina* growth is 7.3-9 (Phillips, 1984, and reference within).

The optimum ocean temperature for eelgrass growth in the region is 6 °C to 17 °C. Temperatures persisting at or above 25 °C have been shown to increase respiration and lower net productivity, resulting in stress to the plants (Thom, Southard & Borde, 2014). Shallow and sheltered bays, where eelgrass likes to grow, are prone to rapid increases in temperature on summer days (Murphy et al., 2021). Intertidal eelgrass, when exposed to air during low tides, can experience heat stress and **desiccation**[19].

SALINITY

Because eelgrass grows in estuaries and nearshore coastal areas where freshwater flows into the ocean from streams and rivers, it is adapted to a wide range of salinities (Phillips, 1984). Eelgrass, however, does not thrive in freshwater, although it can survive for brief periods (e.g. high river flows, freshet) (Cynthia Durance, personal communication, 2025; Phillips, 1984). The optimum salinity for *Z. marina* in the region is 10 to 30 **ppt**[20], although in a few areas it has adapted to lower salinities (Thom, Southard & Borde, 2014; Cynthia Durance, personal communication, 2025). In relation to temperature, salinity is an important factor for seed germination which was shown to double at 10 ppt when water temperatures were between 10 and 15 °C (Phillips, 1984, and reference within).

SURFACE CONDITIONS AND CURRENT VELOCITY

Eelgrass generally likes moderate current with minimal to nil wave action. A moderate amount of current, to a maximum of 3.5 knots, has been shown to enhance eelgrass growth and productivity by making more carbon dioxide (CO_2) and nutrients available to the plants (Phillips, 1984). Faster currents can break leaves and disturb sediments. Eelgrass can adapt to higher currents by increasing the growth of below ground rhizomes and roots for stronger anchoring in the sediments (Murphy et al., 2021, and references within). Very low or no current can result in increased competitive algal growth on the eelgrass plants (Phillips, 1984, and references within).

19. drying out
20. parts per thousand

SEDIMENTS

The relationship between eelgrass and the sediments that support it is dynamic (Phillips, 1984). Eelgrass requires soft sediments ranging from mud to sand, sometimes mixed with gravel, cobble or shell, for its roots and rhizomes to anchor. Once anchored, the roots and rhizomes draw nutrients from the sediments into the growing plant to form leaves. When the leaves die and drop to the bottom, they are broken down by microbes and mechanical processes into organic and inorganic nutrients that are taken up by the sediments, then absorbed by the eelgrass plant, stimulating the production of more leaves, which eventually die and continue the cycle. Over time, the roots and rhizomes form a thick mat, which stabilizes the substrate, increasing the rate at which sediments settle, and changing the sediment characteristics such as grain size and shape and how they are sorted, to favour both increased stability and nutrient availability. Eelgrass roots are known to fix nitrogen, transfer carbon to sediments where it is sequestered, and transfer oxygen into the sediment. Denser eelgrass beds generally have more stable sediments. This sediment-microbial-nutrient-eelgrass cycle can be disrupted by natural or human-caused physical disturbance.

OXYGEN

Eelgrass produces oxygen during photosynthesis, which travels to the leaves, rhizomes, and roots (Borum et al., 2005). Oxygen is lost to the water column and to the sediments. Eelgrass requires sediments to be high in oxygen and does not do well in **anoxic**[21] conditions (Murphy et al., 2021, and references within). Anoxic conditions occur when a build up of organic debris (e.g., wood waste from log storage) creates a cap over the benthic sediments, which increases the biological oxygen demand, and prohibits pore water exchange at the sediment surface (Breems and Goodman 2009; Domarchuk-White et al., 2023, and references within). The organic debris is then decomposed by sulphate-reducing bacteria that produce hydrogen sulphide in the process (Fenchel 1988; Jorgensen 1982; Levings and Northcote 2004; Sutherland et al. 2006). Hydrogen sulphide build-up in benthic sediment is toxic to eelgrass and can cause sudden die-off (Pedersen et al. 2004), and renders eelgrass seedlings more susceptible to damage and death (Dooley et al. 2012).

However, eelgrass has been shown to adapt to muddy and silty sediments that tend to have low oxygen levels, by growing rhizomes closer to the substrate surface where oxygen is more available and sulphide levels are lower (Murphy et al., 2021, and references within). In addition, eelgrass can tolerate low levels of oxygen in the sediments by accessing oxygen from the water column by passive diffusion (Borum et al., 2005).


Credit: Coastal Photogaphy Studio

21. very low oxygen levels

NUTRIENTS

Eelgrass, like all seagrasses, draws nutrients from the water column or from the sediment to support eelgrass growth and productivity. During periods of high nutrient availability, eelgrass can store nutrients in the leaves and rhizomes for use when nutrients are less available (Romero et al., 2006, and references within). The most important nutrients to support eelgrass growth are nitrogen (N) and phosphorous (P), as well as a number of micronutrients such as iron and copper.

Eelgrass benefits from moderate levels of nutrients in the sediment, and low levels in the water column (Murphy et al., 2021, and references within). High organic matter in the sediments can produce harmful sulphides or ammonia, while high nitrogen levels in the water column can stimulate algae growth, resulting in a low oxygen environment, a process known as **eutrophication**[22] (Murphy et al., 2021, and references within) (see Chapter 3). Eelgrass can tolerate high sulphide levels if the water quality is good (Ken Moore, personal communication to Cynthia Durance, 2012). This has been observed in many BC locations (e.g. Port Renfrew, Campbell River, Klemtu). However, less productive eelgrass beds growing in sediments low in oxygen occur in the Salish Sea where long-term wood waste from logging has accumulated on the seafloor (Nikki Wright, personal communication, 2025).


Credit: Jamie Smith Coastal Photography Studio

22. where nutrient pollution builds up in a water body and causes increased plant growth

WHERE IS EELGRASS GROWING? MAPPING IN THE SALISH SEA AND WCVI REGION

Knowledge of the environmental requirements for eelgrass to grow and thrive is a first step in determining where eelgrass might be found. Mapping of coastal areas not only helps locate where eelgrass and other nearshore habitats are currently found but can also be used to determine where it has grown and no longer does, and where it has the potential to grow (PSF is creating modelled habitat suitability maps for select estuaries, which will be made accessible through the restoration Hub in 2027).

The mapping of eelgrass beds provides a baseline from which to:

- set up measures to protect it;
- know where restoration is needed;
- design restoration projects for areas that historically had eelgrass or have physical potential for eelgrass; and
- monitor changes in eelgrass distribution and extent over time as a result of natural variables, climate change, and other stressors.

(Durance, personal communication, 2025).

THE HISTORY OF EELGRASS MAPPING (PRE-2004)

Indigenous Peoples on the British Columbia coast have always known where eelgrass grows in their territories. Consulting Indigenous Knowledge Holders about locations of past and present eelgrass beds, as well as the locations of past and present crab and clam harvesting sites as a proxy for eelgrass beds, is always a good place to start when embarking on locating and mapping eelgrass habitats. Traditional Ecological Knowledge (TEK), as well as the ecological knowledge of non-indigenous local communities (LEK), is increasingly recognized as an important source of information, synthesized with scientific data, to establish historical baseline conditions and assess long-term ecosystem change (Beaudreau & Levin, 2014).

Beginning in the 1970s, information about eelgrass locations was collected as part of other primarily government-funded research. For example, on Fisheries and Oceans Canada (DFO) herring spawn maps, fish habitat mapping, as part of general marine vegetation mapping, or foreshore inventory (Dunster, 2003). Mapping was often at a coarse scale (>1:40,000), providing only general locations of eelgrass beds.

It was not until the mid-1990s, as recognition grew among western scientists and non-indigenous communities about the ecological importance of eelgrass and the ecosystem services it provides, that the specific mapping of eelgrass for conservation purposes by non-governmental organizations (NGOs), and community groups emerged. In response, the Seagrass Conservation Working Group (SCWG) was formed with support from the Canadian Wildlife Service of Environment Canada. The SCWG is a group of community and conservation groups, government agencies, researchers, consultants, and students dedicated to conserving and restoring seagrass and other nearshore ecosystems (Seagrass Conservation Working Group, n.d.). Under its umbrella, from 2002-2004, 1,000 volunteers from twenty communities mapped 12,000 hectares (ha) of intertidal eelgrass habitat from Haida Gwaii to Boundary Bay (Wright, 2005) using the methods described in Precision Identification (2002). As a result, mapping methodology began to shift from coarse scale mapping by aerial imagery covering large areas of the coast to fine scale mapping of smaller, more localized site-specific eelgrass habitats more useful for monitoring, restoration, and protection purposes.

RECENT MAPPING

When large gaps in fine (local) scale mapping of eelgrass habitats in the Salish Sea and WCVI region became apparent, a number of initiatives using various methodologies, ranging from low-tide shore-based inventories of intertidal beds by foot to unmanned aerial vehicles (UAVs, also known as drones) and satellites, have attempted to fill those gaps. Following are several notable regional and local mapping initiatives that have taken place in the region in recent years. A spreadsheet of mapping initiatives in the region by First Nations, NGOs, and government agencies can be viewed and new projects added by contacting the Seagrass Collective at seagrass@hakai.org.

Regional-scale Mapping

ShoreZone

ShoreZone is an aerial imaging and habitat classification system designed in the 1980s and 1990s, and funded by the BC and Canadian governments, to map the coastal nearshore, including intertidal and shallow subtidal eelgrass habitat (Cook et al., 2017). ShoreZone data is stored in a georeferenced searchable database on the ShoreZone website (ShoreZone.org). Applications for ShoreZone data include oil spill response, marine debris cleanup, coastal vulnerability assessment, and habitat and species modelling.

ShoreZone's standardized protocol uses low altitude aerial imagery, both video and stills, taken at low tide from helicopters (preferred) or fixed-wing airplanes, to map attributes such as substrate, geomorphology, aspect, wave exposure, and vegetation type (Cook et al., 2017). Biological attributes are classified into 'biobands,' which are defined by a typical tide height, colour, and texture. The eelgrass bioband, for example, is differentiated on the imagery from the kelp or red algae biobands by a bright to dark green colour, sandy substrate, grassy-texture, low tidal/subtidal height, and the wave exposure (Figure 2.2).

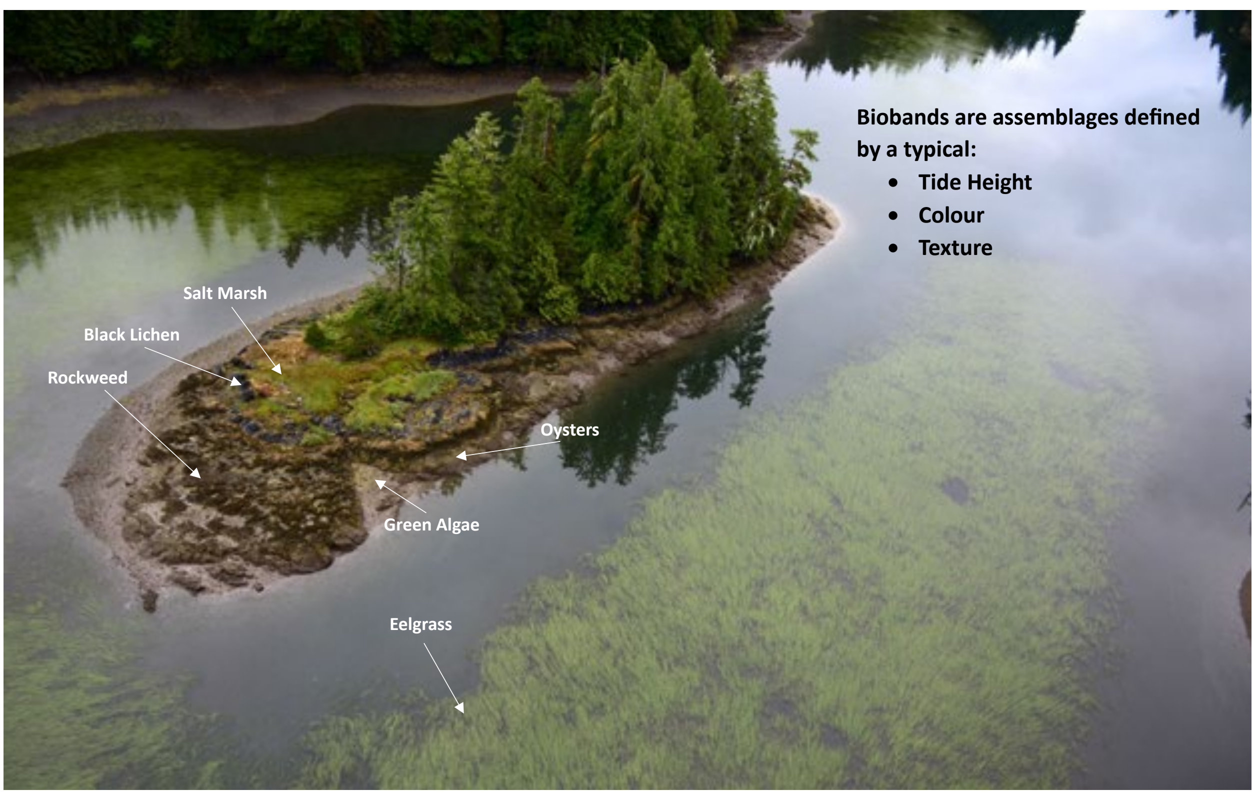


Figure 2.2 The eelgrass bioband is differentiated on ShoreZone imagery by a bright to dark green colour, sandy substrate, grassy-texture, low tidal/subtidal height, and the wave exposure.
Credit: SeaChange Marine Conservation Society

ShoreZone mapping has had some limitations for mapping eelgrass, for example, prior to 2017, the entire bioband would be classified as either patchy (<50% length of the unit) or continuous (>50% length of the unit) despite however small or large the patch might be. In 2017, changes were incorporated into the ShoreZone protocol in order to provide further definition of the space a bioband occupied: **1)** the per cent along-shore length of the unit occupied by a bioband, such as eelgrass, was broken up into more detailed categories than patchy or continuous (<5%, 5-25%, 26-50%, 51-75%, 76-95%, >95%, and not assessed), **2)** the percent cover of the intertidal zone occupied by a bioband was recorded in the intertidal (<5%, 5-25%, 26-50%, 51-75%, 76-95%, >95%, and not assessed) and **3)** width (narrow, medium, and wide) was assigned to all supratidal and subtidal biobands. Assessments of the ability of ShoreZone to accurately detect eelgrass biobands suggest that aerial and ground-based observations are closely matched (Cook et al., 2017, and references within).

Since its inception, ShoreZone has mapped ~133,000 km of the coast from Oregon to the North Slope of Alaska (Cook et al., 2017), including the entire coast of British Columbia (Coastal and Ocean Resources & SeaChange Marine Conservation Society, 2023a). Early ShoreZone work resulted in linear mapping of biobands (patchy, continuous) only, but recent advances have allowed for spatial polygon mapping, which delineates the boundaries of an eelgrass bed (Figure 2.3) and is more useful as a baseline for detecting change and for assessing bed density. The ShoreZone linear and polygon mapping to 2024 for the Salish Sea and WCVI is summarized in Table 2.3 and Figure 2.4.

Table 2.3 Summary of Shorezone eelgrass mapping in the Salish Sea and WCVI region.

Linear Mapping				
Area/type of mapping (linear or polygon)	**Total mapping distance (km)**	**Distance identified as eelgrass biobands (km)**	**Per cent of total**	**Reference**
Salish Sea South of Nanaimo	3,345	645	19.3%	Coastal and Ocean Resources, 2022a
Salish Sea North of Nanaimo to Campbell River	384	171	43.4%	SeaChange Marine Conservation Society, 2024a
WCVI	1,665	347	21%	SeaChange Marine Conservation Society & Coastal and Ocean Resources, 2023
Polygon Mapping				
Location	**# of eelgrass polygons**	**Area mapped (ha)**	**Reference**	
Salish Sea - Gulf Islands	927	1218	Coastal and Ocean Resources, 2022b	
Salish Sea - Islands Trust Area	1,566	1,613.5	Coastal and Ocean Resources, 2022e	
WCVI - Bamfield	211	35.5	Coastal and Ocean Resources, 2022c	
WCVI - Nootka Sound	745	75	Coastal and Ocean Resources, 2022d	
WCVI- Barkley Sound	1,013	79	SeaChange Marine Conservation Society, 2023	
WCVI- Ucluelet	130	59	SeaChange Marine Conservation Society, 2024b	

Figure 2.3 Example of ShoreZone polygon mapping at Penelakut Island in the Salish Sea.
Credit: SeaChange Marine Conservation Society

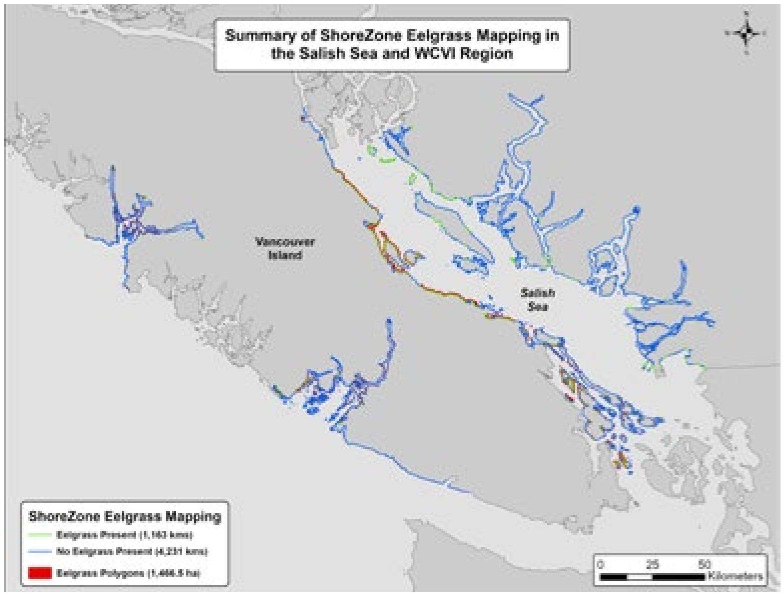


Figure 2.4 Summary of ShoreZone linear and polygon mapping in the Salish Sea and WCVI region. Note:The Islands Trust Area polygon mapping shown in Table 2.3, is not included on this map.
Credit: SeaChange Marine Conservation Society

Islands Trust

The Islands Trust (IT) is a special purpose government in the Canadian Salish Sea, established in the 1970s by the Province of British Columbia with the mandate to "preserve and protect the Trust Area and its unique amenities and environment for the benefit of the residents of the Trust Area and of British Columbia" (islandstrust.bc.ca). The Islands Trust Area encompasses all the islands of the Canadian Salish Sea, including those in Howe Sound and as far north as Hornby Island and Denman Island. IT has elected representatives who make planning and zoning decisions on land and marine areas for the 13 major islands and 450 small islands in the Islands Trust Area. The Islands Trust Conservancy (ITC) is the conservation arm of IT, with a mandate to work with communities to protect unique and fragile ecosystems in the Trust Area.

In 2012, as part of its conservation strategy to preserve and protect nearshore habitats, the Islands Trust Council contracted SeaChange Marine Conservation Society to map eelgrass around the islands under IT jurisdiction (Wright et al., 2014). The work was conducted over three years (2012-2014) by boat with a towed underwater camera and GPS using a standard methodology developed by Precision Identification (2002). Previously conducted ShoreZone linear eelgrass bioband mapping and classification were used for reference. The resulting linear mapping describes eelgrass distribution as patchy or continuous and the narrative report details form (fringing or flat), sediment characteristics, percent cover, potential restoration sites, and other variables. Observed trends were reported where possible. The inventory report can be found in Wright et al. (2014), with mapping available on the MapIT application found on the IT Mapping and Resources webpage (https://islandstrust.bc.ca/mapping-resources/mapping/) .

In August of 2021, IT funded a ShoreZone polygon survey for the Trust Area (Table 2.3). Aerial video and digital stills were collected over three days when low tides were less than 1 m in elevation (Coastal and Ocean Resources, 2022e). The imagery was combined with satellite imagery to delineate the boundaries of eelgrass beds. The total shoreline surveyed was 1,360 km with a total of 1,566 eelgrass polygons delineated over a cumulative total of 1,614 ha. Because 41 per cent of the polygon mapping was low confidence, **ground-truthing**[23] with towed underwater camera, side scan sonar, or dive surveys is required to establish accurate polygon boundaries. To date, ground-truthing has not been conducted. The data is available on the ShoreZone website (ShoreZone.org).

23. field checking to confirm results from other mapping methods

səlilwətaɬ (Tsleil-Waututh Nation) staff and community — including Elders and siʔáḿθət school students participated in cáləm (eelgrass) restoration in səlilwət (Burrard Inlet) co-led by səlilwətaɬ and SeaChange Marine Conservation Society. For more information: https://twnation.ca/transplanting-c%c9%99l%c9%99m-eelgrass-to-restore-ecosystems-in-burrard-inlet/

"səlilwətaɬ Collaborative Work to Map and Restore cáləm in səlilwət (Burrard Inlet)"

Contributed by Tsleil-Waututh Nation

səlilwətaɬ (Tsleil-Waututh) means "People of the Inlet" in the hən̓q̓əmin̓əm̓ language, referring specifically to səlilwət (Burrard Inlet). Tsleil-Waututh people's creation stories originate from within and around səlilwət where they have been since time out of mind. Approximately 90 per cent of the Tsleil-Waututh diet was derived from səlilwət marine resources and Fraser River salmon. Western archaeology and Indigenous science have demonstrated the abundance and diversity of marine foods within the Tsleil-Waututh diet prior to contact with Europeans, as well as evidence that traditional Tsleil-Waututh practices did not deplete marine resources. Tsleil-Waututh Ancestors established sacred, legal obligations to protect, defend, and steward the territory. Those obligations remain today, but the many changes to — and cumulative effects on — the Inlet following colonial settlement have impeded Tsleil-Waututh's ability to enact their laws and practice their ways of being. səlilwət has been damaged to the point that it is no longer able to sufficiently support Tsleil-Waututh needs. Tsleil-Waututh Nation (TWN) (https://twnation.ca/) is playing an active role in finding strategic solutions to improve the ecological integrity and health of səlilwət as a whole. Among TWN's numerous projects has been the mapping, restoration and protection of cáləm (see TWN's Burrard Inlet Stewardship Initiatives Interactive Online Map)

Key Takeaways:

- TWN created the most comprehensive map of cáləm (eelgrass) in səlilwət, compiling data obtained in partnership with SeaChange, along with other sources.
- TWN and SeaChange have restored cáləm at multiple sites on the north shore of səlilwət, involving Tsleil-Waututh youth, Elders and staff.
- TWN organized a səlilwət cáləm symposium in June 2024, inviting key individuals from multiple jurisdictions. This symposium focused on strategies for protecting cáləm in səlilwət. There was general appetite for collaborating on an eelgrass working group, and establishing a voluntary No Anchor Zone.
- Tsleil-Waututh's stewardship efforts and collaborations are working: cáləm restoration has been successful; there is a limited food, social and ceremonial clam harvest after > 40 years of closure; sɬewət̓ (herring) have returned to Indian Arm after 140 years of extirpation; and there are increased sightings of q̓əlɬaləməcən (orcas) following a long absence.

LOCAL-SCALE MAPPING

Much of the local-scale mapping of eelgrass has been undertaken by First Nations, conservation groups, educational institutions, and local governments, often working collaboratively. Many First Nations today are mapping and monitoring eelgrass and other nearshore ecosystems in their territories to inform marine planning and to formulate restoration plans (Table 2.4). Examples of community-based groups taking initiative to map eelgrass along the coastlines of their local communities include: Conservancy Hornby Island for Tribune Bay (Zielenski et al, 2025), Mayne Island Conservancy in the Southern Gulf Islands (Underhill, 2025), Cowichan Community Land Trust (n.d.) in Cowichan Bay, Tsleil-Waututh Nation (n.d.) in səlilwət (Burrard Inlet), and Átl'ka7tsem/Howe Sound Marine Stewardship Initiative working in Howe Sound (Beaty & Sanford, 2019). SeaChange Marine Conservation Society, Comox Valley Project Watershed, Coastal Restoration Society, and Redd Fish Restoration Society often partner with First Nations and community groups in the region to map eelgrass and other nearshore habitats.

Table 2.4 Examples of eelgrass mapping and/or monitoring projects conducted by First Nations in the Salish Sea and WCVI region. Note: Not all relevant projects are included. References: Biebach & Freund, 2024; Dunster, 2003; Tsleil-Waututh Nation, n.d; and personal communications from C. Durance, 2025; J. Dornstauder, 2025; and T'Sou-Ke Nation, 2026.

Location	Nation	Partner Group(s)	Method	Year(s)
Campbell River	Wei Wai Kum	Greenways Land Trust/ Pacificus Biological Services	Dive survey	2024
Nanaimo River Estuary	Snuneymuxw	SeaChange Marine Conservation Society	Towed underwater camera	2002
Sooke Basin: (Billings Spit, Saseenos, Coopers Cove, Hutchinson Cove, Roche Cove, and Anderson Cove)	T'Sou-Ke Nation	LUMAX AI	Drone	2022 2023 2024 2025
səlilwət/Burrard Inlet	Tsleil-Waututh	SeaChange Marine Conservation Society	Towed underwater camera	2015 2018 2019 2020 2021
Zeballos	Ehattlesaht	Rugged Coast/ Precision Identification	Towed underwater camera	2025
Kyuquot	Ka:'yu:'k't'h'/ Che:k'tles7et'h'	Precision Identification	Towed underwater camera	2023
Port Renfrew	Pacheedaht	Precision Identification	Towed underwater camera	2024
Ucluelet Harbour	Nuu-chah-nulth	WCVI Aquatic Management Society	GPS Survey	2001-2002

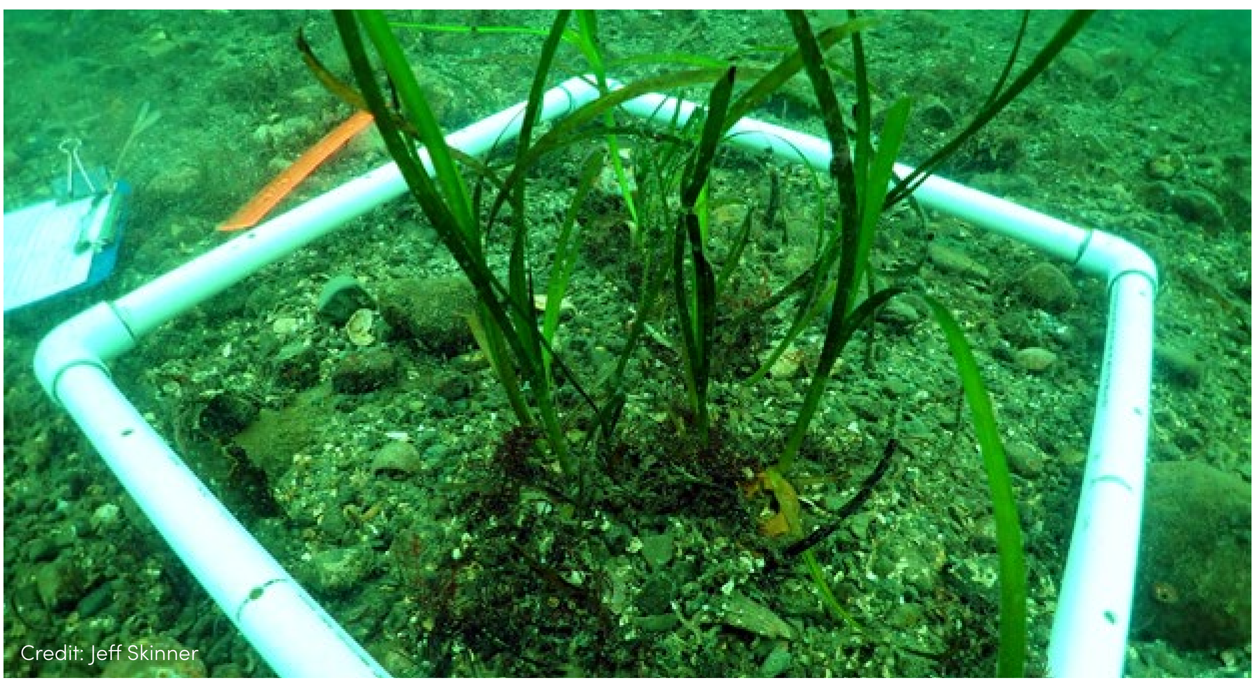
Mapping Networks

The Coastal Resources Management Information System (CRIMS), developed by the Province of BC, was the first effort to bring inventory datasets for BC together into a single electronic catalogue (Province of British Columbia, 2024a). The system includes data sets for habitat, marine plants, sea level rise impacts, coastal fringe vegetation, water quality, tourism and recreational use, birds (waterfowl), and fisheries. CRIMS has been used for environmental protection and monitoring, fisheries management, physical baseline information, and wildlife management. Maps for eelgrass, mostly sourced from ShoreZone data, are available, however, CRIMS is no longer adding layers or updating information.

The Community Mapping Network (CMN) started in 2000 to promote the planning of sustainable communities by providing a storehouse for the sharing of maps, mapping data, and information about coastal resources in BC, including sensitive marine ecosystems such as eelgrass (www.cmnbc.ca). Maps and data generated by community mapping programs and others have been compiled into a single interactive digital BC Eelgrass Inventory (CMN, n.d.). It includes most of the local mapping projects already mentioned. The CMN also hosts the BC Marine Conservation Analysis (BCMCA) Atlas, a partnership with the BC Conservation Foundation, "to provide open access information about marine biodiversity and human activity in BC's marine waters" (BCMCA, 2011). The BCMCA Atlas includes layers for priority eelgrass habitat as well as some linear and bioband data.

The Pacific Salmon Foundation (PSF) Marine Data Centre, a collaboration between PSF and the Institute of Ocean and Fisheries at the University of British Columbia, is a centralized repository for marine data focused on the Salish Sea and WCVI region (marinedata.psf.ca). Initiated in 2011, the Data Centre holds a wide variety of data, including mapping and restoration information for eelgrass and other nearshore ecosystems, which can be found on the interactive Marine Ecosystem Map (marinedata.psf.ca/sogmrg/). PSF has compiled a Community Salmon Restoration Atlas of not-for-profit-funded salmon habitat restoration projects (PSF, n.d.).

Netforce is a Canada-wide depository for eelgrass mapping data coordinated by Fisheries and Oceans Canada and the Bedford Institute of Oceanography (Guijarro-Sabaniel et al., 2024; DFO, 2025d). It holds eelgrass mapping data for the Strait of Georgia and the Southern Shelf bioregion (West Vancouver Island).



Credit: Jeff Skinner

COMPARISON OF METHODS FOR MAPPING AND MONITORING

Eelgrass mapping data is collected by direct (visual) methods by walkers, snorkelers, divers, and boats towing underwater cameras, and indirect methods such as aerial photography and remote sensing using satellite imagery or hydroacoustics (Sherman & DeBruyckere, 2018; Nelson, 2018). Direct methods produce accurate data for eelgrass distribution as well as quality and density, but are time- and labour-intensive, making them most practical for local mapping of smaller areas (Pickard et al., 2015).

In general, indirect methods are preferred for larger and/or remote geographic areas, but accuracy can be limited by clouds, waves, and water turbidity (Pickard et al., 2015, and references within). Mapping using remote sensing often requires ground-truthing by direct methods (Reshitnyk et al., 2014). Using more than one mapping method can be useful for capturing different information on an area, for example, Barrell et al. (2015) found that aerial and satellite remote sensing depicted the same eelgrass seascape differently. Hogrefe et al. (2014) has developed a multi-scale framework of mapping and monitoring at increasingly smaller scales for the vast coastline of Alaska (i.e. broad scale remote sensing followed by targeted progressively finer methods). The various methods that have been employed to map and monitor eelgrass have different uses, as well as advantages and disadvantages (Table 2.5). Detailed mapping and monitoring methodologies can be found in the **MH**

Table 2.5 Comparison of methods for mapping and monitoring eelgrass habitats.
Use codes: l=local /r=regional; c=coarse resolution/f=fine resolution; i=intertidal/s=subtidal; ln=linear mapping/p=polygon mapping. Note: see section text for sources.

Method	Use	Accuracy	Cost	Time required	Training and equipment needs	Suitable for community-based mapping
Direct Methods						
Shore-based survey	l,f,i,p	High	Low	High/Med	Low	Yes
Towed-underwater camera	l/r,f,s,ln/p	High	Medium	High	Medium	Yes
SCUBA diving	l,f,s,ln/p	High	High	High	High	No
Snorkeling	l,f,s,ln/p	High	Low	High	Low	Yes
Underwater remote-operated vehicle	l,f,i/s,ln/p	High	High	Low/High	Medium	No
Indirect Methods						
Aerial imagery/fixed wing or helicopter	r,c,i/s,ln/p	Medium	High	High	High	No
Aerial imagery/drone	l,f,i/s,ln/p	Medium	Low	Low	Medium	Yes
Satellite imagery	r,c/f,i/s,ln/p	Medium	High to Med	Low	High	No
Hydroacoustic/ sonar	l,f,s,ln/p	High	Med	High	High	Yes

DIRECT MAPPING

Direct mapping techniques are those that give the surveyor a visual view of the habitat being mapped. Direct methods are suitable for individual beds or smaller geographic areas.

Shore-based Mapping

Walking or wading along the upper limits of an intertidal eelgrass bed at low tide, while marking waypoints with a hand-held Global Positioning System (GPS) unit, has been a common, and often pleasant, mapping technique in the region since the formation of the Community Mapping Network (Bonar & Zamora, 2024, and references within; Hodgson & Spooner, 2016; Wright, 2005). Shore-based mapping requires little training and is an inexpensive way for volunteer community groups to accurately map local eelgrass beds or for researchers to check the accuracy of data collected by indirect methods (Hodgson & Spooner, 2016; Precision Identification, 2002; Short, 2014; Wright, 2005). However, it is not possible to map subtidal beds by wading, nor is it practical to use this method for large geographical areas. When the lower edges of a bed reach into the subtidal, the mapping can be completed by a diver or snorkeler with a GPS (Hodgson & Spooner, 2016).

SCUBA and Snorkel

Mapping and monitoring of subtidal eelgrass beds in the region has been carried out by SCUBA (Figure 2.5) (Beaty & Sanford, 2019; Bonar & Zamora, 2024) and snorkel surveys (Underhill, 2025; Zielinski et al., 2024). Both of these methods, while producing accurate maps of eelgrass presence (linear) or spatial extent (polygons), are practical for small areas only and require a lot of time and human resources. Safety issues are also a concern (Nelson, 2018). The hiring of certified commercial divers can be prohibitive for community groups.

Figure 2.5 Diver surveying an eelgrass bed. Credit: Rebecca Benjamin-Carey

Freediver mapping eelgrass in Gulf Islands with kayak and GPS support. Credit: Kate Kushneryk

Eelgrass Mapping and Monitoring by Freediving

The Mayne Island Conservancy Society has been mapping and monitoring eelgrass extent by freedivers and kayakers at SḴȾAḴ | Mayne Island since 2009 (Underhill, 2024, 2025). Additional surveys were conducted at 20 select sites around the shores of Valdes, Galiano, Parker, Samuel, Saturna, and S'DÁYES |North Pender Islands during 2019 and 2020. The purpose of the project is to create baseline maps of eelgrass extent surrounding some of the largest eelgrass beds in the Southern Gulf Islands, and to monitor changes over time.

A visual summary showing changes in eelgrass extent over time between 2009 and 2024 for the 16 sites where data is available for at least two years is published in Underhill 2025 and updated annually. The geospatial data for all sites and years is publicly available on the PSF Marine Data Centre, or by request from the Mayne Island Conservancy (biologist@mayneconservancy.ca).

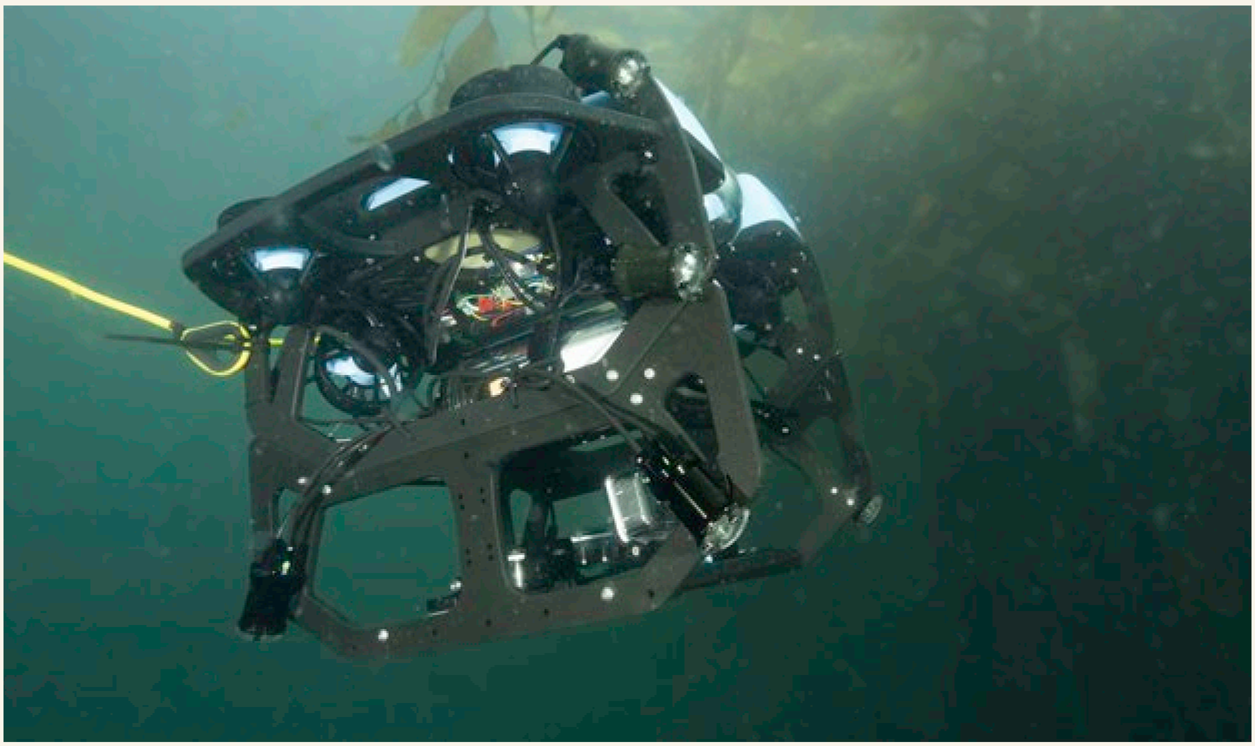
Towed Underwater Camera

The most commonly used cost-effective method for direct mapping is by the use of an underwater camera towed by a boat or fixed to bottom of the hull (Beaty & Sanford, 2019; Christiaen et al., 2022; SeaChange Marine Conservation Society, 2020; Wright et al., 2014). A towed underwater camera is often used to ground-truth data collected by more coarse remote sensing methods (Reshitnyk et al., 2014; Reshitnyk, 2017a,b). A Parks Canada study recommends a towed underwater camera be used to ground-truth new sites, beds with a deeper subtidal edge that can be detected by remote sensing methods, or where algae is present (Reshitnyk, 2017a). This method allows for accurate video recording of the presence/absence or spatial extent of an eelgrass bed (Reshitnyk, 2017a; Wright et al., 2014). Detailed habitat characteristics such as percent cover, substrate, form, and whether the bed is patchy or continuous can also be easily recorded. Towed underwater cameras have been used by the Washington State Submerged Vegetation Mapping Program (SMVP) since 2000 to repeatedly map all of the eelgrass beds in the US Salish Sea, where aerial imagery is unable to detect the deep edge of the bed (Christiaen et al., 2022; Dowty, 2023). The SMVP has been running long enough to determine reliable trends.

It is possible to map eelgrass polygons with a towed underwater camera (Dowty et al., 2022), however it is a time-consuming process to survey large geographical areas by boat and difficult to spatially map fringing eelgrass and small patches (Wright et al., 2014). Turbidity can be a limitation to the quality of the video. Weather, tides and currents, and other boat and swimmer traffic can be limitations for safe boat operation. It is not always possible to distinguish eelgrass from other submerged vegetation (Nelson, 2018).

Underwater Remote Operated Vehicle

The use of an underwater remote operated vehicle (ROV) to video survey and map eelgrass is not yet common in the region (Baum & Csordas, 2023) but has the potential to be fast, efficient, and relatively inexpensive, able to survey large areas rapidly and at a range of depths, and with greater manoeuverability and flexibility than a towed underwater camera (Raoult et al., 2025). The ROV, which is 'flown' underwater from a boat under the control of a pilot, can operate independently or be tethered to the boat. It has several advantages including the ability to collect environmental data via optional sensors. The processing of the video data can be time-consuming and requires a trained technician (Baum & Csordas, 2023), although machine learning can speed up the process (Raoult et al., 2025).



A tethered ROV surveying nearshore habitat. Credit Fernando Lessa

BC Parks Mapping with an Underwater Remote Operated Vehicle (ROV)

During the summers of 2022-2024, as part of BC Parks Living Lab and License Plate Programs, researchers from the University of Victoria, working with many First Nations, used an underwater remote operated vehicle (ROV) to video survey and map eelgrass and kelp occurrence in and around 39 BC Parks in the Salish Sea and WCVI region (Baum & Csordas, 2023; M. Csordas, personal communication, 2026). The purposes of the survey were to provide BC Parks with the information needed to evaluate how well they are currently protecting eelgrass and kelp habitat, to assess priority areas for enhanced protection, and to identify key coastal areas for protected area expansion or for the creation of new parks to help meet the Canada 30x30 goal. In addition, an assessment is underway on the blue carbon stores in eelgrass and kelp within BC Park boundaries to determine the potential contribution of the park system to the coastal carbon sink, and to determine where eelgrass restoration will be most effective to further this potential. This project is being done as part of the Blue Carbon Canada (https://www.bluecarboncanada.ca/) initiative, with mapping and blue carbon stores assessments eventually covering the entire BC coast.

INDIRECT MAPPING

Indirect remote sensing methods such as aerial and satellite imagery make possible the mapping of eelgrass over large geographical areas or for remote coastal locations that are difficult to reach by boat (Clyne et al., 2021; Nelson, 2018). Mapping using remote sensing is usually funded by government agencies and carried out by university researchers and consulting companies, as it is generally costly, requiring an aircraft or purchase of expensive satellite imagery, and expertise for interpretation.

Aerial Photography

Remote sensing using aerial photography taken from an aircraft has been used to map the entire coastline of British Columbia, including eelgrass (e.g. ShoreZone). These maps are often used as a coarse filter to determine where to target local field surveys (Bonar & Zamora, 2024; Wright et al., 2014). Hand-digitized aerial images and false colour aerial imagery (production of coloured biobands) (Davenport et al., 2017) have been shown to clearly delineate eelgrass, but data collection must be standardized for tides and include only exposed eelgrass to ensure accuracy.

Satellite Imagery

The employment of satellite technology for eelgrass mapping and monitoring in recent years has emerged as an alternative to time-consuming aerial or field surveys (Hogrefe et al., 2014; O'Neill & Costa, 2013). A Parks Canada study in Gwaii Haanas National Marine Conservation Area concluded that satellite imagery (WorldView-21) produced accurate maps for nearshore habitats shallower than 3 m where the imagery could distinguish eelgrass from other submerged vegetation (Reshitnyk et al., 2014). Depending on the system used, spatial resolution can be insufficient to detect small fringing and patchy eelgrass, can miss the submerged outer edge of a bed, may have depth inaccuracies in eelgrass coverage, can misidentify algae as eelgrass, and cannot distinguish between eelgrass species (O'Neill & Costa, 2013; Reshitnyk et al., 2014; Short et al., 2016; Nelson, 2018). As a result, ground-truthing is required to confirm eelgrass presence.

Data from some satellite sensing systems such as Landsat-8 are free for download, which can make satellite sensing more affordable, but the resolution is usually coarse (15-30 m), so less accurate for patchy and small eelgrass beds, where the water is turbid, or where other submerged vegetation dominates (Clyne et al., 2021). High resolution satellite systems that can sense to a resolution of 10 m or finer overcome some of these limitations, but data acquisition can be prohibitively costly, especially for community groups (Clyne et al., 2021; Hodgson & Spooner, 2016).

Sonar

Sonar[24] technology, which senses **hydroacoustics**,[25] has been used for mapping both intertidal and subtidal eelgrass extent (e.g. Reshitnyk et al., 2014; Ridder, 2018; Pickard et al., 2015, and references within). Side-scan sonar provides higher resolution than single- or multi-beam sonar. Side-scan sonar is better than aerial photography for detecting the deeper edge of an eelgrass bed and at differentiating eelgrass from other submerged vegetation (Sherman & DeBruyckere, 2018). It has been shown to be more accurate for subtidal mapping (deeper than 3 m) than satellite imagery but requires more field time because it is deployed from a boat (Reshitnyk et al., 2014). Sonar is not limited by water quality, so is a useful alternative to underwater video when turbidity impairs video quality (Reshitnyk et al., 2014; Nelson, 2018). Sonar has been shown to be as accurate as underwater video for detecting eelgrass, but the data processing can be costly and requires more expertise for image interpretation (Ridder, 2018). Sonar images may be limited by wave action and inaccuracies can occur for canopy height, in shallow water, on steep slopes, and where eelgrass is low density and patchy (Ridder, 2018; Nelson, 2018). Data processing can create artifacts that result in false impressions (Ridder, 2018).

24. method or device for detecting and locating objects especially underwater by means of sound waves sent out to be reflected by the objects
25. propagation of sound in water

Unmanned Aerial Systems (Drones)

The recent emergence on the market of relatively low cost, portable, low altitude, unmanned aerial systems (UASs), also known as unmanned aerial vehicles (UAVs) or remotely piloted aerial systems (RPAS), and commonly referred to as drones, has made affordable, efficient and accurate high resolution mapping for nearshore areas less than 100 hectares or even greater in size, possible for NGOs, First Nations, and community-based groups (Figure 2.6) (Barrell & Grant, 2015; Berry & Cowdrey, 2021; Nahirnick, Reshitnyk et al., 2019; Nahirnick, Hunter et al., 2019; Nahirnick, Costa et al., 2020; Proudfoot et al., 2023). UAS mapping of eelgrass in the region has been conducted by Parks Canada in the Pacific Rim National Park Reserve (Reshitnyk, 2017a, 2018a) and the Gulf Islands National Park Reserve (Reshitnyk et al., 2024).

UASs have a number of advantages over other remote sensing methods. The cost of equipment is relatively and increasingly affordable (Berry & Cowdrey, 2021; Nahirnick, Reshitnyk et al., 2019; Nahirnick, Hunter et al., 2019) and training for novice UAV operators makes the technology accessible to community -based organizations and citizen scientists (Yang et al., 2020). The imagery resolution produced by UASs can be higher (<10 m) than satellite or aerial imagery, can detect fine landscape features such as patches, and can produce high confidence subtidal images (Barrell & Grant, 2015; Nahirnick, Reshitnyk et al., 2019). Time of use is flexible allowing data collection to be carried out when conditions are most suitable and/or convenient (Nahirnick, Reshitnyk et al., 2019; Nahirnick, Hunter et al., 2019; Reshitnyk 2017a,b, 2018a,b; Reshitnyk et al., 2024). Images can be processed quickly (Kelly et al., 2019) and collection by UAS is easily repeatable, making it useful for long-term monitoring (Nahirnick, Reshitnyk et al., 2019; Nahirnick, Hunter et al., 2019; Reshitnyk, 2017a; Yang et al., 2020). Reshitnyk (2017a) and Reshitnyk et al. (2024) recommend UAS surveys be repeated every 2-3 years to detect changes in bed extent. Drones have been used in other regions to detect and monitor eelgrass wasting disease (Graham, Harvell et al., 2024; Yang et al., 2023; see Chapter 3), track interspecies distribution in a nearshore seascape (Barrell & Grant, 2015), and detect anchor scouring in eelgrass beds (Kelly et al., 2019).

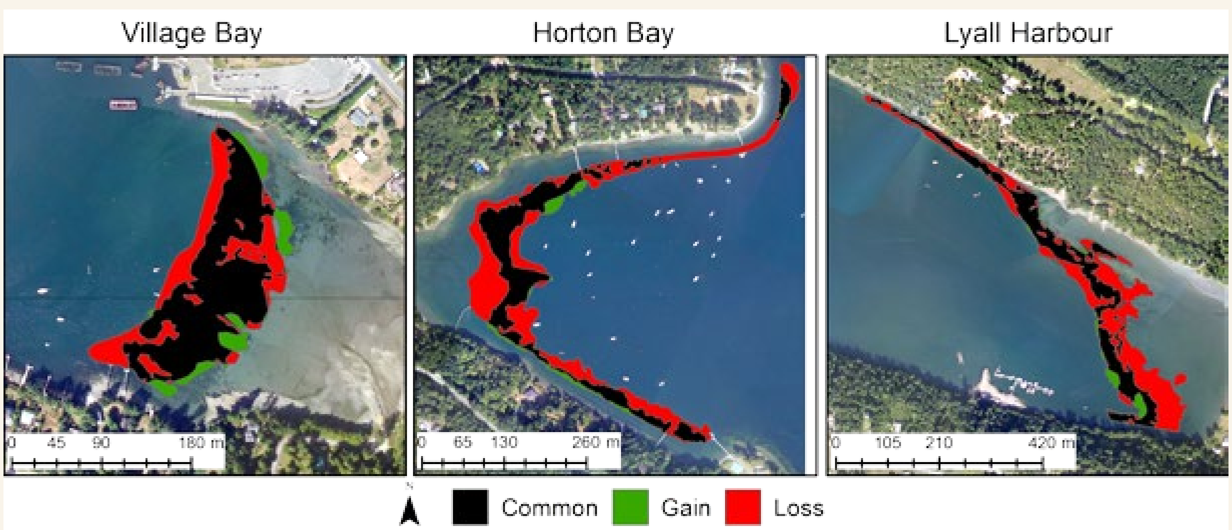
Unsuitable weather conditions and poor water clarity can be limitations to the collection of usable data (Nahirnick, Reshitnyk et al., 2019; Nahirnick, Hunter et al., 2019; Proudfoot et al., 2023; Reshitnyk, 2017a,b; Reshitnyk et al., 2024). The imagery may not be able to detect the subtidal edge of a bed if the water clarity is poor, requiring ground-truthing (Reshitnyk, 2017a). Nahirnick, Reshitnyk et al. (2019) recommends UAS use, for highest confidence in the result, when the sun angle is below 40 degrees, water clarity is greater than <5 m (measured by Secchi disc), cloud cover is 90 per cent, and wind speeds are below 5 km/hr, although results can be sufficiently good when conditions vary from optimal. UAS accuracy is particularly high for dense, continuous eelgrass beds, and where algae is not present.

Figure 2.6 Researcher Luba Reshitnyk from the Hakai Institute uses a drone to map eelgrass habitat.
Credit: Keith Holmes

WHAT TRENDS ARE MAPPING AND MONITORING REVEALING

Murphy et al. (2021) reports 61 trend estimates for eelgrass habitat in Pacific Canada, with 93 per cent showing stable, restored or increasing trends. However, in the Salish Sea and WCVI region, little if any monitoring data sufficient to determine reliable trends in eelgrass extent is available (Dunster, 2003; this report). The lack of spatial data (polygons) for many areas, lack of consistency in mapping methodology, and lack of adequate funding for long-term monitoring have been barriers to date. Note that this section includes mapping and monitoring for extent only. Mapping and monitoring for eelgrass health parameters is thoroughly described in the companion document Eelgrass Mapping and Monitoring Practitioners' Handbook (Durance & Wright, 2026).

For comparison, globally, monitoring of seagrass meadows (all species) has shown a 19 per cent decline in total area since the 1880s (Dunic et al., 2021). The few studies in the Salish Sea comparing historical aerial photos and recent mapping suggest declines in eelgrass extent between 21 per cent (1945-2018) (Nahirnick, Clark et al., 2020) and 45 per cent (1935-2016) (Nahirnick, Costa et al., 2020). On the American side of the Salish Sea, where standardized annual monitoring was initiated in 2000, the majority of eelgrass beds appear to be stable, however the San Juan Islands region, which is contiguous with the Canadian Gulf Islands, has been described as a region of greatest concern, where more sites are showing declines in eelgrass area than sites showing increases (Christiaen et al., 2022). Some bays are showing losses ranging from 50 per cent to total loss.



Eelgrass loss at three Gulf Island sites between 1932 and 2016. Credit: Natasha Nahirnick

Revealing Trends in the Gulf Islands Comparing Historical and Drone Aerial Imagery

Drones have proven useful in determining trends in eelgrass extent at three small estuaries in the Salish Sea Gulf Islands (Nahirnick et al., 2020). A comparison of historical aerial photos from 1932 to 2010 and 2016 video footage taken with a drone (also known as remotely piloted aerial systems RPAS or unoccupied aerial system — UAS) at Village Bay and Horton Bay on Mayne Island and Lyall Harbour on Saturna Island revealed an average 45.1 per cent loss of eelgrass area coverage of all three sites. A 66.3 per cent increase in meadow fragmentation was also observed. The changes are suspected to be the result of a marked increase in residential housing along the waterfront, dock construction, and an increase in boating activities over the 84 years of the study period. The impacts of the construction of a ferry terminal and a boat launch, and a dramatic increase in boating traffic at Village Bay, Mayne Island are suspected to have contributed to eelgrass loss and fragmentation in the bay. The impacts from increased boating traffic and dock installation are evident in Horton Bay.

To begin to remedy the critical gap in trend data for the Salish Sea and the WCVI region, the recent regional (IT and ShoreZone) mapping and local efforts by community groups, First Nations, and conservation organizations to produce comprehensive maps of eelgrass beds have advanced the goal of establishing baselines from which to monitor restoration and measure change. Many gaps still exist, and there is a lack of longer-term monitoring data using standardized protocols repeated for more than a year or two. Caution must be taken in using short-term monitoring data to determine trends because eelgrass beds are dynamic ecosystems and can shift naturally in size and location, sometimes over long periods of time and over substantial distance, with patches coming and going (Munsch et al., 2023). Recommended monitoring intervals to determine contraction or expansion of eelgrass beds vary depending on the stability of the eelgrass habitat 🗺. More frequent monitoring using affordable methods can be more useful than occasional complex and costly ones (Gilkerson & Merkel, 2014).

With this knowledge in mind, mapping and monitoring of eelgrass sites over more than one year have been conducted at several locations (Table 2.6), with few able to show a trend. One example of an increasing trend is the eelgrass habitat adjacent to the city of Nanaimo, which has increased dramatically over the last few decades. The removal of industrial sites, shoreline restoration, and eelgrass transplant projects facilitated the increase (Cynthia Durance, personal communication, 2025).

Table 2.6 Some locations with multi-year eelgrass extent mapping and monitoring.
Note: for trends ↑=increasing, ↓=decreasing, U=undetermined.

Location	Agency	Method	Years	Trend ↑↓U	Reference
Salish Sea: Roberts Bank	Vancouver Port Authority	Annual Orthophoto interpretation, ground truthing	2006 - 2014	↑	C. Durance, personal communication
Salish Sea: Nanaimo River Estuary	DFO/ Aquaparian/ Nanaimo Port Authority/ MoTI	Aerial digital photographic survey & boat, kayaks, and scuba surveys	Historical photos compared to 2015 and 2020	↑	Bonar and Zamora, 2024
Salish Sea: Gulf Islands	Mayne Island Conservancy	Snorkel and kayak	2009-2024	↓	Underhill, 2025
Salish Sea: Mayne Island and Saturna	Nahirnick graduate work/ PS Salish Sea Marine Survival Project	Historical and aerial photos compared to ground-based mapping by kayak and diver	1935-2016	↓	Nahirnick et al., 2020
WCVI: Pacific Rim and Gulf Island NPR	Parks Canada	Towed underwater camera/ drone	2010-present; Drone – 2017, 2018	U	Reshitnyk, 2017a,b; 2018 a,b; 2024
Salish Sea: Rebecca Spit Marine Provincial Park, Quadra Island	BC Parks, Project Watershed, Ecofish	Towed underwater camera	Historic aerial photos 1945-1996 compared with 2018 aerial photos, 2019 uw camera	↓	Nahirnick, Clark, et al., 2020
Salish Sea: Cortes Island	BC Parks, Project Watershed, Ecofish	Satellite imagery and air photos in reference to 2023 ShoreZone photo and video data	1995/2001 compared with 2023	U	Baker-French et al., 2024

HABITAT SUITABILITY MAPPING

Habitat Suitability Mapping (HSM) is a site-selection modelling technique first developed in the northeastern United States to determine where eelgrass restoration might be most successful (Short et al., 2002; Thom et al., 2014, 2018). HSM gathers site data from literature, reference data, and field studies on the conditions required for eelgrass to be healthy (e.g. substrate, wave exposure, water depth, water quality, etc.), and combines it with information on the presence of stressors and limitations (e.g. docks, upland development, pollution, presence of hydrogen sulphide, etc.) into a single map. Theoretically, HSM can identify areas suitable for eelgrass even if eelgrass is not currently present and may never have been present. It can also be used to evaluate areas where eelgrass has disappeared to determine if reintroduction has a chance of success.

Habitat Suitability Mapping to predict where eelgrass restoration will likely succeed has been developed for other jurisdictions (e.g. Denmark, Flindt et al., 2016), including Puget Sound in the US Salish Sea (Borde et al., 2014; Thom et al., 2014, 2018). PSF, in colaborations with M.C. Wright and Associates Ltd., is currently developing a Habitat Suitability Map for select estuaries in the Salish Sea, adapted from the methods used for a Habitat Suitability Model developed for the Cowichan Bay Estuary (Figure 2.7). The use of a site-selection model to both identify suitable habitat and remove stressors has shown promise to increase restoration success in some places (Short et al., 2002).

Credit: Rebecca Benjamin-Carey

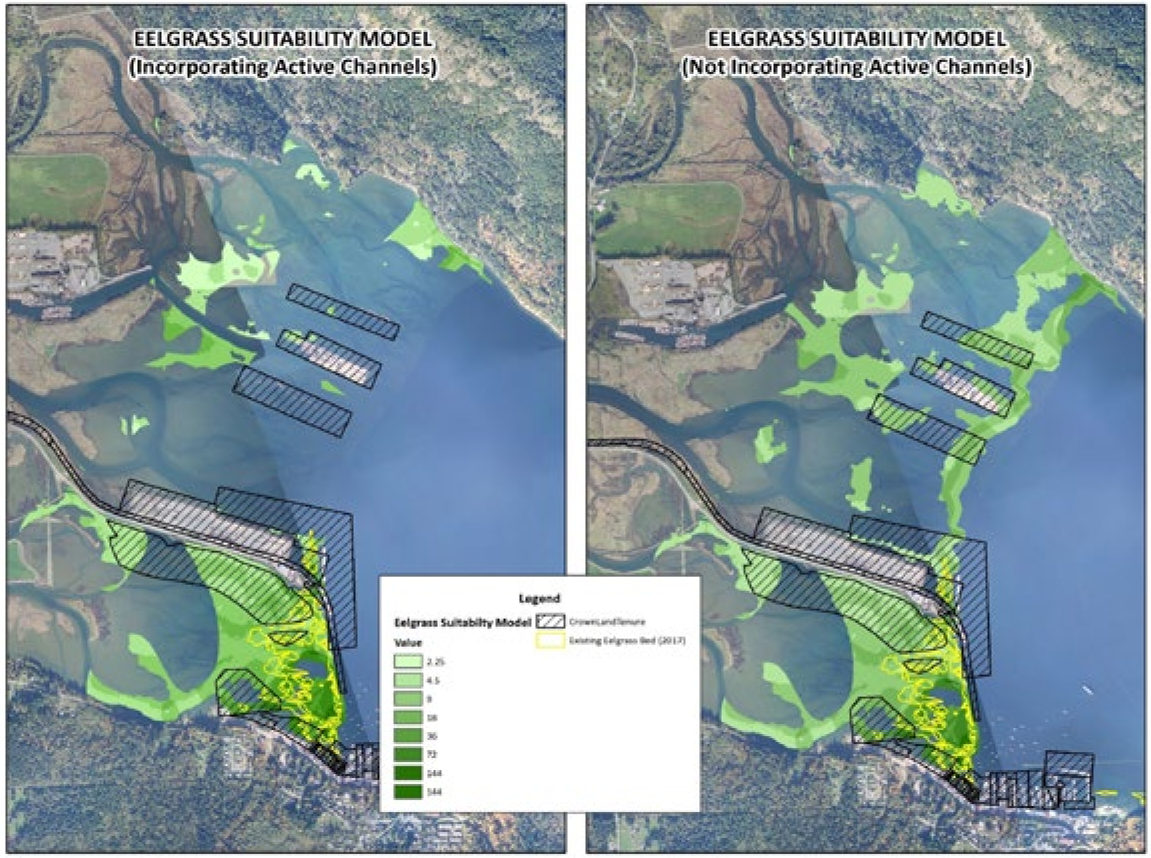


Figure 2.7 Habitat Suitability Model for the Cowichan River Estuary in the Salish Sea.
Credit: Miranda Smith, M. C. Wright and Associates Ltd.

Habitat Suitability Modelling in Cowichan Bay

Recent habitat modelling in the Cowichan estuary, on behalf of Cowichan Tribes, was used to generate a suitability model for potential eelgrass transplants in the estuary based on known environmental requirements. Key parameters considered in the model included sediment grain size, wave exposure, water depth, water quality (temperature, pH, salinity, and dissolved oxygen), current velocity, hydrogen sulphide, bed mobility, proximity to active channels, and Crown land tenures. The final suitability model identified areas within the estuary with the highest likelihood of transplant success and was used to inform future eelgrass transplant initiatives (Smith, 2024).

CHAPTER TWO LESSONS LEARNED

- ✓ *Zostera marina* forms linear fringing beds along coastal shorelines, larger flat meadows in sheltered bays and estuaries, and narrow beds in tidal channels.
- ✓ Most of the *Z. marina* in the region is subtidal but extensive intertidal meadows grow in the Fraser River Estuary and Boundary Bay area on the lower mainland.
- ✓ *Z. marina* requires specific environmental conditions for optimal growth.
- ✓ Most of the shoreline in the Salish Sea and WCVI region has been mapped for eelgrass extent (mostly linear mapping but some polygon mapping) by various coarse and fine scale methods, each with advantages and disadvantages.
- ✓ Long-term monitoring of eelgrass extent is lacking in the region to reliably detect changes in extent.
- ✓ Habitat Suitability Maps are being developed for the region to help pinpoint suitable sites for eelgrass restoration.

Next Chapter: Anthropological and Biological Stressors: from Watershed Sources to Climate Changes

CHAPTER THREE
ANTHROPOGENIC AND BIOLOGICAL STRESSORS: FROM WATERSHED SOURCES TO CLIMATE CHANGES

Explore Seafloor-friendly Moorings.
Restoring Our Eelgrass
(11:48 min) Credit: Bob Turner

INTRODUCTION

Eelgrass in the Salish Sea and WCVI region faces a variety of stressors. These include anything that alters the factors that control eelgrass growth and health, such as light and temperature, or that directly damages plants, for example by uprooting whole plants, consuming leaves, or causing disease. In 2011, Dr. Ron Thom and colleagues published a report identifying nineteen stressors impacting eelgrass in Puget Sound in the US Salish Sea (Thom et al., 2011), all of which are relevant to the Canadian Salish Sea and WCVI region (Figure 3.1). Since then, significant progress has been made towards better understanding these stressors and how they impact native eelgrass habitats, linking stressors to observed declines in eelgrass populations and predicting which stressors are expected to become worse with climate change.

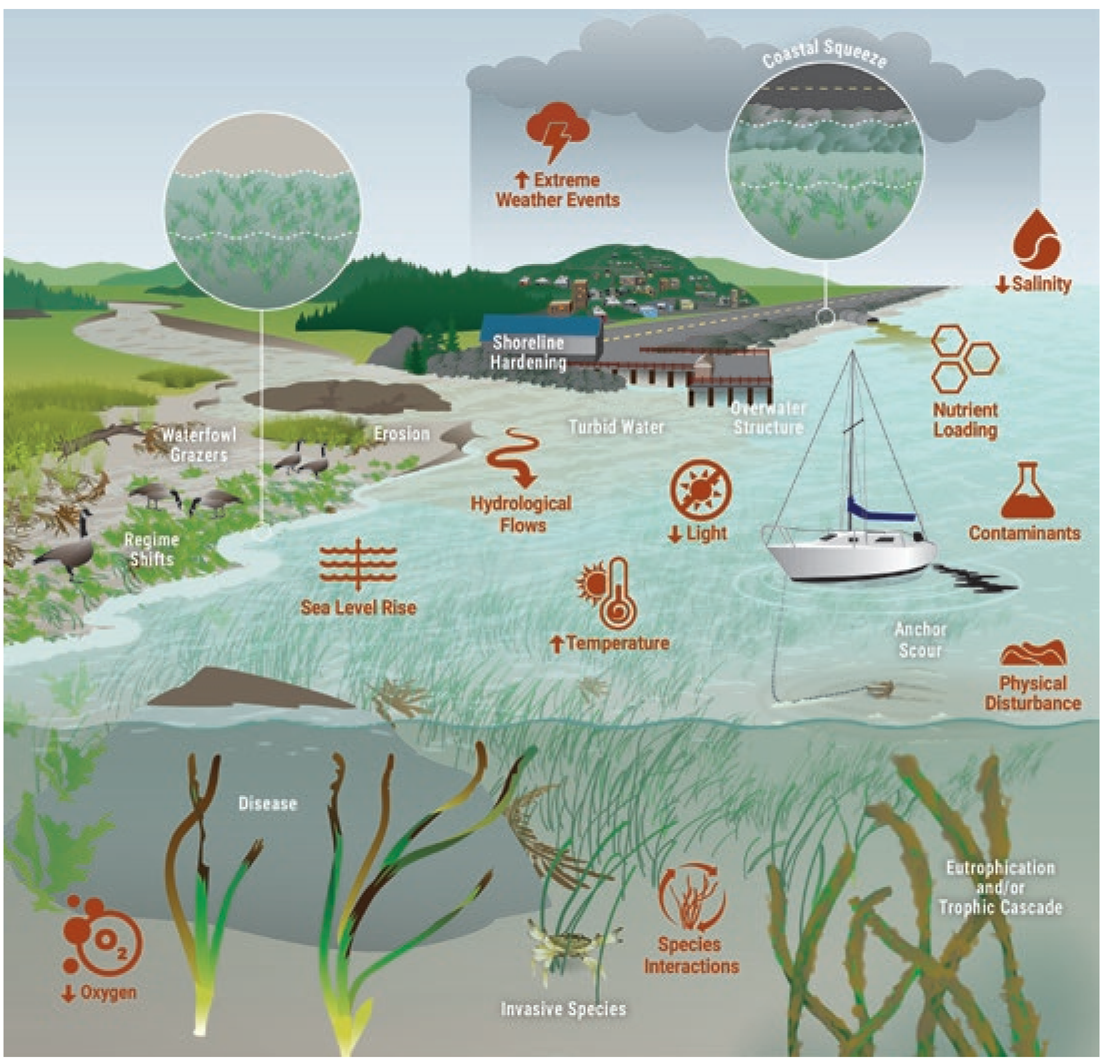


Figure 3.1 Eelgrass is impacted by multiple stressors and the effects accumulate over time.
Credit: Fisheries and Ocean Canada (2026)

This chapter provides an overview of new research, supported by select foundational literature, about stressors on native eelgrass habitats between 2014 and 2025, including anthropogenic stressors (overwater structures, boating, the logging industry, construction, overfishing, aquaculture, and contaminants); biological stressors (wasting disease and invasive species); and stressors associated with climate change (sea temperature rise, sea level rise, changes to fresh water inputs with increased precipitation and ice melt, and hypoxia).

Stressor research is fundamental to eelgrass management and restoration. This knowledge will help practitioners focus efforts to manage stressors most efficiently and effectively, prioritising those that are having the greatest impact. For stressor research to be most useful to eelgrass management and restoration, it needs to be site specific. Scientists have emphasized that eelgrass ecotypes respond differently to stressors, and that each location has unique characteristics (geology, proximity to human population centres, etc.) that determine what stressors are present and which are most impactful to eelgrass (Breiter et al., 2024; Nagel et al., 2021; Thom, Southard & Borde, 2014). For example, the response of *Z. marina* in Puget Sound to stressors like sea temperature rise varies widely depending on ecotype (Breiter et al., 2024), and Thom, Southard, and Borde (2014) showed that eelgrass in embayments may be most at risk as temperatures warm. Site specific research can also highlight which populations are most resilient to stressors and changing conditions and therefore may be the best candidates for protection (Chapter 5) (Graham et al., 2023; Graham, Harvell et al., 2024). Unfortunately, the majority of research on eelgrass ecotypes and stressors in the Salish Sea over the last decade has been on U.S. Salish Sea eelgrass. BC eelgrass remains under-studied. While these populations are likely similar, improving our understanding of eelgrass ecotypes across the entire Salish Sea and WCVI region will allow us to better target stressor management and improve restoration efforts.

Credit: Rebecca Benjamin-Carey

ANTHROPOGENIC STRESSORS

COASTAL DEVELOPMENT

Overwater Structures

Overwater structures, particularly docks, have long been known to negatively impact eelgrass, which grows primarily in the shallow subtidal zone where docks are constructed (Rehr et al., 2014; Cynthia Durance, personal communication, 2025). Docks cause stress to eelgrass chiefly by limiting the light that can reach plants growing underneath or nearby (Figure 3.2) (O'Regan et al., 2018, and references within; Simensted et al., 1998; Thom et al., 2011; Wright, n.d.). Plants can also be damaged or stressed by the installation of pilings or dredging during dock construction, or by associated boating activities.

In 2018, M.C. Wright and Associates Ltd. published the first field assessment on the impact of private docks on eelgrass in British Columbia (O'Regan et al., 2018). Their survey of sites at Pender Harbour, BC, found the complete loss of eelgrass below all but one newly constructed dock, where the eelgrass was in poor health, indicated by a low number of shoots. The docks impacted not only eelgrass growing directly underneath the dock, but also around the dock, with the median area of eelgrass loss to be 4.4 times larger than the area occupied by the structures. The orientation of the docks in Pender Harbor made no difference to eelgrass survival.

In 2025, DFO published a Code of Practice for the construction of docks, boathouses and moorings in BC (Fisheries and Oceans, 2025a). Previous guidelines recommended for BC coastal waters were designed for the southwest United States, and did not consider the fluctuations in daylight hours throughout the year in northern latitudes (O'Regan et al., 2018).

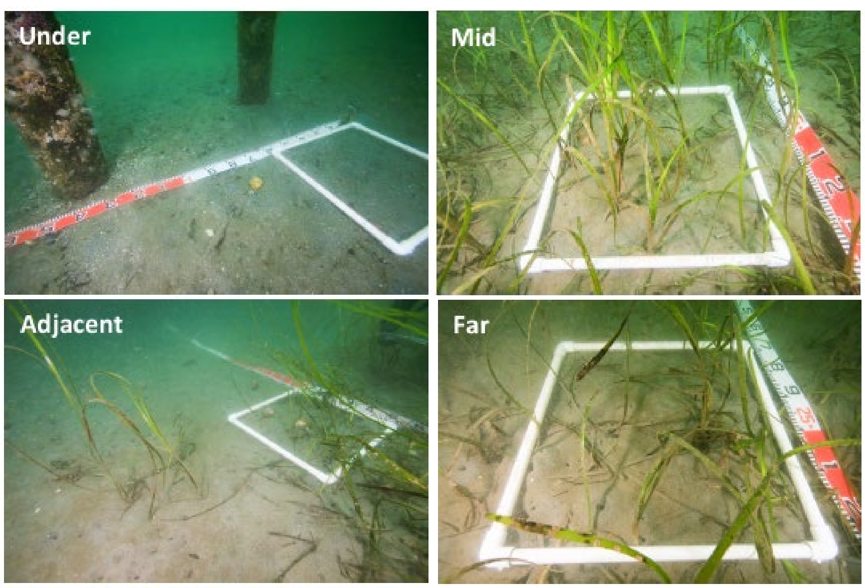


Figure 3.2 Effects of dock shading on eelgrass growth. No eelgrass grows under or adjacent to the dock owing to the lack of light.

Credit: M.C. Wright and Associates Ltd. Image extracted from O'Reagan et al. (2018)

Waterfront property in Salish Sea (A) before sea wall removal and (B) after Green Shores restoration.
Credit: Kelly Loch

Green Shores®: A Nature-based Framework for Alternatives to Shoreline Armouring

Shoreline armouring, such as a sea wall or rip rap, is used in an attempt to protect waterfront properties from erosion, an issue which will worsen with increased storm activity and sea level rise associated with climate change (Francis & Kinney, 2018). The documented ecological impacts of shoreline armouring structures are many because the adjacent shoreline profile becomes steepened and fine sediments are removed by increased wave energy. This leads to loss of forage fish spawning habitat; changes to invertebrate density and composition; reduced abundance of fish, including salmon; and herring egg mortality (Francis & Kinney, 2018 and references within). In relation to eelgrass ecosystems, armoured shorelines prevent the migration of eelgrass beds shoreward to maintain adequate light levels as sea levels rise. This trapping of submerged vegetation, such as eelgrass, against hard armouring as it tries to migrate shoreward is known as coastal squeeze (Figure 3.9) (PSF, 2022). This is also a problem for other organisms trying to adapt their habitat landward in response to sea level rise because the armour interrupts the ecosystem continuum from the marine up towards terrestrial areas. Overall wave energy is increased by five to ten times when it meets an armoured shore and waves reflected back onto the beach expose coarse sediment unsuitable for marine plants such as eelgrass (Dethier et al., 2016). It is important to note that armoured shorelines are also subject to erosion and scouring at the base of the armour can lead to catastrophic failure of the structure over time.

A 'soft shores' approach is a nature-based alternative to shoreline armouring that aims to minimize impacts from development and restore and maintain ecological shoreline functions by working with natural elements and ecological processes. Soft shore approaches use reprofiling of the shoreline, beach nourishment, large woody debris such as logs with root wad ends, and native vegetation plantings to create a shoreline that replicates natural features and has increased resilience to climate change impacts thus providing enhanced property protection (Francis & Kinney, 2018 and references within). As can be seen in the diagram, a soft shoreline benefits eelgrass by maintaining finer sediments by absorbing wave energy rather than deflecting it. This allows shoreward migration of eelgrass habitat as sea levels rise.

In BC, Green Shores (https://stewardshipcentrebc.ca/green-shores-home/) is an initiative of the Stewardship Centre for British Columbia to promote sustainable shoreline ecosystems for residential commercial, institutional and park properties in Canada and the United States. It is based on four key guiding principles and is supported with science-based best practices, training, and resources for residential landowners, Indigenous and non-Indigenous government land managers, and shoreline professionals to help minimize impacts from coastal development while restoring or maintaining ecological functions of shoreline ecosystems.

Boats and Boating

Boats and boating can harm eelgrass in a variety of ways. Permanent moorings with chains can scour the seafloor as the boat swings (Figure 3.3) and temporary anchoring can bend and break shoots and uproot rhizomes (Unsworth et al., 2017). The study of docks in Pender Harbour also noted that no eelgrass was present where boats were moored (O'Regan et al., 2018). Damage to eelgrass caused by moorings has been clearly documented in other regions (Unsworth et al., 2017; Kelly et al., 2019). Boat wake and propellors can uproot or damage plants and wash from propellers can suspend sediment, causing erosion that smothers eelgrass, limits light, and creates plumes of bubbles that also reduce light. Boats can be a source of anthropogenic contaminants, such as excess nutrients from sewage, and heavy metals (O'Reagan et al., 2018, and references within; Phillips, 1984; Simensted et al., 1998; Thom et al., 2011; Wright, n.d.).

Shoreline activity has been linked to the decline of eelgrass at three sites at Mayne Island and Saturna Island, BC. At these sites, an assessment of historical and UAV aerial photographs spanning 1932-2016 identified a correlation between the loss and fragmentation of eelgrass beds and the installation of docks and boat launches (Nahirnick, Costa et al., 2020). In the years following the construction of boat launches and docks, eelgrass declined along common pathways used by boaters to travel to and from these structures, which fragmented the eelgrass beds. In this case, shoreline activity impacted only intertidal eelgrass, with no significant loss of subtidal eelgrass detected from boat traffic. Loss of eelgrass in areas heavily used for recreational boat anchorages and a boat launch has also been documented by BC Parks at Rebecca Spit Marine Provincial Park (Nahirnick, Clark et al., 2020).

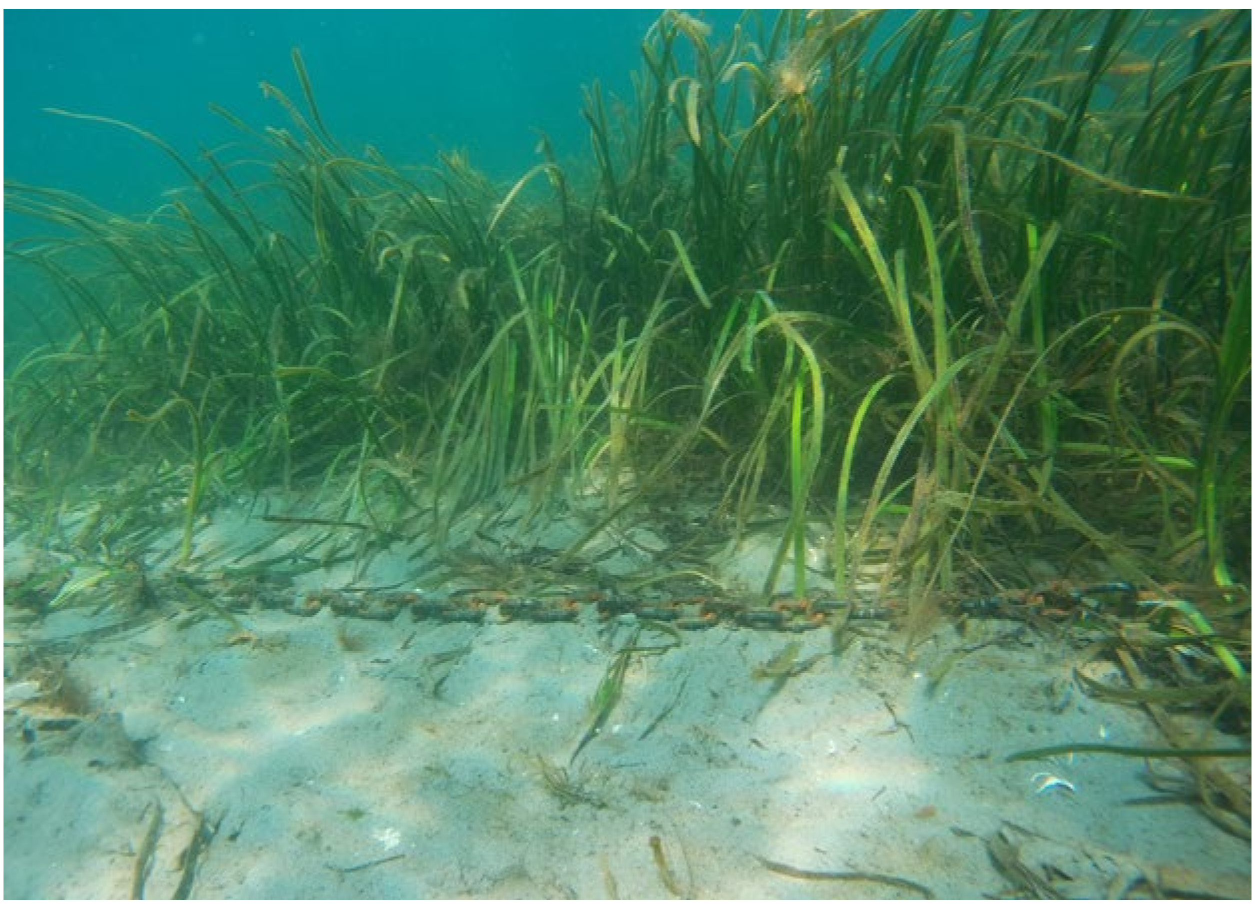


Figure 3.3 A single swinging boat anchor chain, like this one in Ford Cove, Hornby Island, has the potential to scour out a circular scar of 122 square metres of eelgrass.
Credit: Hornby Island Diving

Desolation Sound Marine Provincial Park is a popular destination for recreational boaters.
Credit: Ron Vandergaag

Mitigating Impacts of Anchorages in Desolation Sound

Desolation Sound Marine Provincial Park, located in the Salish Sea within the traditional territory of the Tla'amin and Klahoose First Nations, is a prime recreational destination with over 250,000 visitors a year, many of them boaters. Because of concerns about boating-related impacts to the Park's eelgrass beds, in 2023, BC Parks collaborated with the Department of Zoology at UBC to study ecosystem health at eelgrass locations with and without anchorages (Raymond et al., 2024). The study revealed a clear deterioration of eelgrass health, with lower biomass and shorter shoot length, at sites where anchoring was allowed. In addition, by employing a baited underwater video system, the study documented changes in fish diversity in eelgrass areas when boats were present, regardless of anchoring activity. As a result, BC Parks closed two anchorage sites in 2023 and is considering additional closures. A resurvey of eelgrass beds within the Park in 2024 showed some promising signs of eelgrass biomass recovery at the two closed sites. Continued monitoring is required for declines to be conclusive (Raymond et al., 2025).

Credit: Nicole Christiansen

Industry (Logging)

British Columbia's coastline has historically been the site of numerous industrial activities, but logging is perhaps the most studied activity in recent years in relation to eelgrass loss (Hessing-Lewis, 2005, and references within; Murphy et al., 2021, and references within). Stressors associated with the logging industry include shading and physical disturbance of eelgrass beds by log booms rafted in bays (Figure 3.4); increased sediment run-off caused by upstream deforestation, which limits light and smothers eelgrass; and the accumulation of woody-debris on seafloor sediments, which becomes anaerobic over time and produces hydrogen sulphide, a toxin to eelgrass (Hessing-Lewis, 2005; Thom et al., 2011; Murphy et al., 2021). The analysis of historic aerial photographs at Mayne Island and Saturna Island observed loss of eelgrass growing at the limit of its depth range (subtidal edge) in the twenty years following the near deforestation of the Gulf Islands, which took place between 1880 and 1930 (Nahirnick, Costa et al., 2020). The main driver of this loss was suspected to be high levels of silt in the water, a known consequence of inland deforestation, and which would limit the light reaching subtidal eelgrass. Increased rate of sedimentation can also inhibit or destroy eelgrass plants, if the rate of deposition exceeds the rate of growth at the **sheath**[26] (Figure 1.6), where the **meristomatic**[27] cells are located (Cynthia Durance, personal communication, 2025).

Research published in recent years has shown ongoing impacts of logging on eelgrass in the Salish Sea, even though logging has substantially decreased since the early 20th Century. An eelgrass survey completed in 2020 in the Nanaimo River Estuary found that eelgrass was absent around log booms and that the substrate surrounding these log booms was "comprised of thick, anoxic mud" (Bonar & Zamora, 2024). The failure of a 2007 eelgrass transplant experiment in the estuary was suspected to be due to sediment from the Nanaimo River and nearby log booms, which prevented eelgrass from establishing. A survey of eelgrass in the Cowichan River Estuary in 2022 found no eelgrass where log storage was concentrated (Douglas et al., 2022). A 2023 study mapping woody debris and vegetation cover at seven BC sites with a history of log booms observed no eelgrass growing in sediment with woody debris over 10 mg/g (Domarchuk-White et al., 2023). These findings all suggest that eelgrass is unable to grow where there are high concentrations of woody debris.

Figure 3.4 Log booms rafted in bays, like these in the Cowichan River Estuary, shade eelgrass beds, cause physical disturbance, and result in the accumulation of woody debris on seafloor sediment which produces hydrogen sulphide, a toxin to eelgrass. Credit: Jamie Smith, Coastal Photography Studio

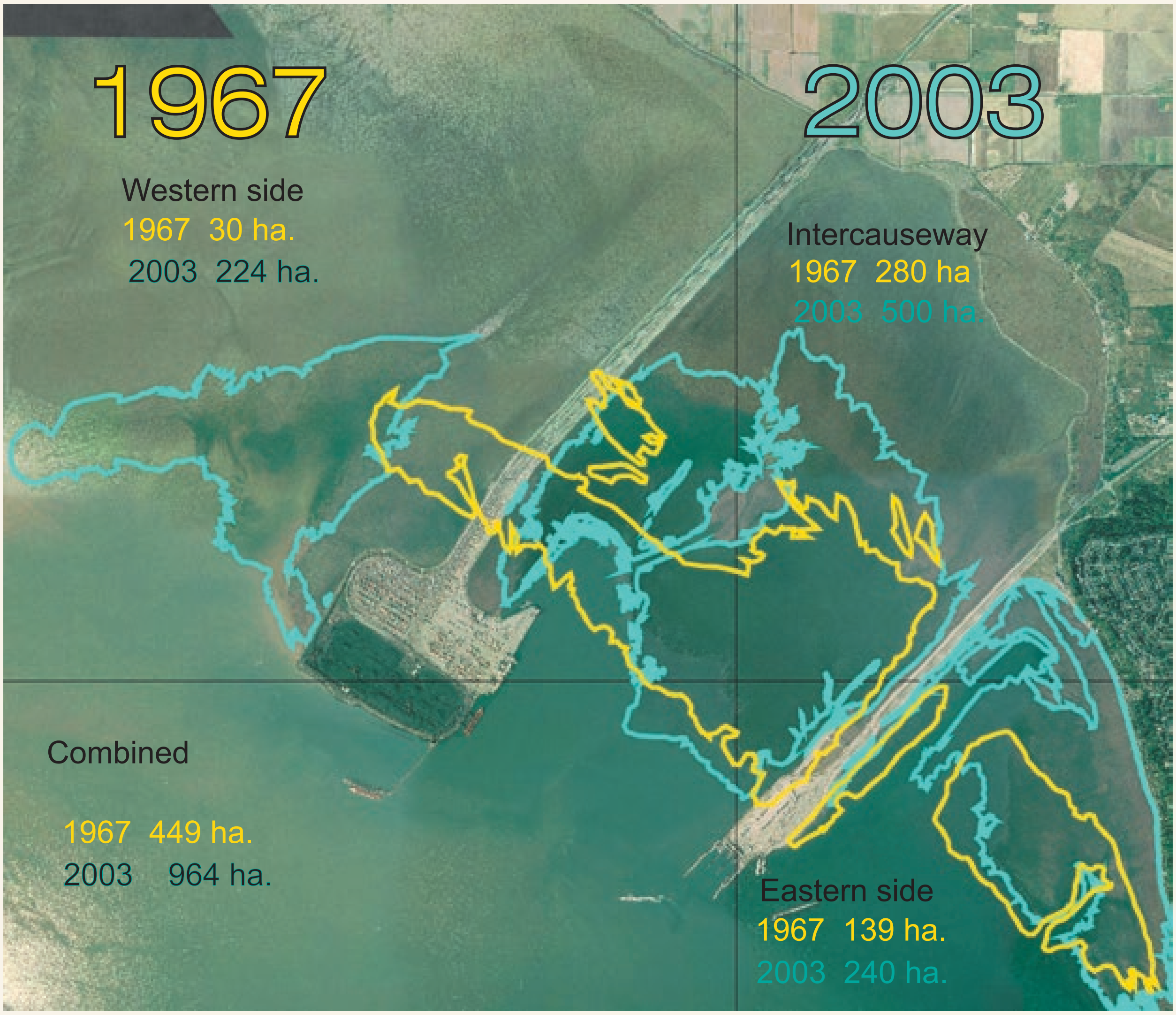
26. tubular structure at base of eelgrass leaves that protects them from strong currents
27. plant tissue where cell division and growth occurs

Construction, Channelization, and Diking

The construction of ferry terminals, industrial ports, docks, piers, or the laying of pipes and cables in or nearby eelgrass beds can be highly disruptive to eelgrass habitats (Simensted et al., 1998; Thom et al., 2011). Construction activities can destroy or uproot plants. The creation of channels and dikes in bays and estuaries can kill plants and cause increased sedimentation from erosion (Hessing-Lewis, 2005; Phillips, 1984; Rubin et al., 2018; Thom et al., 2011). The process to construct industrial facilities may involve other known stressors, such as boat traffic or the use of chemicals (see Boats; Anthropogenic Contaminants). Once a project is completed, stressors may continue to impact eelgrass beds, for example, ferry terminals will continue to have ferry traffic with regular turbulence from boat wash and structures will require ongoing maintenance (Simensted et al., 1998).

Building any new structure in the ocean — such as a port, pier, or dike — will alter a site's natural hydrology. These alterations can have complex effects on eelgrass, both positive and negative. For example, the construction of the Tsawwassen ferry terminal and the Westshore coal port at Roberts Bank, BC, in the 1960s, led to an increase in eelgrass extent in the area (Harrison & Dunn, 2004). Numerous studies of fish use of these eelgrass habitats near the Roberts Bank terminals between 1979 and 2013 documented 57 species of fish, including Chinook salmon, present as permanent or temporary residents (Archipelago Marine Research Ltd, 2014, and references within). Similarly, a 2018 study of the channelization and diking of the Skagit River Estuary in Puget Sound also documented both positive and negative effects on eelgrass (Rubin et al., 2018). Channelization altered hydrology in the estuary by focusing river discharge to one major outlet, which increased water velocity and sediment load to that one point, burying and damaging plants and fragmenting the beds. At the same time, some eelgrass beds in the estuary expanded in extent after the channelization and diking, because the alterations sheltered them from river discharge and sediment.


Credit: Jamie Smith, Coastal Photography



Changes in eelgrass extent over time after construction of Roberts Bank terminal in the Salish Sea.
Credit: Cynthia Durance

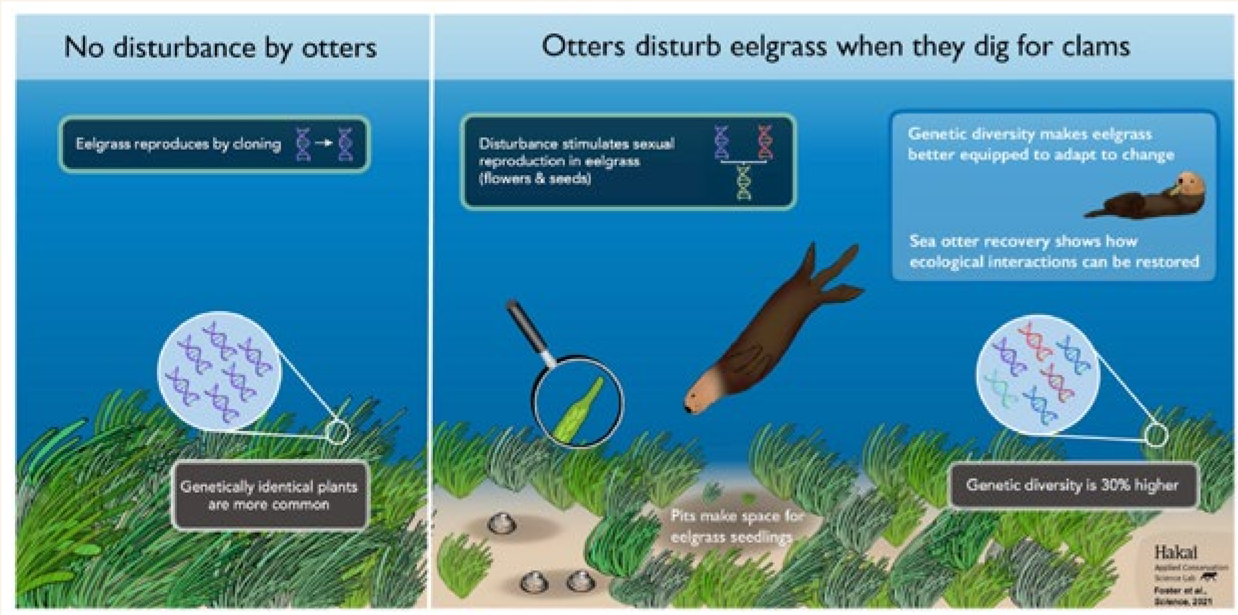
A Surprising Increase in Eelgrass Extent at Roberts Bank following Coastal Development
Contributed by Cynthia Durance

A coalport causeway was constructed parallel to the Tsawwassen ferry causeway in 1969. There were 449 hectares of eelgrass on the flats surrounding the ferry causeway at that time. The eelgrass meadow expanded to 964 hectares by 2003. It has remained relatively unchanged since that time. The increase is thought to be due to the hydrogeomorphic changes that resulted from construction of the second causeway and the introduction of *Z. japonica*. The second causeway deflects the sediment laden Fraser River plume, improving water quality between the causeways providing the eelgrass with more light. When *Zostera japonica* colonized the mid to high sandflats shoreward of the 1969 meadow, the baffling action of the dense *Z. japonica* shoots converted the sandflat to mudflat and ponded water during low tides. These changes enabled *Z. marina* to expand shoreward replacing the *Z. japonica*; *Z. japonica* can't compete with the larger, faster growing *Z. marina*.

Overfishing and Food Web Interruptions

Overfishing has long been suspected as a potential stressor to eelgrass because it can upset the balance of an ecosystem by altering food-web dynamics and reducing biodiversity (Thom et al., 2011). For example, disruptions to the food-web can lead to the loss of grazer species that perform an important ecosystem function by removing light-limiting algae from eelgrass blades (Iacarella et al., 2018, and references within; Thom et al., 2011). A field study at 15 sites spanning the geographic range of *Z. marina* (including one site in BC) found that grazers had more of an impact on algae growth than the addition of nutrients, an effect that increased with higher temperatures and diversity of grazer species (Duffy et al., 2015). The experimental addition of high levels of nutrients, which increased algal growth, also increased grazer numbers, which in turn controlled the algae growth. The results of this study suggest that preserving biodiversity and keeping food webs intact may be more important than management of human nutrient inputs and related eutrophication when tackling the problem of harmful algal blooms and epiphyte loads in eelgrass beds (see Anthropogenic Contaminants). Importantly, the study underlined the importance of classifying biodiversity as a controlling factor for the health of eelgrass ecosystems.

Credit: Rebecca Benjamin-Carey



Sea otter recovery and associated ecological disturbance is positively correlated with eelgrass genetic diversity. The conceptual diagram shows the demonstrated and hypothesized ecological pathways that support this correlation. Genetic diversity increases ecological resilience in eelgrass, making it more resilient to environmental change (Foster et al., 2021). Credit: Josh Silberg, Hakai Institute and Erin Foster Illustrations by Miguel Neves dos Reis

Species Interactions and Cascading Effects: Can Restoration of Sea Otters Increase Eelgrass Diversity?

From the mid-1700s to early in the 1900s, the maritime fur trade resulted in the extirpation of sea otters (*Enhydra lutris*) from the BC coast (COSEWIC, 2022). During the period 1969 to 1972, 89 otters were captured in Alaska and reintroduced to Checleset Bay on the west coast of Vancouver Island. The introductions have been successful and sea otter populations have expanded north and south.

While the role sea otters play in maintaining kelp forests is well known, the relationship between sea otters and eelgrass ecosystems has not been as well studied. Sea otters forage in eelgrass beds for sediment-dwelling prey such as clams and worms. The foraging can break eelgrass shoots, dig up rhizomes and leave pits and bare patches in the beds. A recent study tested the effects of sea otter foraging on eelgrass beds by comparing eelgrass shoot density and genetic diversity in areas along the BC coast where sea otters had been absent for more than 100 years, had arrived within the past 10 years, or had been present for decades (Foster et al., 2021). The results of the study showed that genetic diversity was greater in those eelgrass beds where sea otters have been present for decades. Eelgrass reproduction can occur sexually or clonally. When it occurs sexually, genetic diversity increases, whereas when it occurs clonally the genetic makeup stays the same. Researchers believe that sea otters digging in eelgrass meadows triggers a switch from clonal to sexual reproduction. The bare patches created by sea otter digging provides space for seeds to settle and grow resulting in greater genetic diversity in an eelgrass meadow than would be present in an undisturbed meadow dominated by clones. Greater genetic diversity enhances the ability of an ecosystem to adapt to change, and increases its resilience to perturbations.

Aquaculture

The extent to which bivalve aquaculture — predominantly oysters and clams — is a stressor to eelgrass in the Salish Sea and WCVI region is not clear. Some aquaculture practices are known to cause direct damage to eelgrass, such as the use of hydraulic dredging for harvesting or the power washing of nets, but less harmful methods can be used (Phillips, 1984; Thom et al., 2011). Recent research has investigated whether alternative methods of growing oysters can limit the shading and disturbance of eelgrass beds underneath or nearby an aquaculture site. A 2019 global meta-analysis determined that there were positive and negative impacts to eelgrass from both on-bottom and off-bottom oyster aquaculture methods (Ferriss et al., 2019). For example, on-bottom methods were linked to an increase in eelgrass growth and reproduction, but a decrease in density and biomass. Off-bottom methods were accompanied by a decrease in eelgrass density, cover and reproduction; had no impact on biomass and growth; and were found to improve the environment for eelgrass by stabilizing sediment and reducing wave impacts. The impact of aquaculture on eelgrass was shown to depend on the unique situation in each region, for example, where eelgrass grows in relation to an aquaculture site, the methods used — whether the oysters are grown in suspended cages or on the substrate — and if there are other stressors present that may limit eelgrass resilience (Ferriss et al., 2019). While research prior to 2014 has linked oyster aquaculture methods to poor eelgrass health (Kelly & Volpe, 2007), there is a dearth of research since then linking oyster aquaculture and eelgrass health in the Salish Sea and WCVI region (Cynthia Durance, personal communication, 2025). One area where there has been new research is the relationship between aquaculture and greater disease prevalence in eelgrass, but field experiments have so far not shown a clear link (Agnew et al., 2022; see Wasting Disease; Biological Stressors).

Credit: Greenways Land Trust

CONTAMINANTS

Eelgrass beds are exposed to many different contaminants from human activities, such as sewage discharge, oil spills, heavy metals from industry, and fertilizers and pesticides used for agriculture. Past research has found eelgrass to be remarkably resilient to a variety of contaminants, such as oil and some heavy metals (Phillips, 1984, and references within). Recent studies have added to our knowledge of which anthropogenic contaminants are present in eelgrass meadows in the Salish Sea and WCVI region and potential sources of contamination, but there remain many uncertainties as to how contaminants affect eelgrass.

Nutrient Loading

Nitrogen, phosphorus, and other nutrients that stimulate plant growth, when present in the water column in excess (from contaminated rivers, shoreline runoff, and boat discharges) are known to cause eutrophication. The result is poor water quality, harmful algae blooms, and high epiphyte loads, all of which can block light to eelgrass (Levings & Thom, 1994; Short, 2014, and references within; Thom et al., 2011). Eutrophication has also been linked to **hypoxia**[28]. Compared to other areas, nutrient loading is commonly considered less of an issue in the Salish Sea because the waters are naturally high in nitrogen due to upwelling of nutrient-rich water from the depths of the Pacific Ocean (Murphy et al., 2021; Rehr et al., 2014; Short, 2014). Eelgrass in the region has therefore adapted to survive in a high nitrogen environment, as long as the water is clear and well circulated (Murphy et al., 2021; Nagel et al., 2021; Short, 2014).

However, evidence is growing that the nitrogen balance in the Salish Sea is being disrupted by an increase in inputs from human sources. For example, monitoring in Washington State between 1999 and 2012 showed that nitrogen concentrations have significantly risen, resulting in impacts to eelgrass beds, including reduced water clarity, phytoplankton blooms, and excess seaweed and epiphyte growth (Short, 2014). In the first Puget Sound-wide assessment of contaminants in eelgrass, a high level of nitrogen in the environment was noted, with suggestions that any further increases would stress eelgrass (Gaeckle, 2016a). Nitrogen in sewage and wastewater enters the ocean primarily via outfalls (Gaeckle, 2016b). A decline of eelgrass was observed at the deep edge of a bed at the location of a new outfall in Puget Sound (Gaeckle 2016b). While poor water quality caused by the outfall was suspected as the reason, complex variables like tidal circulation and hydrodynamics make this conclusion uncertain (Gaeckle et al., 2015; Gaeckle, 2016b).

A study of heavy metals and organic contaminants in eelgrass habitats in Puget Sound identified levels consistent with global measurements, but did not determine what impact, if any, these contaminants are having on eelgrass (Gaeckle, 2016a). Eelgrass is known to be unharmed by most heavy metals, but metals do bioaccumulate in tissues and can cause harm to organisms that eat eelgrass (O'Reagan et al., 2018, and references within). At high concentrations, copper has been shown to affect photosynthetic activity in some Australian seagrass species, but similar research has not been carried out for Salish Sea and WCVI eelgrass (Gaeckle, 2016a, and reference within). Gaeckle (2016a) did find high concentrations of copper in an eelgrass bed near the Seattle waterfront, suggesting that urban runoff was a source of this contaminant.

Organic chemicals such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenols (PCBs), and persistent organic pollutants (POPs) were found in relatively low levels in Puget Sound eelgrass compared to global measurements (Gaeckle, 2016a). However, there has been no research on how these chemicals may affect eelgrass in the Salish Sea and WCVI region (Gaeckle, 2016a).

28. reduced supply of oxygen

BIOLOGICAL STRESSORS

WASTING DISEASE

Eelgrass wasting disease, identified by dark lesions on eelgrass leaves, is caused by the opportunistic, **epiphytic**[29] protist (single-celled organism) *Labyrinthula zosterae*, a slime mold (Figure 3.5) (Thom et al., 2011). Note that similar dark lesions can also be caused by poor water quality, nutrient deficiencies, environmental stress, grazers, and other diseases (Cynthia Durance, personal communication, 2025). As lesions from *L. zosterae* spread, the plant loses the ability to photosynthesize and dies as a result (Thom et al., 2011). Significant declines in eelgrass populations attributed to wasting disease have occurred on the east coast of North America (for example, a massive die off attributed to wasting disease took place in the 1930s), but it has never reached epidemic proportions in the Salish Sea and WCVI.

Testing of eelgrass beds — primarily in the U.S. Salish Sea — has shown that wasting disease is widespread (Eisenlord et al., 2018; Groner et al., 2014, 2018). In 2014 and 2016, the first demographic assessments of declining eelgrass beds in the U.S. Salish Sea proposed that wasting disease was a key factor in eelgrass loss (Groner et al., 2014, 2016). Other studies in the U.S. Salish Sea clearly linked wasting disease to poor plant and meadow health, showing that it decreases leaf growth and rhizome production, limiting the plant's ability to store energy and be resilient to changing conditions (Eisenlord et al., 2018; Graham et al., 2021).

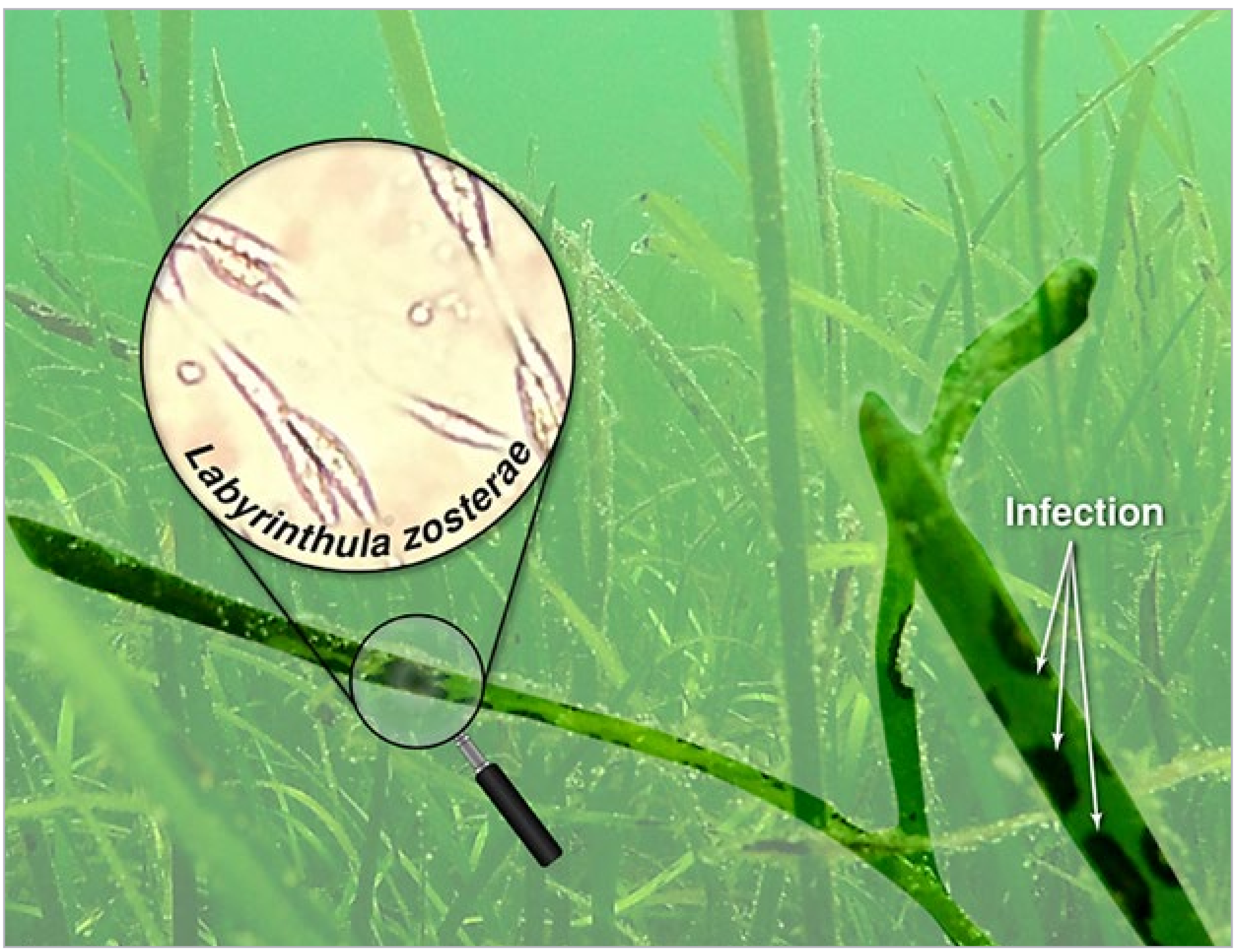


Figure 3.5 Eelgrass wasting disease is an increasing problem for eelgrass health as sea temperatures rise with climate change. Graphic Jonathan Kellogg, Photo Olivia Graham; Use of graphic courtesy of Hakai Institute

29. A plant that grows on another plant

Considerable progress has been made toward a better understanding of eelgrass wasting disease, including insights into the relationship of wasting disease to other factors such as temperature, the health of the eelgrass microbiome, the presence of invertebrate grazers, and the impacts of aquaculture. Strains of *L. zosterae* studied in the San Juan Islands varied in their virulence to cause disease, with higher ocean temperatures linked to an increased growth rate for *L. zosterae* in lab experiments (Dawkins et al., 2018). However, field experiments determined that light, rather than temperature, was more strongly linked to disease prevalence in eelgrass, suggesting that anything that limits light for eelgrass (such as docks) may make eelgrass more vulnerable to wasting disease. Temperature increases stimulate *L. zosterae* growth in the environment, increasing the likelihood of more virulent strains.

A study in the San Juan Islands of 'the Blob' marine heatwave of 2014-2016 linked ocean temperature to wasting disease prevalence and severity (Groner et al., 2021). Wasting disease became more prevalent, with a range of 5-70 per cent prevalence during summer before the heatwave to a range of 60-90 per cent by the end of the heatwave. A study combining satellite remote sensing of ocean temperature with field surveys of *Z. marina* within its range along the Pacific coast of North America demonstrated that temperature did not need to be extreme to increase disease prevalence, and that sites with cumulative positive temperature anomalies in the summer had three times more disease presence (Aoki et al., 2022). It can be expected that the risk of wasting disease outbreaks will increase across the entire range of *Z. marina* as ocean temperature increases with climate change. Cooler temperatures have been associated with less disease prevalence (Eisenlord et al., 2018; Graham et al., 2023; Graham, Harvell et al., 2024), suggesting that subtidal beds, which are located in deeper and cooler waters, especially those in temperate climates, may be a refuge for eelgrass from wasting disease as ocean temperatures rise globally.

Microbes and invertebrate grazers have also been shown to increase wasting disease severity. Some microbes that occur naturally on eelgrass can increase the risk and severity of wasting disease (primarily bacteria in the *Cellvibionazeae* family, known to degrade plant cell walls), highlighting the need for more research into the eelgrass microbiome (Beatty et al., 2022; Graham, Adamczyk et al., 2024). Grazing on eelgrass blades by invertebrates has been linked to an increase in wasting disease risk across the range of *Z. marina*, from southeastern Alaska to southern California (Aoki et al., 2025; Graham et al., 2025).

A recent study at Shaw Island in the U.S. Salish Sea assessed the extent to which oyster aquaculture alleviated or exacerbated wasting disease in eelgrass (Agnew et al., 2022). Lab experiments showed that the presence of oysters (*Crassostrea gigas*) at two temperature treatments (11 °C and 18 °C) decreased the severity of wasting disease in eelgrass. However, the experiment also found that oysters with previous exposure to the wasting disease pathogen (*Labyrinthula zosterae*) had the potential to infect eelgrass that had no previous exposure. Oysters had no effect on the severity of wasting disease in the field experiments. This complex result suggests a connection between aquaculture and wasting disease, but further research is required to determine in which situations aquaculture can benefit or harm eelgrass.


Credit: Nicole Christiansen

INVASIVE SPECIES

Research into invasive species and eelgrass in the Salish Sea and WCVI between 2014 and 2025 has identified some emerging threats.

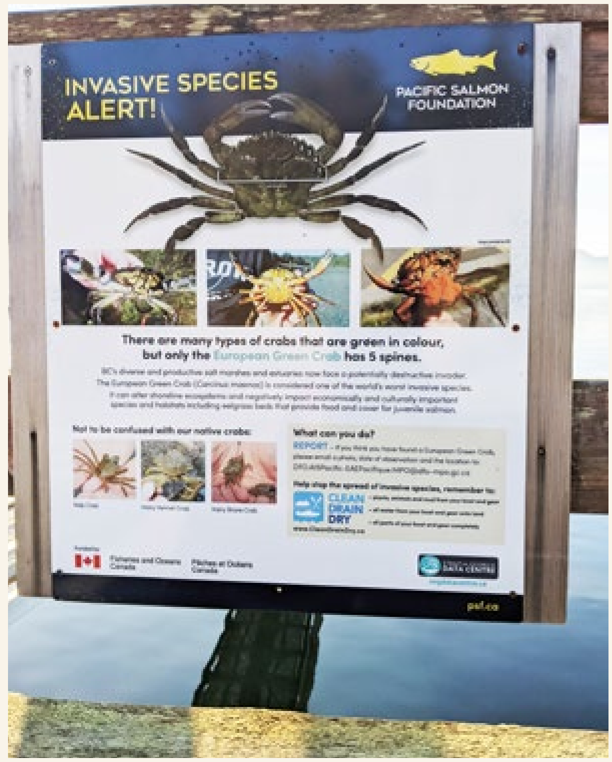
European Green Crab

European green crab (EGC) (*Carcinus maenas*), a native species of Europe, has caused ecosystem-altering impacts to eelgrass beds in areas where it has become invasive, even turning productive eelgrass meadows into mud flats (Figure 3.7) (Behrens Yamada et al., 2017, and references within; Howard et al., 2019, and references within). The EGC functions as an ecosystem **engineer**[30], shredding blades during foraging and disturbing sediment and root structure through **bioturbation**[31]. Eelgrass density in some coastal areas of Nova Scotia and Newfoundland has been reduced by up to 75 per cent (Garbary et al., 2014; Matheson et al., 2016).

Figure 3.6 Invasive European green crab. Credit: Maria Catanzaro

30. a species that modifies their environment
31. the disturbance of sediments by living organisms

Community volunteers monitor for invasive European green crab. Credit: Charlotte Fesnoux



Signage has been installed throughout the Salish Sea to alert people to watch for invasive European green crab. Credit: Ann Eriksson

Community Science Meets Invasive European Green Crab (EGC)

Pacific Salmon Foundation (PSF) and Coastal Restoration Society (CRS), with funding from the Fisheries and Oceans Canada's Aquatic Invasive Species Program, developed the Pacific Region EGC Mitigation and Capacity Development Project to work with coastal communities throughout the Salish Sea and beyond to monitor for and trap European green crab (EGC) using a standardized early detection monitoring protocol (PSF & CRS, n.d.). The project partnered with 19 different groups, who selected culturally and ecologically important sites with suitable green crab habitat. Alert signage has been posted at marinas, community docks, and other locations to inform the broader public. Training videos describing how to identify EGC and a site selection tool to assist community groups with choosing locations to monitor are available on the PSF European Green Crab webpage (https://marinescience.psf.ca/invasive-species/european-green-crab/).

For several years, the Ahousaht, Tla-o-qui-aht, and T'Sou-ke First Nations, in partnership with CRS, worked in their traditional waters in Clayoquot Sound and Sooke Basin to monitor and trap EGC to control their spread. The South Coast European Green Crab Control Project (SCEGCCP) (https://www.coastrestore.com/south-coast-egc-control) employed 30 members of the Nations. As of the end of 2024, when funding for the program ended, field technicians had trapped and removed a shocking 596,330 EGC from Clayoquot Sound and 268,735 from Sooke Basin, with EGC filling traps in every bay monitored. A video about the project can be viewed on the CRS web page.

EGCs were first introduced to the west coast of North America in the 1980s, likely in shipping ballast or packaged shellfish. Since the first reproductive population was discovered in San Francisco Bay in 1989, EGCs have steadily made their way northwards, arriving off the west of Vancouver Island in the late 1990s (Gillespie et al., 2007, 2015). An established population was found in the Sooke Basin in 2012 and the species has since spread into the Salish Sea on both sides of the US/Canada border (Behrens Yamada et al., 2017; Drinkwin et al., 2019; Gillespie et al., 2015; Murphy et al., 2021). Mapping of EGC detections in eelgrass beds in BC by PSF's Marine Data Centre shows that, as of 2023, they have spread into many eelgrass beds in the Salish Sea and WCVI region, with large numbers collected at WCVI sites (PSF Marine Science Program, n.d.b). A Salish Sea Transboundary Plan for Invasive European Green Crab was released by the Puget Sound Partnership in 2019 (Drinkwin et al., 2019). A citizen science program to detect and monitor EGC to prevent their spread is ongoing.

In 2019, an enclosure experiment in Barkley Sound to determine whether EGCs behave similarly in a Pacific eelgrass ecosystem compared to the east coast found that the crabs damaged Pacific eelgrass predominantly by shredding blades, and less so by bioturbation (Howard et al., 2019). While east coast studies documented juveniles eating only blades, Howard et al. (2019) observed adult crabs eating blades and rhizomes. These impacts are expected to limit the ability of eelgrass to reproduce clonally, the main method of reproduction for Salish Sea and WCVI eelgrass (Howard et al., 2019). Studies examining how EGC spread to the region have determined that increases in temperature and changes to ocean circulation have likely facilitated its introduction (Behrens Yamada et al., 2017). These factors are expected to become more favourable to EGC with climate change, and recent hydrological modelling has predicted the larval spread of green crab northward as the ocean warms (Engel et al., 2025; Iacarella et al., 2020).

Japanese Eelgrass (*Zostera japonica*): Friend or Foe?

Research conducted over the past ten years has produced convincing evidence that the introduced species, Japanese eelgrass (*Zostera japonica*) is not currently a threat to native eelgrass in the Salish Sea and WCVI region. Japanese eelgrass was found in Washington State in 1956, thought to arrive decades earlier in shipments from Japan of Pacific oyster seed packed in eelgrass (Shafer et al., 2014 and references within). The first collection in BC was at Boundary Bay in 1974 and the species has since spread throughout the Salish Sea and WCVI region (Precision Identification, 2004 and references within). Some U.S. states classify it as a “noxious weed” and attempt to eradicate it with herbicides, while others consider it “benign” or even “beneficial” (Mach et al., 2014; Murphy et al., 2021; Nomme, 1989; Shafer et al., 2014; Thom et al., 2011). Canada has no policy on Japanese eelgrass (Shafer et al., 2014).

A growing body of evidence suggests that Japanese eelgrass functions as a non-native foundation species as it colonises mudflats in the upper-tidal zone where native eelgrass is unable to establish (Knight et al., 2015; Shafer & Kaldy, 2014 and references within). This increases the total available habitat for eelgrass communities (Knight et al., 2015). Researchers propose that Japanese eelgrass, when colonizing mudflats, may make more of the inter-tidal zone favourable to native eelgrass by trapping water, thereby expanding available habitat for native eelgrass (Knight et al., 2015; Mach et al., 2014; Shafer et al., 2014). Japanese eelgrass, an annual with limited habitat value, is unlikely to displace native eelgrass in tidal zones where both species can grow, as perennial native eelgrass may be the superior competitor (Hannam & Wyllie-Echeverria, 2015). In a transplant experiment in Padilla Bay, WA, native eelgrass excluded Japanese eelgrass from pools where the species overlapped. These new insights support the argument that there is little value in targeting management efforts at Japanese eelgrass removal (Hannam & Wyllie-Echeverria, 2015; Shafer et al., 2014). As climatic conditions change, however, the dynamic between native and Japanese eelgrass may change and should be monitored (Sund, 2015).

Other Invasive Species

Other invasive species observed to negatively impact eelgrass are Canada geese (*Branta canadensis*) (Figure 3.7) and **biofouling**[32] species, such as tunicates and limpets, but there has been little research on the extent of their impacts to eelgrass in the Salish Sea and WCVI region.

In the Strait of Georgia, Canada geese have been observed consuming significant amounts of eelgrass and seriously impacting the local eelgrass populations (Cynthia Durance, personal communication, 2025). A 2020 survey of the Nanaimo River Estuary observed that foraging by Canada geese was reducing vegetation on the riverbank and shore, leading to erosion, which might be negatively impacting eelgrass in the estuary by increasing sediment in the water (Bonar & Zamora, 2024).

Invasive biofouling species can accumulate on leaves, limiting light which reduces plant growth, and can damage plants by breaking leaves and shoots (Murphy et al., 2021, and reference within). Species known to cause these impacts to eelgrass beds include the colonial golden star (*Botryllus schlosseri*) (Figure 3.8), the violet tunicate (*Botrylloides violaceus*) and other *Botrylloides* species (Murphy et al., 2021, and reference within), all of which have been identified in BC eelgrass meadows (Nagel et al., 2021). A 2020 study of climate change and invasive species spread predicted an increase in invasive tunicates in BC inner Salish Sea waters as a result of rising temperatures and increases to shipping and aquaculture, which are known vectors of invasive species transmission (Iacarella et al., 2020). Other species, like the painted limpet (*Tectura depicta*), have been documented in California to cause significant damage to eelgrass beds (Hessing-Lewis, 2005, and references within). While this species has not been identified as a threat to Salish Sea and WCVI eelgrass, it is possible that it could move northward as temperatures increase (Hessing-Lewis, 2005). While geese and biofouling species may only cause moderate impacts to eelgrass on their own, when accompanied by other stressors they can contribute to eelgrass decline (Nagel et al., 2021; Thom et al., 2011).

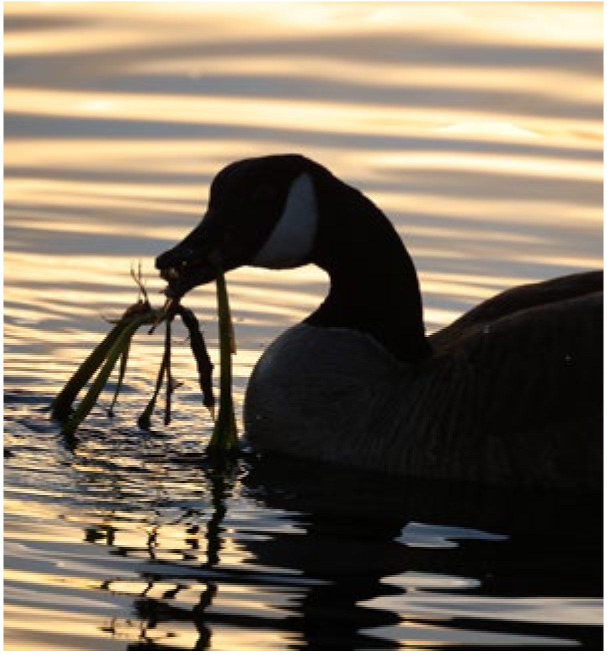


Figure 3.7 Canada geese forage on eelgrass shoots, pulling them from the substrate.
Credit: Mitch Miller

Figure 3.8 This invasive colonial golden star tunicate (*Botryllus schlosseri*) found in Ladysmith Harbour, is a known eelgrass biofouling species.
Credit: Rick Harbo

32. an accumulation of organisms where they are not wanted

STRESSORS FROM CLIMATE CHANGE

SEA LEVEL RISE

Sea level rise is known to affect light availability for eelgrass, particularly for plants growing at the species average depth limits (Thom et al., 2011). A drop in sea level, on the other hand, can increase the **desiccation time**[33] for eelgrass, which plants can tolerate up to a point (Thom et al., 2011). In a field experiment at Sequim Bay, WA, researchers found that eelgrass had a lower growth rate if desiccation time was over 29 per cent (Thom, Southard & Borde, 2014). While a mean sea level rise is confidently predicted with climate change for the Salish Sea and WCVI region (Harrison & Dunn, 2004; Mauger et al., 2015; Okey et al., 2014; Riche et al., 2014; Khangaonkar et al., 2019), anomalies where the sea level drops and rises are also expected from **isostatic rebound**[34] since the last ice age and as changes in sea temperature cause thermal expansion and contraction of the Pacific Ocean (Thom, Southard & Borde, 2014). A study published in 2014 saw a moderate correlation between the cyclical weather patterns La Niña (cooling) and El Niño (warming) that occurred during the late 1990s to sea level anomalies in the northern Pacific Ocean, when sea levels rose 30 cm during the El Niño event and dropped 15 cm during the La Niña event, compared to long term averages (Thom, Southard & Borde, 2014).

Eelgrass distribution is expected to shift upwards in the tidal zone as mean sea level rises, and conditions may improve for eelgrass already growing at the upper limit of the intertidal zone (Harrison & Dunn, 2004; Mauger et al., 2015; Thom et al., 2011). However, as climate change increases the chance of sea level anomalies and extreme events that contribute to sea level rise and fall (such as precipitation, droughts and storms) (Mauger et al., 2015; Murphy et al., 2021), concerns grow that eelgrass will be lost at the upper and lower depth limits, unable to shift range up and down fast enough to accommodate rapidly changing conditions (Thom, Southard & Borde, 2014). How severely changes in mean sea level rise will stress eelgrass populations over the long term will be determined by a variety of other factors that are location specific, such as the depth of the eelgrass at that location; water quality factors affecting light penetration; the resilience of the eelgrass ecotype to changing conditions; and the nature of shoreline development.

An unusual storm event in 2021 wiped out a 2019 eelgrass restoration in Hope Bay, Pender Island.
Credit: Jamie Smith, Coastal Photography Studio

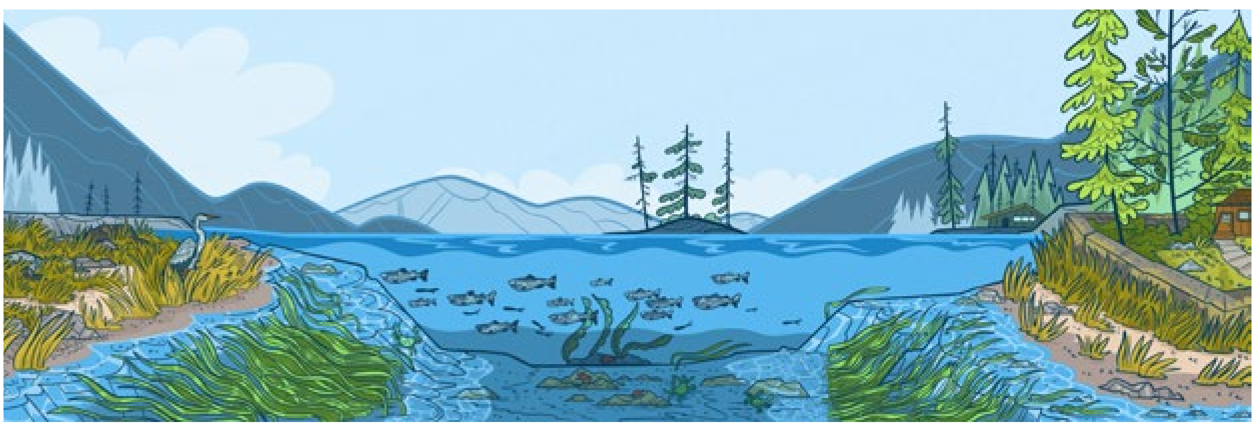
An Unusual Storm Event: Eelgrass Loss in Hope Bay, Pender Island.

In 2019, community volunteers and staff from SeaChange planted 700 shoots in Hope Bay on Pender Island as part of the CRF-funded Salish Sea Nearshore Habitat Recovery project. Monitoring during the first year showed a nicely recovering eelgrass bed. Then, an usual winter storm event, with high intensity and coming from an unexpected direction, completely wiped out the transplant. Undaunted, the team went back to work and replanted the area. However, the frequency and intensity of storm events will increase with global heating and are unpredictable, challenging eelgrass restoration efforts in the future.

33. length of time in a day that a plant is exposed to drying conditions
34. lifting of land masses after the removal of the weight of ice sheets following the last ice age.

Increasing storms and shoreline armouring are both stressors that are expected to impact eelgrass more with sea level rise (Dethier et al., 2016; Thom et al., 2011; Thom, Southard & Borde, 2014; Mauger et al., 2015). Shoreline armouring can cause 'coastal squeeze' and change sediment composition to unfavourable conditions (Figure 3.9). Greater erosion and sedimentation resulting from increased storms, as well as sea level rise itself, depending on its rate and extent, can smother eelgrass beds or create new eelgrass habitat (Boyer & Wright, 2016, and reference within). Relatively little recent information has been produced about how these multiple stressors might affect eelgrass in the Salish Sea and WCVI region in the future (Francis & Kinney, 2018).

Before sea level rise



After sea level rise

Figure 3.9 As sea levels rise, an armoured shoreline such as a sea wall (right), or naturally rocky topography, creates coastal squeeze, whereby the hard structure prevents the shoreward migration of an eelgrass bed as it tries to maintain adequate light levels. A natural gently sloping shoreline (left) allows the eelgrass bed to migrate up the slope as sea levels rise. Coastal squeeze is not the only problem with shoreline armouring. When wave energy from storm activity meets an armoured shore, it is reflected back onto the beach, exposing coarse sediment unsuitable for marine plants such as eelgrass (Dethier et al., 2016).
Credit: Delaney Cox

SEA TEMPERATURE RISE

Over the last 100 years, average sea surface temperatures (SST) in the Salish Sea have risen by an average of 1 °C and are expected to rise more with the advance of global heating (Khangaonkar et al., 2019; Mauger et al., 2015; Okey et al., 2014; Riche et al., 2014). Data from a series of lighthouse stations that measure SST every day, show that the rate of increase in the Strait of Georgia between 1973 and 2010 was up to 0.56 °C/decade, higher than the global average, and which is predicted to result in another 3 °C of warming by 2100 (Amos et al., 2014).

In addition to long-term ocean warming, marine heat waves (MHW), when water temperatures rise above the 90th percentile of the historical average for at least five days, are becoming more common with global heating. Dozens of MHWs were recorded at monitoring stations in the BC Salish Sea between 2002 and 2022 with the highest number at Departure Bay (42), Entrance Island (42) and Race Rocks (32) (Mora-Soto et al., 2024). Between 2014 and 2016, the Pacific coast of North America experienced the longest MHW ever recorded called "the Blob," when sea temperatures in some areas rose between 2 °C and 6 °C higher than historical averages (Starko et al., 2025, and references within). In the US Salish Sea, monitoring stations observed temperatures of +2.3 °C above normal in some spots, but the average temperature of the region did not increase more than +0.6 °C, owing to the mitigating effects of the Salish Sea's unique underwater **topography**[35] and hydrology (Khangaonkar et al., 2021). Sea surface temperatures of over 20 °C were recorded in some areas of the BC Salish Sea and WCVI in the summer months of 2014-2017 (Mora-Soto et al, 2024; Starko et al., 2024), MHWs are predicted to become hotter, more frequent, and last longer in the future (Mauger et al., 2015; Starko et al., 2025, and references within).

Studies in the 1970s and 1980s determined that eelgrass growing in the Pacific Northwest, from California to Alaska, has adapted to a wide range of temperatures (Phillips, 1984). Eelgrass growing along this north to south range also differs in its tolerance of temperature fluctuations. For example, a study in the 1970s found eelgrass in Alaska could survive in temperatures ranging from -6 °C to 27 °C, while eelgrass in Puget Sound and California died at -6 °C (Phillips, 1984, and references within). Lab experiments with Salish Sea eelgrass found that plants had optimal net primary productivity between 6 °C and 17 °C, and that temperatures over 25 °C resulted in zero net primary productivity and stress to the plant (Thom, Southard & Borde, 2014). A lab experiment in Oregon found that temperatures over 30 °C were lethal to eelgrass (Kaldy et al., 2014).

However, MHWs may be challenging eelgrass tolerance. Breiter et al. (2024) tested eelgrass from four different ecotypes of *Z. marina* in Puget Sound in water temperatures that were 2.5 °C and 5.6 °C higher than normal, but not exceeding 20.5 °C. The study suggested that even moderately elevated temperatures could impact eelgrass if they persist long term. For example, the prevalence and severity of eelgrass wasting disease increased with both levels of warming and, at increases of +5.6 degrees, some ecotypes experienced a reduction in their growth rates and energy storage over time. A systematic review of the ecological impacts of the Blob described several studies reporting stress to eelgrass (Starko et al., 2025, and references within). Monitoring of eelgrass health at nine sites in the San Juan Islands before, during, and after the Blob showed that observed declines in shoot density of up to 60 per cent did not recover once the heat wave had passed (Groner et al., 2021). Declines in eelgrass meadow density and biomass were also observed in some Washington State estuaries with little recovery evident by 2019 (Magel et al., 2022). The Blob also impacted eelgrass associated communities by reducing epiphyte and invertebrate numbers, as well as the abundance of some fish (Robinson et al., 2022). Invasive European green crab breached what was thought to be a cold-water barrier at the mouth of the Juan de Fuca and entered the Salish Sea for the first time (Behrens Yamada et al., 2017). Results such as these underline the threat posed to eelgrass by long-term warming and marine heat waves.

35. the depths and shapes of the seafloor

Importantly, eelgrass ecotypes vary in their resilience to warm temperatures (Breiter et al., 2024). For example, plants that grow rapidly in the spring, using up stored energy, were less resilient to warmer temperatures in the winter because they did not have enough energy left to maintain a rapid growth rate past the normal growing season.

Plants that had similar growth rates in spring and winter were better able to cope with long-term warming because they retained energy stores. Site specific factors may also determine how vulnerable an eelgrass bed is to rising temperatures. For example, a bed located in a sheltered bay where water circulates less frequently may be more affected than a bed in an area with high water circulation (Thom, Southard & Borde, 2014). Better understanding of the various ecotypes of eelgrass in the Salish Sea and WCVI region, and other site-specific factors are required in order to predict which populations are most vulnerable to a rise in ocean temperature.

An increase in ocean temperature may not always lead to eelgrass decline on its own, but effects may worsen when warming is combined with other stressors. A study by Thom, Southard, and Borde (2014) showed that plants require clear water to maintain the high productivity that warming temperatures stimulate. Stressors that limit light, such as poor water quality, overwater structures and sea level rise, will create worse outcomes for eelgrass as temperatures rise with climate change (see Cumulative Effects) (Breiter et al., 2024; Thom, Southard & Borde, 2014). Prevalence of diseases affecting eelgrass will also increase with rising sea surface temperatures (see Wasting Disease; Biological Stressors).

Just as sea level rise is expected to lead to a range shift of eelgrass upward into the current intertidal zone, sea surface temperature rise is expected to lead to a shift of geographic range northward. Blok et al. (2018) assessed eelgrass data along the north-south Pacific range of *Z. marina*, and found that, in all regions, a mean temperature increase of 1 °C was advancing flowering and seed maturation by 12 and 10.8 days, respectively, which may lead to migration northward and an increase in the size and number of eelgrass beds in northerly latitudes. However, southern populations already living at the species high temperature limit may not survive and local ecotypes that are less able to adapt — such as Salish Sea eelgrass, which primarily relies on clonal reproduction — may also decline. A range shift is only possible if northern waters are free of other stressors. Another stressor also predicted to move northward with warming temperature is the invasive European green crab (Engel et al., 2025).

FRESHWATER INPUTS

In the Salish Sea and WCVI region, fresh water enters the sea primarily from rivers but also from precipitation, in the form of direct rainfall and runoff from the land. The amount of fresh water going into the sea varies seasonally. For example, inputs tend to be higher in the spring when snow and ice are melting upriver or during peak precipitation in the winter, and less in the summer when precipitation decreases (Mauger et al., 2015; Okey et al., 2014; Riche et al., 2014). Freshwater inputs play an important role in driving ocean circulation and bringing necessary nutrients and dissolved oxygen into marine ecosystems, especially for more sheltered estuaries (Mauger et al., 2015; Murphy et al., 2021; Short, 2014).

Climate change and human activities are changing the balance and content of freshwater inputs. Freshwater from rivers and run-off increasingly contain excess nutrients, such as nitrogen from agriculture and sewage discharge, as well as higher amounts of sediment and debris, as human alterations to the landscape increase erosion (Mauger et al., 2015; Thom et al., 2011). At the same time, climate change is affecting the amount and timing of freshwater inputs into Salish Sea and WCVI waters. Over the last 50 years, precipitation has risen and salinity has decreased in BC waters (Okey et al., 2014). Rising temperatures are changing the timing of snow and ice melt, meaning that freshwater discharge occurs earlier in the season and these inputs are expected to decrease over time with losses of ice and snow pack (Mauger et al., 2015; Okey et al., 2014; Riche et al., 2014). In addition, rainstorms are increasing in frequency and severity, causing high amounts of freshwater inputs to enter the sea at once, often containing high levels of sediment and contaminants (Curry et al., 2019; Murphy et al., 2021).

Sedimentation and anthropogenic contaminants are known to stress eelgrass populations (see Industry and Anthropogenic Contaminants; Anthropogenic Stressors), but the impact of changing salinity is more complicated. Eelgrass is **euryhaline**[36], surviving in a range of salinities from freshwater to 42 **ppt**[37] (see Chapter 2) (Phillips, 1984), but there is evidence that salinities below 5 **PSU**[38] for long periods are lethal to eelgrass. A study in China showed that salinities lower than 20 PSU resulted in decreased growth rate, higher mortality and lower seed establishment in *Zostera marina* (Murphy et al., 2021, and references within).

HYPOXIA

Hypoxia is a known stressor to eelgrass. It occurs when dissolved oxygen in the marine environment decreases to levels that are harmful to plants and animals (less than 2 mg/L) (Khangaonkar et al., 2018). It has been shown in global studies to reduce photosynthetic efficiency and growth rates in *Z. marina* (Evans et al., 2023; Ciesielski, 2015, and references within). No studies have been conducted on the effects of hypoxia on *Z. marina* populations in BC (Evans et al., 2023). An experiment in Padilla Bay, WA, showed that eelgrass experienced reduced photosynthetic efficiency and lower growth rates in hypoxic conditions (Ciesielski, 2015). Furthermore, hypoxia made eelgrass less resilient to hydrogen sulphide, a known toxin to eelgrass and a by-product of organic matter accumulation (see Industry; Anthropogenic Stressors).

Hypoxia develops in response to two conditions: **stratification**[39] and excess nutrients. Stratification occurs when large amounts of warm, fresh water entering the sea from rivers and land-run off, forms a layer on top of the cooler, denser, salty ocean water. (Okey et al., 2014). The more different these layers are in density, the more they are resistant to mixing. Stratification inhibits the normal mixing of ocean layers usually encouraged by ocean circulation and upwelling (Mauger et al., 2015) and leads to hypoxia when less dissolved oxygen is transferred to the lower ocean levels. Warming sea surface temperatures and increases to and changes in timing of freshwater inputs, all consequences of the changing climate, can create persistent or permanent stratification (Mauger et al., 2015; Okey et al., 2014). Hypoxia can also be exacerbated by increased inputs of nutrient inputs. For example, algae blooms triggered by excess nutrients deplete dissolved oxygen at lower ocean layers, because decomposition of the algae takes place on the sea floor, a process that requires oxygen (Ciesielski, 2015).

A series of monitoring stations measure oxygen and ocean acidity levels along the BC coast and out into the deeper ocean (Evans et al., 2023). A 15 per cent reduction in oxygen over the last six decades has been reported for the upper 3000 m of the Northeast Pacific (Ross et al., 2020). Warming temperatures and increases in freshwater inputs are expected to expand the total area of the Salish Sea that will experience hypoxia in the future (see Sea Temperature Rise and Fresh Water Inputs). Modelling by Khangaorkar et al. (2019) has predicted that the annual hypoxic area in the Salish Sea will increase from <1 per cent to 16 per cent by 2095 in the high emissions scenario predicted by the IPCC.


Credit: Jeff Skinner

36. adapted to a wide range of salinities
37. parts per thousand
38. Practical Salinity Unit; 1 unit is defined as 1 gram of salt per 1,000 grams of water
39. the process of separating into layers or strata

MULTIPLE IMPACTS AND CUMULATIVE EFFECTS

Cumulative effects are defined as "the collective impacts of past, present, and future human activities on the environment" (Diefenderfer et al., 2021, and references within). Cumulative effects on an eelgrass bed may be related to a single stressor or multiple stressors (Figure 3.1). For example, an eelgrass bed growing next to a farm or a golf course may be impacted in winter by runoff of excess nutrients causing high epiphytic growth that reduces light to the plants. The bed may recover at first, when nutrient levels fall in summer, but if, every time it rains, the nutrient levels rise again, the damage to the bed may be long-term. In addition, the anchor of a boat moored in that same eelgrass bed is scouring the bottom, increasing sea temperatures have caused more wasting disease, and European green crabs have moved in. Over time, the eelgrass bed may not be able to recover from the repeated and multiple impacts. A global review of seagrass protection policies and management revealed that cumulative effects and the impacts of multiple stressors are often not considered or implemented (Griffiths et al., 2020).

Cumulative effects can also be beneficial, such as when stressors are removed or reduced. For example, an eelgrass transplant can improve water quality, stabilize the shoreline, and improve biodiversity over time at the broader land- or seascape-level (Diefenderfer et al., 2021). It may take time before effects are visible, emphasizing the need for long-term monitoring (Griffiths et al., 2020). Diefenderfer et al. (2021) recommends applying cumulative effects analysis for both harmful and beneficial effects of restoration efforts in order to improve restoration outcomes and facilitate **adaptive management**.[40]

CHAPTER THREE LESSONS LEARNED

- ☑ The extent of *Zostera marina* has declined in some areas of the Salish Sea and WCVI region, but the lack of long-term monitoring presents many unknowns.
- ☑ Eelgrass extent and health is impacted by many anthropogenic and biological stressors.
- ☑ Emerging threats to eelgrass include European green crab, wasting disease, and climate change.
- ☑ While knowledge about multiple stressors on eelgrass in BC has improved in the past decade, many gaps exist, making it difficult to predict outcomes in the future.
- ☑ The effects of cumulative impacts over time are not well studied and are unpredictable.
- ☑ Impacts to eelgrass from stressors is often site specific.

Next Chapter: Restoring Eelgrass: What We've Learned from Our Failures and Successes.

Credit: Rebecca Benjamin-Carey

40. a process of learning by doing that uses feedback from the environment to continuously improve management strategies

CHAPTER FOUR
RESTORING EELGRASS: WHAT WE'VE LEARNED FROM OUR FAILURES AND SUCCESSES

Explore a Subtidal Eelgrass Transplant.
(16:56 min) Credit: Jamie Smith, Coast Photography Studio

INTRODUCTION

We know that healthy eelgrass ecosystems are good for salmon, as nursery habitat and refugia, providing protection, prey and opportunities for metabolic growth before they move into open ocean (Chapter 1). Loss or damage of eelgrass ecosystems means functions that benefit salmon and other species are reduced or no longer available (Chapters 1,3).

Restoration has been described as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (Society for Ecological Restoration, n.d.). Restoring eelgrass habitat in nearshore areas where it has occurred in the past but is no longer there, where the beds have been damaged, or where the habitat is suitable, has been shown, in many cases, to relatively quickly (4–5 yrs) regain the attributes that benefit salmon and other species (Beheshti et al., 2022; Lewis & Henkel, 2016; Reynolds et al., 2016; Saunders et al., 2020).

A global study of seagrass recovery timescales showed that *Z. marina* is a suitable seagrass for restoration work because it is highly adaptable, making it resistant to change, and able to rapidly recover from disturbance (O'Brien et al., 2018). These qualities result from its large rhizome diameter, shoot weight and biomass, and its ability to change its above:below ground biomass ratios and to form large long-lived clones.

These factors make the restoration of eelgrass using *Z. marina* fit the attributes of a nature-based solution to biodiversity loss (Saunders et al., 2020).

> In 2019, the United Nations General Assembly declared 2021 through 2030 to be the Decade on Ecosystem Restoration. The Resolution, signed by representatives of over 70 countries, is **"a rallying call for the protection and revival of ecosystems all around the world, for the benefit of people and nature. It aims to halt the degradation of ecosystems, and restore them to achieve global goals."** Oceans and Coasts, including seagrasses, is one of seven categories for restoration.
>
> - United Nations Economic Commission for Europe, n.d.

Credit: Marcello Ogata

A HISTORY OF EELGRASS RESTORATION IN THE SALISH SEA AND WCVI REGION

Eelgrass beds have been valued and cared for by coastal Indigenous Peoples over thousands of years. For example, similar to other traditional coastal practices, such as the cultural burning of camas meadows (Lutz, 2020) and the creation of clam gardens (Williams, 2006) to provide food, the tending of eelgrass meadows by thinning shoots to promote the development of thicker rhizomes by the Kwakwaka'wakw is a form of enhancement (Cullis-Suzuki, 2007).

Before colonization, restoration of eelgrass meadows was unnecessary. Indigenous Peoples could not imagine the human-caused stressors of today. In recognition of the losses and damage to eelgrass habitats over the past 200 years (Chapter 2, 3) and the ecological value of eelgrass (Chapter 1), dedicated restoration of eelgrass habitat has emerged as a nature-based solution, along with conservation strategies (Chapter 5), to reverse these losses.

In BC, successful eelgrass restoration is just over four decades old. An interactive map of known restoration projects carried out in the Salish Sea and WCVI region since the 1990s can be found at https://arcg.is/1a4S5b0 and the data accessed and new projects added by contacting seagrass@hakai.org. Early restorations were conducted by Precision Identification under a DFO 'No Net Loss' policy to address the loss of eelgrass from coastal development projects. Note that this policy has been replaced by a broader policy for applying measures to offset harmful impacts to fish and fish habitat (DFO, 2025c), which is described in Chapter 5.

Eelgrass restoration in the Salish Sea for conservation purposes began with the emergence of marine conservation organizations such as Comox Valley Project Watershed Society (Project Watershed), which formed in 1993, and SeaChange Marine Conservation Society (SeaChange), which formed in 1998. The first of these eelgrass restoration conservation projects took place in 1999 with the planting of 1800 shoots in Tod Inlet within the W̱SÁNEĆ Territory of the Saanich Peninsula (Nikki Wright, personal communication, 2025). A second phase of the project followed in 2001 with the planting of 2300 shoots in a bay adjacent to the Tsartlip First Nation Reserve. Since then, conservation-focused eelgrass restoration projects[41] using various methods have been carried out in the Salish Sea and WCVI region by First Nations and conservation groups, often in collaboration, and often funded by the Canadian government. Of particular note are the eelgrass restoration projects funded by the Coastal Restoration Fund (DFO, 2025e) between 2018 and 2022 in the Salish Sea. The program resulted in the transplant of 27,733 eelgrass shoots and the removal of 79 metric tonnes of seafloor debris by SeaChange and partners (Wright, 2022); the restoration of 9,600 m^2 of eelgrass habitat by Cowichan Tribes and partners in the Cowichan/Koksilah River Estuary; eelgrass transplants along the Nanaimo River Estuary by The Nature Trust of British Columbia in partnership with Snuneymuxw First Nation; and the planting of 2,479 m^2 of eelgrass habitat by Project Watershed with K'omoks First Nations and other partners.


Credit: Crystal Norman

41. Not including DFO mitigation or offsetting projects (see Chapter 5)

Volunteers from Ka:’yu:’k’t’h’ / Che:k’tles7et’h’ First Nations preparing shoots for transplant in ʔOTSO:S (Hankin Cove). Credit: Katarina Duke

Eelgrass Restoration by Kayu:'k't'h' / Che:k'tles7et'h' First Nations (KCFN) Brings ʔOTSO:S (Hankin Cove) Back from the Dead

For the Ka:’yu:’k’t’h’ / Che:k'tles7et'h' First Nations (KCFN), ʔOTSO:S (Hankin Cove) was dead (Wayne Vincent Sr., 2023 as cited by Duke, 2024) — decades of logging decimated the once-rich nearshore ecosystems to the point that harvesting ceased many years ago. ʔOTSO:S became a forgotten place.

That began to change in 2024. KFCN partnered with Cynthia Durance from Precision Identification and Angela Spooner from the DFO Restoration Centre for Expertise to breathe new life into ʔOTSO:S. Together, they restored hundreds of square metres of eelgrass habitat. Youth from Ka:’yu:’k’t’h’ and Che:k’tles7et’h’ Elementary Secondary School, future stewards of the territory, prepared shoots for transplanting and learned about the ecological and cultural importance of ʔOTSO:S. Commercial divers from Pacheedaht First Nation and Under Control Environmental Services, one of whom is of Ka:’yu:’k’t’h’ ancestry, planted the shoots — providing the opportunity for them to visit the territory for the first time and meet relatives. KCFN Witwaak (Stewardship Officers Trevor Gillette and Wayne Vincent Jr.) led the eelgrass seeding work under the guidance of DFO. This work restored a crucial cultural landscape, honoured the ancestors, and brought a greater sense of place and spiritual comfort — representing a step toward food sovereignty and cultural revitalization for the community. KCFN is committed to protecting ʔOTSO:S and is monitoring the return of herring, salmon, and cockles to the restored eelgrass meadow.

A COMPARISON OF RESTORATION METHODS

Eelgrass restoration is carried out using two general categories of methodologies (Ward & Beheshti, 2023). Passive methods are those which assist eelgrass beds to recover naturally by removing stressors that inhibit the growth and or health of eelgrass. Examples are the removal of a dock or seafloor debris (Figure 4.1), improvement of water quality, or redistribution of sediments to recreate suitable habitat. The removal of stressors before restoration is considered essential to ensure successful active restoration as is the determination of habitat suitability (Sherman & DeBruyckere, 2018; Thom et al., 2014; van Katwijk et al., 2021). Active methods involve the planting of eelgrass shoots or seeds to expand an existing bed, recreate a bed in an area where eelgrass once grew but has been lost, or start one in a new area where the habitat has been deemed suitable (Spooner, 2025; van Katwijk et al., 2021; Ward & Beheshti, 2023). Passive and active methods, each with advantages and disadvantages, are often used together (Table 4.1).

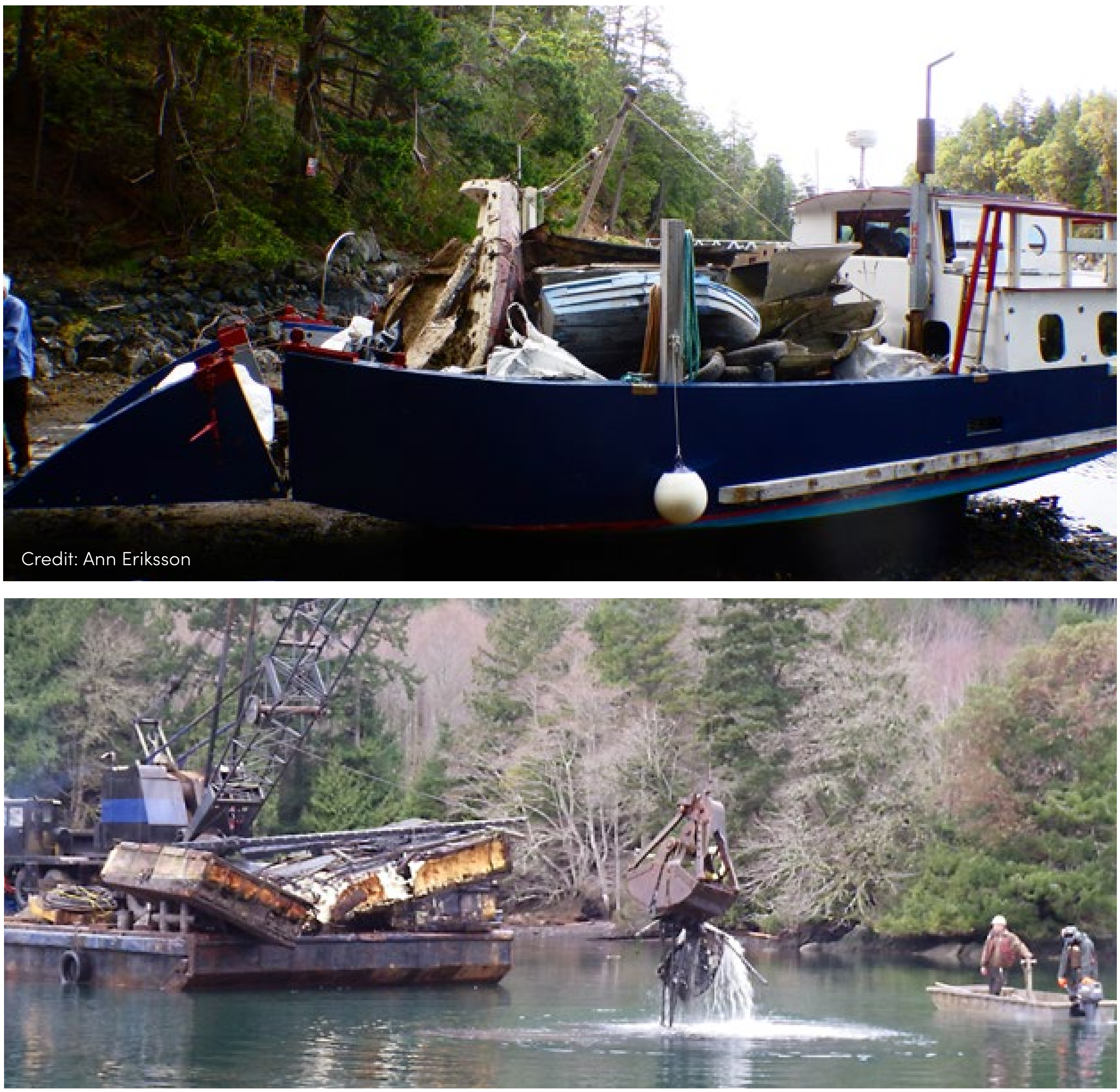


Figure 4.1 The removal of seafloor debris from an eelgrass bed is a form of restoration, helping the bed recover naturally. Credit: SeaChange Marine Conservation Society

Table 4.1 Comparison of subtidal eelgrass restoration methods (Beheshti & Ward, 2021; Spooner, 2025; Ward & Beheshti, 2023; Yang et al., 2016).

Method	Advantages	Disadvantages
Passive methods		
Debris removal	• Ecosystem-level improvements	• High cost • Slow prep time • Potential damage to donor or reference bed
Hydrological restoration	• Ecosystem-level improvements	• High cost • Slow prep time • Heavy machinery needs
Water quality improvements	• Ecosystem-level improvements	• High cost • Slow prep time
Active methods		
Transplants	• Suitable for high energy sites • Easy to monitor plots • Moderate time requirement • Compatible with community-level engagement	• High cost • Subtidal sites require diver support • High human resources requirements
Seeding (BuDS, Hessian (burlap) bags for reproductive shoots or seed spathes, hand-broadcasting or injecting seeds)	• Increases genetic diversity • Low time requirement (high for hand-broadcasting) • Low cost • Can be used when/where transplants are not possible (archaeological sites, dangerous or no-disturbance areas) • Suitable for low to moderate-energy sites • Potential for use to restore large areas • Compatible with community-level engagement	• Harder to monitor plots (with existing eelgrass) • Wet lab required for bare seed methods • Not suitable for high energy sites • Security risk for BuDS
Land-based *Z. marina* aquaculture followed by transplant	• Efficient • Cost-effective	• Labour intensive • Special set up and expertise needed

Credit: C. Doucet

Pacheedaht eelgrass restoration dive team. Credit: Helen Jones

Pacheedaht First Nation Restoration of Brown's Slough, Gordon River

Contributed by Cynthia Durance

The Pacheedaht First Nation (PFN) has been actively restoring salmon habitat in Brown's Slough on the west coast of Vancouver Island. The Slough was part of the Gordon River's active channel before industrial impacts. It was separated from the River by construction of a dike between 1952 and 1970. Sediment was dredged from the slough to construct the dike, burying salt marshes and resulting in a channel too deep to support eelgrass. The PFN secured funding through Fisheries and Oceans Canada's Coastal Restoration Fund (CRF) and their Aquatic Habitat Restoration Fund (AHRF) to deconstruct the dikes using the sediment to create two eelgrass benches. The first was transplanted with eelgrass in December 2022 (1250 m^2) the second in December 2023 (800 m^2). Buoy Deployed Seeding (BuDS) was conducted on the second bench during the summer of 2024.

Habitat was also enhanced in Harris Cove, at the mouth of the San Juan River in 2024. The sediment from the intertidal mudflat was used to increase the elevation of the upper mudflat to an elevation suitable for salt marsh and deepen the lower part of the mudflat to a depth suitable for eelgrass (500 m^2). The PFN is currently mapping all the eelgrass habitat in the Gordon and San Juan River systems using a towed underwater camera.

SAFE: EELGRASS RESTORATION USING TRANSPLANTS

A variety of eelgrass restoration methods have been used in BC and around the world with varying rates of success (Beheshti & Ward, 2021; Harrison, 1990; van Katwijk et al., 2016). Since 1995, a well-established methodology for active eelgrass restoration using transplants in suitable subtidal habitats, known as Safely Anchored with Iron (SAFE), has been used in BC (Durance & Kyte, 2011). The methodology was published in 2026 as a practitioners' guide by PSF to make it more accessible to First Nations and stewardship groups (Wright et al., 2026). SAFE was developed in response to the high rate of failure of eelgrass transplants in the Pacific Northwest prior to 1995 (Levings, 1991; Wright, 2018) and has resulted in a marked increase in success (Wright, 2018). Of 48 eelgrass restoration projects with known outcomes, 34 (71%) have been successful (spreadsheet of restoration projects is available by contacting seagrass@hakai.org).

In a restoration project using SAFE, eelgrass shoots of a locally adapted ecotype are harvested from a healthy nearby donor bed by SCUBA divers, prepared on land for transplant by attaching ungalvanized steel washers to individual eelgrass shoots (Figure 4.2), bundled together, then transplanted into suitable restoration site substrate by the divers (Figure 4.3)(Wright et al., 2026). Ideally, monitoring of the donor and/or reference site in comparison to the restoration site takes place every six months for the first year, then annually over an extended period of five years or more to measure donor site recovery and restoration success (Beheshti et al., 2018; Beheshti & Ward, 2021; Francis et al., 2022).

This method is particularly suited to collaborations with First Nations and local conservation groups, within communities focused on marine ecosystem recovery, because volunteers can assist with shoot preparation and on-the-ground organization (Figure 4.4). Volunteer engagement provides much more than labour. It connects people to place, increases awareness about eelgrass and the need for marine conservation, and engages local individuals and communities in the effort to bring eelgrass ecosystems back in the region (Wright, 2005, 2018).

Figure 4.2 Bundles of eelgrass shoots ready for transplant by divers. Credit: Ann Eriksson

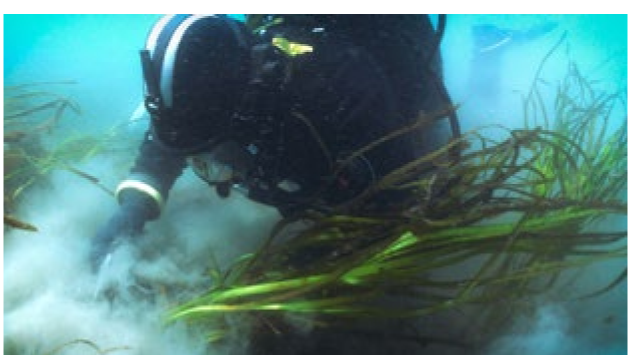


Figure 4.3 Diver transplanting eelgrass.
Credit. Jamie Smith, Coastal Photography Studio

Figure 4.4 Volunteers tying shoots for Otter Bay, Pender Island restoration. Credit: Ann Eriksson

The selection of suitable sites has been the main factor determining eelgrass transplant success in BC over the years (Wright, 2018). Transplant failures have resulted from poor site selection, poor donor stock, use of wrong ecotype, grazing by geese and other wildlife, and unusual weather events (Wright 2005, 2018). The impacts of severe storms and rising sea temperatures from climate change are already causing stress for eelgrass ecosystems, increasing uncertainty for restoration projects into the future (Thom, Southard & Borde, 2014).

DFO Restoration Centre of Expertise staff (two at left), Hakai Institute staff (far right and third from right) and members of the Quadra Island Conservancy and Stewardship Society and their dog, prepared eelgrass seeding BuDS sets in preparation for a seeding trial in 2023. Credit: Angela Spooner

Eelgrass Restoration Using Seed: A Pilot Project.

Starting in 2023, Fisheries and Oceans Canada, partnering with First Nations, is testing Buoy-deployed seeding (BuDs) at five sites in the region, as well as in Haida Gwaii with the Council of Haida Nation, Juus K̲áahlii. Sites include two test plots in bays on the west coast of Vancouver Island (Pacheedaht Nation, Gordon River and the Ka:'yu:'k't'h'/Che:k'tles7et'h' First Nations, Hankin Cove, Kyuquot Sound), and three sites in the Salish Sea (Cowichan Tribes at Maple Bay; K'ómoks First Nation at Ships Point, Fanny Bay; and We-Wai Kai Nation at Gowlland Harbour, Quadra Island) (Spooner, 2025; see BuDS profile). An additional Salish Sea test plot at the Tsleil-Waututh First Nation, Taylor Creek site in Burrard Inlet was planted with hessian bags on bottom substrate. Monitoring of the first sites has found new seedlings at expected germination rates or lower. The success of these seeding pilot projects is as yet undetermined with lessons still to learn. The complete seeding methodology can be found in the PSF Eelgrass Restoration Practitioners' Handbook (Wright et al, 2026).

BuDS: EELGRASS RESTORATION BY SEED

In recent years, concerns about the tendency of transplanted clonal eelgrass shoots to lose genetic diversity, the high cost of eelgrass transplants, and potential impacts of plant harvest on donor beds, as well as an interest in increasing eelgrass resilience to climate change, have inspired restoration practitioners to explore alternative restoration methods such as seeding (Figure 4.5). Seeding has successfully been used to restore seagrasses, including *Z. marina*, in other parts of the world (Beheshti & Ward, 2021; Oreska et al., 2021; Orth et al., 2007; Pan et al., 2014; Unsworth et al., 2019; van Katwijk et al., 2021; Zhang et al., 2015; Zhang et al 2024).

In the Pacific Northwest region, where eelgrass reproduces primarily by rhizomes and where few seeds in nature germinate and survive to maturity, with most swept away before rooting, or buried by sedimentation, eaten, or are not viable, seeding has not been seen as an option until recently (Cynthia Durance, personal communication, 2025; Spooner, 2025). Several pilot projects to restore *Z. marina* by using seed to increase genetic diversity and climate change resilience are underway in BC (Spooner, 2025), Washington State (Wyllie-Echevarria et al., 2022), Oregon (Breitkreutz, 2024), and California (Beheshti & Ward, 2021). Seeds are collected from flowering shoots, placed into mesh bags that are tied to floating buoys, (Figure 4.6) and left to release seed into suitable substrate (Spooner, 2025; Ward & Beheshti, 2023). Alternatively, hessian (burlap) bags are placed directly on the seafloor or seed suspended in sand or gel is injected directly into the substrate. Seed is sometimes hand broadcast. Seed can also be cultured in a tank on land to produce eelgrass shoots which are then transplanted out, a mariculture method that is being used in Washington State (Wyllie-Echeveria et al., 2022).

Figure 4.5 Repoductive eelgrass shoot with seeds. Credit: Angela Spooner

Figure 4.6 Seeds are collected from flowering shoots, placed into mesh bags that are tied to floating buoys and left to release seed into suitable substrate. Credit: Angela Spooner

While the great advantage of seeding is the potential to increase the genetic diversity and resilience of the restored habitat to stressors, seeding is also expected to be less expensive, less labour-intensive, have less impact on donor beds than transplanting shoots, and has potential to be easily scaled to cover large areas (Spooner, 2025; Unsworth et al., 2019; Ward & Beheshti, 2023). For a comparison of seeding with other methods see Table 4.1. Seeding can be used where transplanting is not possible such as in archaeological sites or dangerous areas, or for infilling disturbed patches (Spooner, 2025). Since the germination rate of *Z. marina* seeds is naturally low, it is recommended that seeding be used in conjunction with shoot transplants to increase genetic diversity and restoration success. The same best practices used when transplanting shoots, to select suitable sites, reduce impacts on donor beds, and plan for long term monitoring are required.

Site selection for seeding also has unique considerations. Studies conducted in other regions showed that competition with existing vegetation for light, space, and nutrients reduces the survival of seedlings, suggesting that the timing of seeding during seasons when eelgrass shoots are less dense may increase success (Hays et al., 2021, and references within; Johnson et al., 2020). Predation by crabs, bioturbation by worms, seed dislocation by currents, lack of light, and physical disturbance have been cited as reasons for restoration failure when using seed (Infantes et al., 2016). In recent years more work has been done to achieve increased germination rates and trial larger scale restoration methods, for example the use of robots for seeding and bioengineering techniques that create environmental conditions which improve recovery (Unsworth & Rees, 2025; Wyllie-Echevarria et al., 2022).

MEASURING SUCCESS

How do we know a restoration project is a success? Beheshti et al. (2022) considers an eelgrass restoration to be successful if the restored habitat is equal to or greater than a healthy reference bed in eelgrass productivity (shoot density, biomass, and canopy height), ecological habitat functions (macrofaunal species richness and abundance as evidence of nursery function), and **biogeochemical**[42] functions such as water quality modulation. In BC, eelgrass productivity (shoot density) and area coverage have been the main criteria for measuring success (Wright, 2018).

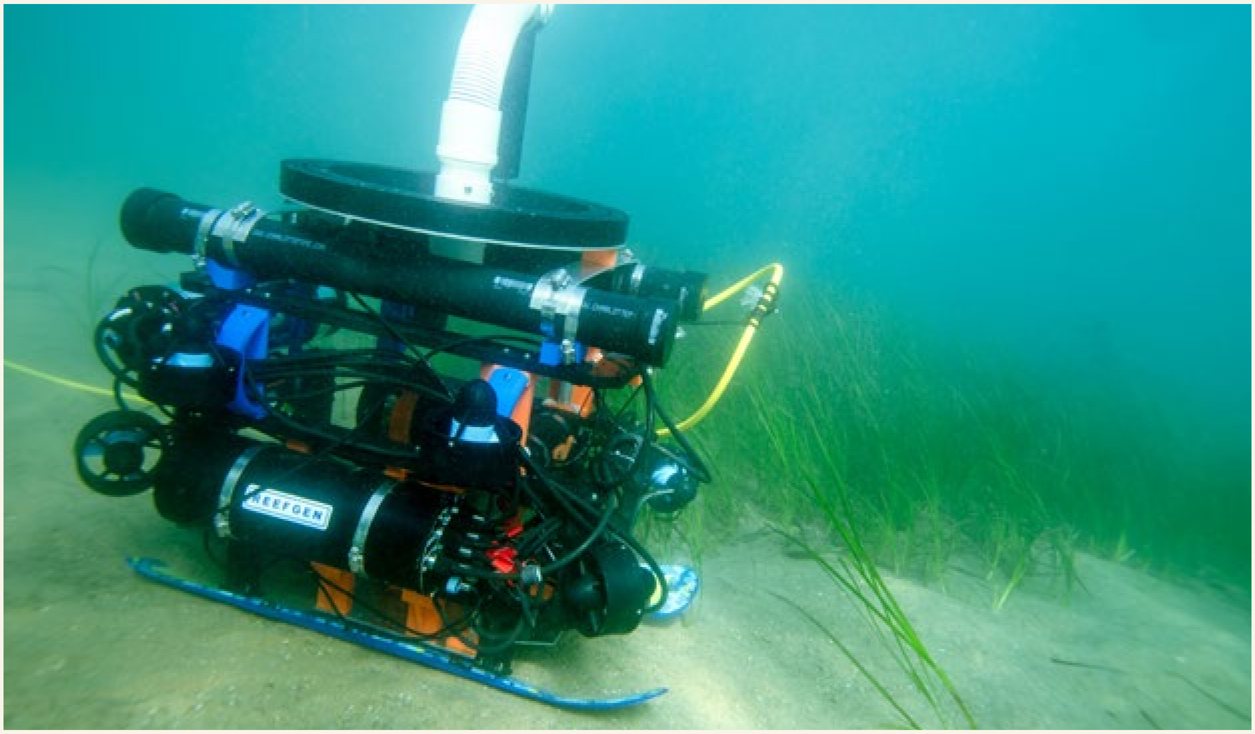
Ideally, the goal of a restoration project should be to create a self-sustaining system similar in structure and function to a nearby natural bed growing at the same depth, with the same seabed topography, sediment and other conditions, and that is resilient to disturbance within its tolerance range (Wright, 2018). Other criteria have been used in other areas, for example, using the quantity of nitrogen removed and carbon stored as a measure of the contribution of the restoration to ecosystem services even if the restoration does not re-create the conditions of the reference bed (Reynolds et al., 2016). Gamble et al. (2021) uses the measure of natural variability compared to the reference bed. As previously mentioned, long-term or effectiveness monitoring for five years or more is essential for determining success (Beheshti et al., 2018; Beheshti & Ward, 2021; Francis et al., 2022).

NEW FRONTIERS IN EELGRASS RESTORATION

Innovations to improve restoration success are being explored by researchers. Many areas of investigation, like seeding, are directed towards improving genetic diversity to enhance eelgrass habitat resilience to climate change impacts such as ocean warming and severe storms. Examples of other directions of inquiry that may advance eelgrass restoration efforts are:

- incorporating connectivity mapping of genetic information through the seascape to ensure a level of gene flow between adjacent populations of eelgrass (Pazzaglia et al., 2021);
- using non-local 'climate adapted' donor plants along with local donor stock in transplants to improve long-term resilience to future climate disruptions, recognizing that degraded local beds may be genetically susceptible to disruptions (Pazzaglia et al., 2021);
- considering **epigenetics**[43] when developing restoration programs to assist the evolution of an eelgrass habitat to be more resilient (Pazzaglia et al., 2021);
- considering the cumulative effects of restoration over time as a way to improve success and facilitate adaptive management in interconnected ecosystems (Diefenderfer et al., 2021);
- understanding the role of the microbiome, on eelgrass health and resilience (Wang et al., 2021);
- learning about eelgrass/sediment/microbe interconnections as a way to understand eelgrass die-offs and perhaps improve restoration success (O'Connor, 2024);
- investigating whether restored, non-thriving and failed meadows have different microbiota (O'Connor, 2024);
- exploring the benefits of inoculating eelgrass shoots with certain bacteria to increase seagrass resilience to stressors and increase restoration success (Tarquinio et al., 2019); and
- understanding local conditions to avoid introducing invasive species (Gamble et al., 2021) and pathogens like eelgrass wasting disease during transplants (Dawkins et al., 2018).

42. the cycling of chemical elements and compounds between living systems and the environment
43. how the environment and other factors change the way that genes are expressed



Grasshopper, a robot designed to plant eelgrass shoots or seeds. Credit: ReefGen

Grasshopper: The Restoration Robot

Are robots the way of the future for eelgrass restoration? A mechanized underwater planting system named Grasshopper is being used to transplant eelgrass shoots and seeds in coastal areas of California, Hawaii, and Indonesia. In 2025, the Washington State Department of Natural Resources (n.d.) conducted a pilot project to test the use of Grasshopper to plant eelgrass shoots in Puget Sound where a new law, passed in 2022, requires the restoration of at least 10,000 acres of eelgrass meadow and kelp forest by 2040, part of a Kelp Forest and Eelgrass Meadow Health and Conservation Plan. The robot, designed by Reefgen (2025), a team of marine scientists and ocean engineers, can plant longer and at faster rates (10-100 times) than divers and may be most helpful for large areas requiring restoration.

CHAPTER FOUR LESSONS LEARNED

- ☑ Indigenous Peoples have stewarded eelgrass ecosystems for millennia.
- ☑ Practitioners have been restoring eelgrass in the Salish Sea and WCVI region for coastal development mitigation and offsets, and for conservation, for over thirty-five years.
- ☑ The majority of BC restoration projects carried out for conservation since the mid 1990s have been successful owing to a refined transplant technique known as Safely Anchored with Iron (SAFE).
- ☑ Concerns about the health of donor beds has inspired pilot projects in the region using seed.
- ☑ Other innovations in science may improve restoration success, particularly in light of the progressive and uncertain impacts from climate change and other stressors.
- ☑ Investigations into methods to improve genetic diversity at transplant sites are ongoing.

Next Chapter: Protecting Eelgrass: Strategies for Conservation

CHAPTER FIVE
PROTECTING EELGRASS: STRATEGIES FOR CONSERVATION

Explore Q, ENT Marine Protected Area
SȾÁUTW̱ Indigenous Protected and Conserved Area
(5:33 min) Credit: Tsawout First Nation

INTRODUCTION

If eelgrass is protected from multiple and cumulative stressors, restoration efforts, which are high risk and costly, can be avoided in the future. In addition, restored habitats and investments of labour and funding will also be protected. In a hierarchy of conservation measures for eelgrass, well designed and managed ecosystem protection is considered to be the highest priority strategy (Figure 5.1) (Thom, 2024). The question posed in this chapter is whether, where, and how *Zostera marina* is protected in the Salish Sea and WCVI region.

In a 2024 report to the Tsleil-Waututh Nation regarding protection of eelgrass ecosystems in their territory, the Environmental Law Centre at the University of Victoria concluded that “[c]urrently, there is no legal protection for eelgrass in British Columbia” (Curran et al., 2024). Attendees at the Eelgrass Symposium held in Campbell River in October 2024 called for more eelgrass to be protected (Wright, 2024). What then have been the barriers to protection? In the preparation of this report, two issues emerged that stand in the way of eelgrass protection in BC: the lack of legal status for eelgrass and overlapping jurisdictions (See Chapter 6 for recommendations to improve protections).

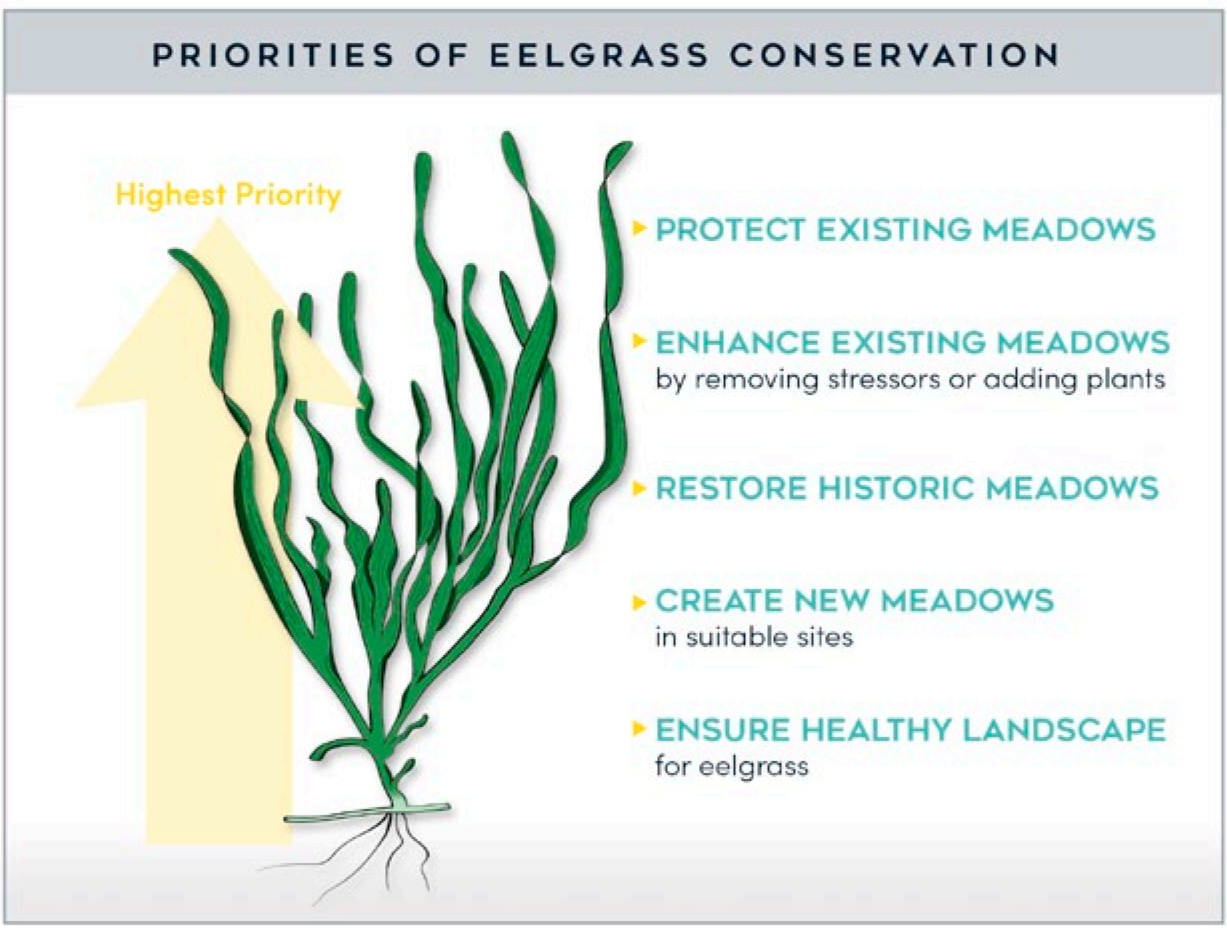


Figure 5.1 Protection should be the highest priorty for eelgrass conservation. Adapted from Thom (2024). Credit: Anisha Parekh

THE PROBLEM OF LEGAL STATUS

Griffiths et al. (2020), in a global study assessing seagrass protections, including one case study in the Salish Sea, asks whether a "seagrass habitat…[is] explicitly identified as an ecosystem of environmental significance by legislation" as a criterion for determining if the habitat is adequately protected. In Washington State, *Z. marina* habitat is legally protected as a critical habitat and a habitat of special concern, actively managed, mapped, monitored, and restored with a renewed legislated goal to "conserve and restore" at least 10,000 acres of eelgrass (and kelp) by 2040 (Washington State Department of Natural Resources, n.d.). In Europe, eelgrass is a protected habitat type under the EU Habitats Directive, and a Nature Restoration Law adopted in 2024 sets binding targets for restoration of seagrass meadows (MarLIN, n.d.). In the UK and Wales, *Zostera* species eelgrass beds are listed as a threatened and or declining habitat. In 2009, eelgrass was declared to be an Ecologically Significant Species (ESS) in Atlantic Canada by the federal government for its role as nursery habitat for juvenile Atlantic cod (DFO, 2009). The ESS designation provides enhanced protection for species that are "significant to maintaining ecosystem structure and function." In comparison, *Z. marina* in BC has no ESS designation, is not considered at risk or as **critical habitat**[44] under the federal Species at Risk Act (SARA) (Government of Canada, n.d.a), and is not designated as a species- or ecosystem-at risk by the BC Conservation Data Centre (Province of British Columbia, 2021). Today, eelgrass in BC remains without explicit legal recognition. This lack of legislative acknowledgment of its importance leaves eelgrass habitat more at risk of decline and less likely to be targeted for protection on its own (Griffiths et al., 2020).

Table 5.1 Examples of government responsibilities for marine planning and stewardship in BC as related to eelgrass conservation (adapted from Province of British Columbia, 2024b).

Federal Government	Indigenous Governments	Provincial Government	Local Governments
• Fish habitat	• Aboriginal and treaty rights and responsibilities as per individual First Nations	• Tenures over seabed and foreshore (Aquatic plants, aquaculture, pollution, docks and wharves, log handling sites, underwater utilities)	• Zoning regulations and OCPs and bylaws related to shoreline development
• **Protected Areas**	• **Protected Areas (incl Indigenous Protected and Conserved Areas)**	• **Protected Areas**	• **Parks and trails**
• Marine habitat restoration	• Marine habitat restoration and conservation	• Marine habitat restoration and conservation	• Public education
• Environmental assessments	• Coastal Guardians: research, monitoring and stewardship	• Marine spatial planning	
• Shipping and navigation	• Community management of harvesting for food, social and ceremonial use	• Waste management and authorizations	
• Oil spill response	• Oil spill response	• Environmental emergency planning (e.g., oil spill response)	
• Species at risk		• Heritage and cultural protection	
• Migratory birds			

44. habitat necessary for the survival or recovery of a listed wildlife species

THE PROBLEM OF OVERLAPPING JURISDICTIONS

All four levels of government (Indigenous, Federal, Provincial, and Local) have some form of jurisdiction and/or planning power, often overlapping, over BC nearshore waters and the species that live there (Table 5.1) (Province of British Columbia, 2024b). Jurisdiction over marine and coastal waters goes way back to the Constitution Act of 1867, which ignored the rights and title of Indigenous Peoples and divided the powers between the federal and provincial governments (Curran et al., 2024, and references within). In all other provinces with ocean coastlines, provincial powers generally stop at the low water mark and include only foreshore and intertidal lands. But for BC, two unique exceptions were made. Bays, inlets and estuaries (waters "between the jaws of the land") and the "submerged waters between the lower Mainland and Vancouver Island" (i.e., the Salish Sea) are under the jurisdiction of the province so long as activities don't interfere with federally regulated navigation and shipping. The seabed and, by extension, marine plants such as eelgrass, are provincial responsibilities (complicated by Port Authorities where they exist). Regional and municipal local governments, designated under the authority of the provincial Land Act (1996) and the Community Charter (2003), through their respective planning processes (e.g. zoning, bylaws, Official Community Plans) may regulate marine activities such as anchorages, shoreline development, pollution, or the building of docks in nearshore areas, particularly if their boundaries extend out into the ocean.

While Indigenous Peoples have always taken guidance from their inherent sacred and legal obligations to protect and restore the environment for future generations, the right to self-government and rights and title over their territories were enshrined in Canadian and BC law with the passing of the BC Declaration on the Rights of Indigenous Peoples (2019) (DRIPA) and the United Nations Declaration on the Right of Indigenous Peoples (2021) (UNDRIP) by Canada. Indigenous governments are increasingly asserting their inherent right to manage and steward marine (and other) resources in their territories.

Overlapping jurisdiction between various governments becomes a problem when it's unclear which level of government(s) is/are responsible for a particular marine decision, which can result in confusion, delays and inaction (Curran et al., 2024; Hewson et al., 2023). The Government of BC, which has jurisdiction over intertidal areas, has not been active in its management or protection role (Hewson et al., 2023, and references within). It is important to note that various levels of government and Indigenous territorial rights and title holders often collaborate on marine planning and stewardship initiatives. For a thorough discussion of the strengths and weaknesses of marine conservation law in BC, see Hewson et al. (2023).


Credit: Rebecca Benjamin-Carey

A SUMMARY OF INDIRECT PROTECTIONS FOR EELGRASS IN BC

While the lack of legal status and the barrier to conservation that overlapping jurisdictions can pose, in practice, eelgrass habitat is often identified as a priority for marine planning in BC (Gomez et al., 2021). As is evident in previous chapters, a great deal of effort and money is spent to map, monitor and restore eelgrass in the Salish Sea and WCVI region. Eelgrass is often indirectly protected by general nearshore habitat measures under federal, provincial and local government policies and regulations, and within marine protected areas (MPAs).[45] In addition, several voluntary measures have emerged to protect eelgrass habitats where official protections are either not in place or not working to stop declines and damage.

POLICY AND REGULATIONS

Fisheries and Oceans Canada (DFO)

The Fisheries Act (1985) is a key piece of environmental legislation which provides protection for fish and fish habitat. 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.

Nearshore development activities are a common threat to eelgrass. DFO's Projects Near Water website (DFO, n.d.) provides guidance, standards, mitigation measures and relevant Codes of Practice to assist proponents in planning and carrying out their project. *The Fish and Fish Habitat Protection Policy Statement* (DFO, 2019) encourages proponents to first avoid and mitigate impacts to fish habitat where possible. Where a HADD cannot be avoided, proponents are required to apply for a Fisheries Act Authorization prior to carrying out their works.

When reviewing projects, DFO applies a risk management framework (DFO, 2024) to inform its decision making and considers cumulative effects (DFO, 2025b) when contemplating issuance of an authorization. **Offsetting**[46] may be required to counterbalance residual effects. DFO's *Policy for Applying Measures to Offset Harmful Impacts to Fish and Fish Habitat* (DFO, 2025c) provides key guiding principles for developing offsetting measures. Monitoring of offsetting is required to ensure offsets effectively counterbalance adverse effects to fish habitat.

Note that protections for fish habitat, including eelgrass, under the *Fisheries Act* are limited to addressing impacts only from coastal development projects. A review of the ability of the Act to advance fish and fish habitat conservation and restoration is provided by Imhof et al. (2021).

45. The terms 'marine protected area' and MPA are used broadly in this report to include any geographic area legally set aside for marine protection. Note that the Oceans Act uses the term Marine Protected Area or MPA to refer to a marine protected area designated under the Act. There are no Oceans Act MPAs in the Salish Sea and WCVI region as of December 2025.

46. Eelgrass offsetting involves creating or restoring an eelgrass bed to compensate for an approved alteration or destruction of eelgrass habitat during a marine development.'

Transport Canada

Transport Canada is responsible for shipping and navigation and related impacts on the marine environment. Under the *Canada Shipping Act* (2001), Transport Canada has the mandate to regulate and prohibit vessel anchorage and mooring, and regulate marine traffic to protect ecologically sensitive areas. Transport Canada funds the removal of derelict vessels and local governments can apply to restrict boating in certain areas (Transport Canada, n.d., 2025).

Eelgrass habitats potentially benefit from Transport Canada's Vessel Pollution and Dangerous Chemicals Regulations which prohibits discharge of sewage and garbage into nearshore waters from recreational boats less than 400 gross tonnes and which carry 15 passengers or less (Transport Canada, 2012). However, these prohibitions do not apply in waters that are less than six nautical miles wide, which includes most of BC's coastal fjords. This along with the lack of access for recreational boaters to sewage pumpout stations means that raw sewage is often legally discharged near to shore (Living Oceans Society, 2015).

Province of BC

As previously mentioned, under the Constitution Act of 1867, the Province of BC has jurisdiction over the marine environment in the Salish Sea and the foreshore, bays, and estuaries on the west coast of Vancouver Island. BC regulates many coastal activities, some which are relevant to eelgrass habitats, for example, aquaculture, wharves, marinas and the harvesting of marine plants (Hewson et al., 2023). BC has lacked overarching legislation for the management of coastal areas (Hewson et al., 2023), a gap which may be addressed with implementation of the BC Coastal Marine Strategy (Province of BC, 2024b) released in 2024 but at publication of this report not yet legislated (CPAWS-BC & West Coast Environmental Law, n.d.). The Strategy aspires to facilitate healthy coastal marine ecosystems through, among other goals, protecting and monitoring nearshore ecosystems including eelgrass, improving salmon survival, and preventing and cleaning up marine pollution. The lack of a strategy has meant that BC didn't have adequate tools to identify and/or protect marine ecosystems within its boundaries from threats, often leaving local governments with the responsibility for marine planning (Hewson et al., 2023).

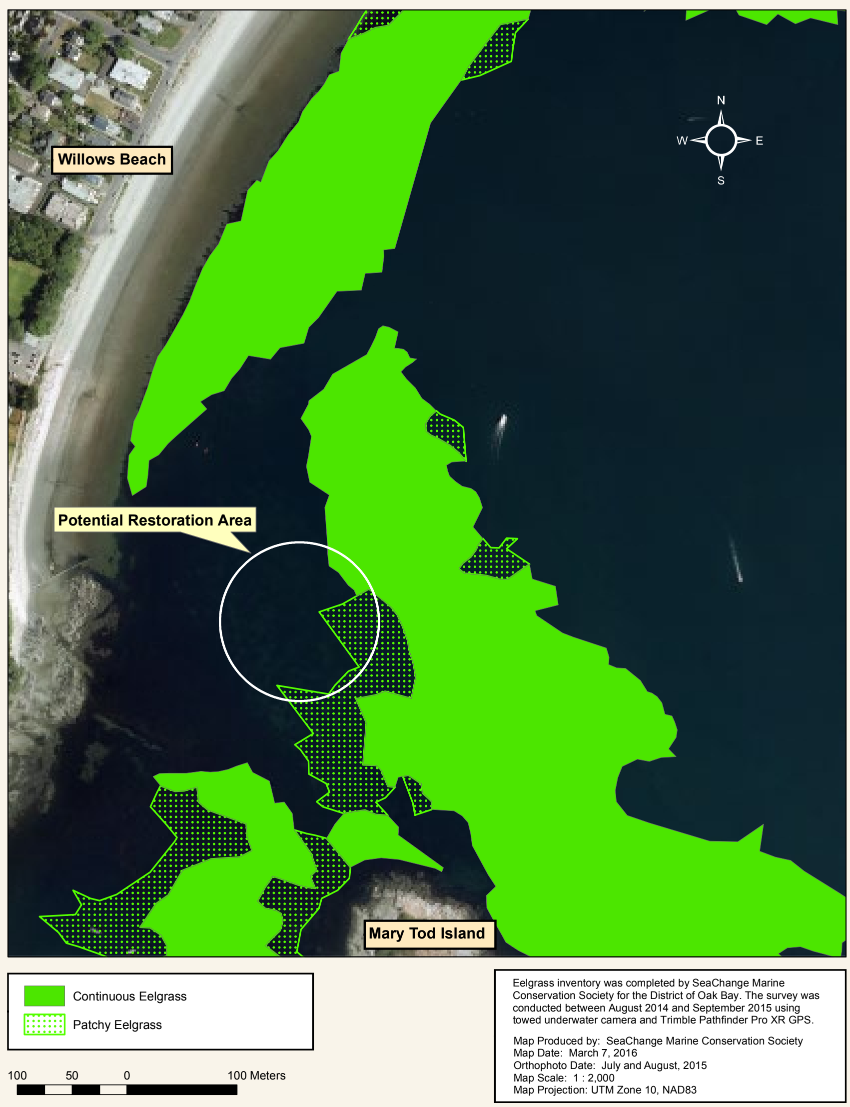
An important weakness in provincial powers is its lack of authority over federal regulated activities such as shipping and marine fisheries, leaving nearshore areas open to such activities (Hewson et al., 2023) (see also Marine Protected Areas). BC has the option to request the closure of federal fisheries in certain areas, but action is not guaranteed. It is important to note that the province has partnered with federal agencies and Indigenous governments to achieve conservation goals.

An example of collaborative ecosystem-based marine planning in the region was the WCVI Coastal Strategy, an initiative of the non-profit organization West Coast Aquatic (westcoastaquatic.ca), which brought together federal, provincial and regional governments, Nuu-chah-nulth First Nations, commercial harvest, aboriginal harvest, sport/recreational harvest, aquaculture, environment, labour, processing, tourism/recreation, marine transportation, and forestry (West Coast Aquatic, 2012). Another successful marine planning initiative is the Marine Plan Partnership (MaPP) (mappocean.org) between the Province of BC and 17 First Nations to develop recommendations for marine management including stewardship. To date, the focus of the MaPP process has been on areas outside the Salish Sea and WCVI region, however the North Vancouver Island Marine Plan (https://mappocean.org/north-vancouver-island/) includes K'ómoks and Wei Wai Kum First Nations located in the Salish Sea.

Eelgrass Mapping for the District of Oak Bay

Oak Bay is an urban municipality adjacent to the City of Victoria, both bordering the Strait of Juan de Fuca and Haro Strait in the Salish Sea. The District of Oak Bay's Environmental Advisory Committee wanted to know what policies and land use decisions were needed to protect and enhance the eelgrass meadows growing there. In 2014, the committee contracted SeaChange Marine Conservation Society, with funding from PSF and a Grant-in-Aid from Oak Bay Council, to survey all eelgrass habitats along the coastline of the municipality. The surveys took place over two summers using a towed underwater camera and a GPS unit (Boyer & Wright, 2016). Results showed that Oak Bay supports a healthy population of eelgrass meadows over 174,604 square metres of nearshore habitat, with 78 per cent of the eelgrass continuous meadows and 22 per cent patchy habitat. Plants noted to be growing deeper in some areas (up to 9 m below the low tide line) than the Salish Sea average suggest good water quality. Bottom scour from moorings and anchor damage near the Oak Bay marina were found to be the greatest source of impact.

The project report recommended that the District conduct eelgrass restoration in certain areas, reduce marine pollution, create No Anchor Zones, promote soft shore approaches to shoreline development, and produce signage and pamphlets to educate boaters and residents about the importance of eelgrass and the impacts of moorings and anchoring. In 2024, SeaChange conducted a debris removal, an eelgrass transplant, and installed voluntary No Anchor buoys near the Oak Bay Marina (SeaChange, 2024c).



The eelgrass mapping project along the Oak Bay waterfront identified this potential transplant site near the Oak Bay Marina. The transplant was completed in 2024 and voluntary No Anchor Zone buoys installed.

Credit: SeaChange Marine Conservation Society

Local Government

Local governments, established under the provincial Local Governments Act (2015), have the ability to influence coastal and marine protections through their land use planning authority and jurisdiction over shoreline development (Hewson et al., 2023). Local government boundaries often extend several hundred metres seaward beyond the normal high-water mark and include the surface of the water. As long as they don't interfere with federal and provincial responsibilities, local governments can enact land and water zoning for conservation, create restrictive Development Permit Areas (DPAs) for conservation purposes, and promote long-term planning and policies, including protection of ecosystems through Official Community Plans and bylaws. Examples of local governments initiatives that can benefit eelgrass ecosystems include the creation of parks and protected areas, the regulation of docks, shoreline armouring restrictions, the promotion of soft shore approaches to coastal development, and regulation of moorage and anchorages. Habitat restoration work is also possible but requires permission from the province and federal authorization from DFO to comply with the Fisheries Act (Hewson et al., 2023).

Examples of local government marine conservation initiatives are a Salt Spring Island DPA for shoreline protection that extends 300 metres from shore and includes, among others, guidelines for protecting eelgrass from dock construction; and a Cowichan Bay no-go zone marked by buoys to keep motorized vessels away from eelgrass beds (Hewson et al., 2023, and references within). The latter came about through cooperation among the Cowichan Valley Regional District, Cowichan Tribes, Transport Canada, DFO, RCMP, Living Waters, and the BC Wildlife Federation.

Islands Trust

The Islands Trust (IT) is a unique special purpose government in the Salish Sea, a federation of local trust committees elected on each of the 13 major islands of the Islands Trust Area, established under the provincial Islands Trust Act (1996) (Figure 5.2). The Islands Trust Policy Statement is its high-level land use planning document. The policies it contains guide the development of official community plans and land use bylaws for the islands of the Islands Trust Area. A draft new Policy Statement currently under development contains the following reference to protecting nearshore ecosystems: "Local trust committees and island municipalities shall, in all official community plan bylaws, and other bylaws that require Executive Committee or Trust Council review of approval… identify and prioritize the preservation, protection, and restoration of eelgrass meadows, kelp forests, forage fish spawning areas, clam beds, estuaries, tidal salt marshes, mud flats, and coastal wetlands." (Islands Trust, 2025). IT has been actively mapping eelgrass in the Trust Area since 2012 (Wright et al., 2014; Coastal and Ocean Resources, 2022b).

Figure 5.2 The Islands Trust Area comprises much of the Salish Sea. Credit: Islands Trust

Similar to a local government, IT has influence over marine areas through its marine zoning bylaws and shoreline development permit areas. Any shoreline development proposed under IT jurisdiction where a zoning bylaw is in force must comply with that zoning. Where a development permit area for shoreline protection is in place, a development permit may need to be obtained. Shoreline development that needs a Crown Lease from the Province will typically be referred to IT for comment to ensure that the proposal is consistent with zoning and any development permits that are required. For example, if there is a proposal for dock construction in the Thetis Island Local Trust Area, where 25 per cent of the fore-shore has been mapped as eelgrass habitat (Wright et al., 2014), and where maintaining the integrity of the marine ecosystem and the coastal areas is an objective for planning (Thetis Island OCP), it must align with the Thetis Island Land Use Bylaw and any development permit area requirements. If it does not align, the proposal will be rejected or modifications to the proposal will be necessary. Eelgrass protection could be a consideration in the decision, with an opportunity for IT to request changes that bring the proposed project into alignment with the bylaws.

Broken Group Unit, Pacific Rim National Park. Credit: Hakai Institute

Canada's Commitment to Marine Protection

As a result of Canada's participation in the UN 1992 Convention on Biological Diversity and other international agreements, Canada, through the Oceans Act (1996, updated 2016), made a commitment to establish a network of marine protected areas that "protects the biological diversity and health of the marine environment for present and future generations" (Government of Canada, 2011). More recently, by signing the Kunming-Montreal Global Biodiversity Framework (Convention on Biological Diversity, n.d.,) along with 192 other countries, Canada committed to protect 30 per cent of the country's lands and waters by 2030 (30 x 30 goal), while respecting the Rights and Title of First Nations. Under the Oceans Act, to reach this goal, Parks Canada Agency (PCA), Environment and Climate Change Canada (ECCC), and Fisheries and Oceans Canada (DFO) have been given the mandate to create a network of MPAs made up of IPCAs and federal and provincial parks and protected areas. The majority of MPAs in the region currently in place predate the Oceans Act.

MARINE PROTECTED AREAS

Geographic areas of ocean set aside and managed for conservation purposes are commonly known as marine protected areas (MPA)[47] or marine refuges. What makes a good marine protected area? According to Arafeh-Dalmau et al. (2023), a well managed MPA will allow time for species recovery, conserve biodiversity, and improve ecosystem resilience to climate impacts. Fully protected MPAs with strong prohibitions against extractive activities such as fishing, oil and gas exploration, and seafloor bed mining, will provide a place for marine ecosystems, species, and processes to exist and/or recover without threat of harm. An effective MPA will protect critical and unique areas, incorporate connectivity, allow time for recovery, avoid or mitigate local stressors, and promote adaptation to changing conditions (Arafeh-Dalmau et al. 2023; Graham, Harvell et al., 2024).

MPAs in the Salish Sea and WCVI have been established by the federal and provincial governments, and some have been declared by First Nations as Indigenous Protected and Conserved Areas (IPCAs). A summary of the locations of Indigenous-led, federal, and provincial MPAs with marine zones in the region, including a comparison of their strengths and weaknesses to protect habitat, is provided in Table 5.2. While local and regional parks have the potential to contribute to eelgrass conservation, they are not included in this summary, except where specific examples are provided. An interactive map of national and provincial parks and protected areas in the region can be viewed at BC Parks Advanced Map (Government of BC, n.d.).

Credit: Anne Shaffer, Coastal Watershed Institute, All rights reserved

47. In the context of this report, MPA refers to any legislated marine protected area.

Table 5.2 Summary of Indigenous-led, federal and provincial protected areas with marine component in the Salish Sea and WCVI region as of December 2025. References for protected area numbers at links; Strengths and Weaknesses (Hewson et al., 2023, and references within). BC Parks protected area numbers from Canadian Protected and Conserved Areas Database (CPCAD) as of Dec 8, 2025. Note: PC=Parks Canada; ECCC/CWS=Environment and Climate Change Canada/Canadian Wildlife Service; DFO=Fisheries and Oceans Canada

Agency/Category	Protected Areas	Purpose	Strengths	Weaknesses
Indigenous-led Conservation Areas (e.g. Indigenous Protected and Conserved Area; Tribal Park)	SS-1, WCVI -1 • QEN, T Marine Protected Area • Tla-o-qui-aht Tribal Parks	"lands and waters where Indigenous Nations, communities, and/or governments have the primary role to protect and conserve ecosystems through Indigenous laws, governance and knowledge systems" (Tomkinson, 2024)	• Leadership by Indigenous Peoples supports strong conservation outcomes • Contribute to biodiversity conservation goals • Provide local oversight in remote areas (Canada Conservation, 2024)	• Not always recognized by crown governments
Federal				
PC/ National Park Reserve (NPR)	SS: 1, WVI: 1 • Gulf Islands • Pacific Rim	National Park that is subject to Indigenous land claims	• Long term Strong habitat protections Can regulate fisheries	• Protections subject to court challenges
ECCC-CWS/ National Wildlife Area (NWA)	SS: 1, WVI 1 • Alaksen • Qualicum • Scott Islands	Conservation and study of nationally significant habitat for animals and plants	• Long term • Strong prohibitions of extractive activities • Can be used to protect rare and unusual habitat areas or with restoration potential	• ECCC must own or control site • Lack of up-to-date management plans • Not effective for marine conservation other than for birds
ECCC/Migratory Bird Sanctuary (MBS)	SS: 4, WVI: 0 • Victoria Harbour • Shoal Harbour • George C. Reifel • Esquimalt Lagoon	Protection and conservation of migratory birds and are managed by the Canadian Wildlife Service.	• Long term • Can be established anywhere • High Ocean Act protections standards for future MBS	• Limited application to marine conservation other than birds • Potentially harmful activities allowed • Monitoring and enforcement not well funded.
DFO/ Rockfish Conservation Area (RCAs)	SS:84, WCVI:19	Refuges to allow rockfish populations to rebuild	• Easily implemented • Allow for network planning • Prohibit fishing and bycatch • Indirect habitat protections	• Temporary • Apply only to fishing of rockfish • Species-specific habitat protections • Don't require a management plan or effectiveness monitoring

Provincial				
BC Parks/BC Marine Provincial Parks and other Parks with marine zones	SS-22, WCVI-24	Preservation of natural marine environments and recreation	• Long term • Strong habitat protections • Fines for breach of regulations	• No authority over federally regulated activities e.g. fishing, oil and gas • Recreational values often take precedence over ecological values • Vulnerable to development • Legislation is discretionary over what is permitted or prohibited
BC Parks/ Ecological Reserve (ER)	SS: 3, WCVI-7: • Rose Islands • Ballingal Islets • Hudson Rock • Anne Vallee (Triangle Island) • Baeria Rocks • Beresford Island • Checleset Bay • Klaskish River • Sartine Island • Tahsish River	Preserve representative and special natural ecosystems, plant and animal species, features, and phenomena	• Long term • Strong habitat protections • Consumptive activities prohibited	• Small so less resilient and adaptive • No requirement of management; • Lack for coordination between levels of government (e.g. commercial fisheries often allowed, not consistent with purpose)
Ministry responsible for *Wildlife Act*/ Wildlife Management Area (WMA)	SS-5. WCVI-1: • Parksville-Qualicum Beach • Roberts Bank • Boundary Bay • Sturgeon Bank • Skwelwil'em Squamish Estuary • Tofino Mudflats	Protection of fish and wildlife and their habitats	• Long term • Some harmful activities are prohibited • Can increase connectivity between other protected areas. • Breaches of regulation publishable by fines and other remedies	• Protective tools often not used • Often out of date management plans

Effectiveness of MPAs to Protect Eelgrass

Federal MPAs with marine zoning in the Salish Sea and WCVI region include two National Park Reserves managed by Parks Canada (PC), three National Wildlife Areas, and four Migratory Bird Sanctuaries under the Ministry of Environment and Climate Change Canada but managed by the Canadian Wildlife Service, and close to 100 Rockfish Conservation Areas (RCAs) under DFO.

Provincial MPAs with marine zoning in the region include 46 Class A[48] Provincial Parks[49] and ten Ecological Reserves managed by BC Parks, and six Wildlife Management Areas which are under the Minister responsible for the *Wildlife Act*, currently the Minister of Forests, Lands, and Natural Resources and Rural Development. BC Parks also manages Protected Areas[50] and Conservancies[51], which are not included in this report because none in the region currently have marine zones (Stephen Ban, personal communication, 2025).

No MPAs in BC have been established to specifically protect eelgrass habitat, one likely result of the lack of legal status for both the species and the habitat it provides. However, except for Rockfish Conservation Areas which can be temporary, federal and provincial MPAs are long-term and have the potential to provide indirect protection for eelgrass habitat under the general habitat protections specific to each MPA. In addition, eelgrass is often included in conservation measures within management plans and policies. Fish habitat protections of the *Fisheries Act*, Transport Canada regulations, and the BC *Wildlife Act* apply within all MPAs. The two categories of MPAs in the region with the strongest habitat protections that have the potential to indirectly protect eelgrass are federal National Park Reserves and BC Class A Parks with marine zones.

Federal National Park Reserves

Of all the MPAs in the region, National Park Reserves (NPRs) have the strongest general habitat protections under the Canada National Parks Act (2000) (Hewson et al., 2023, and references within). Importantly, PC can regulate fisheries within NPR boundaries (Hewson et al., 2023). Although recognized as an important ecological habitat by PC, eelgrass is not specifically protected within NPR boundaries (PC staff, personal communication, 2025). The NPA does provide species and ecosystems general protection from harm with any work within the NPR requiring approvals. SARA, the Fisheries Act, Rockfish Conservation Area prohibitions, and Transport Canada Regulations all apply within NPRs, with enforcement supported by Park Wardens.

In each of the two NPRs, eelgrass habitats have been monitored since 2005 for eelgrass fish community biodiversity under Parks Canada Coastal Health Assessment Eelgrass Monitoring Program (Government of Canada, n.d.b) and each NPR's Ecological Integrity Monitoring Program (Parks Canada, 2014). A mapping and monitoring component to assess changes in eelgrass extent and distribution in response to environmental factors, including boat traffic and anchoring, was piloted in 2010 (Reshitnyk 2017a,b, 2018a,b; Reshitnyk et al., 2024).

48. Class A is one of three provincial park classifications and the most restrictive for development activities.
49. Includes BC Marine Provincial Parks and other Provincial Parks with marine zones.
50. A Protected Area is land where the administration of the land use considers the preservation and maintenance of the natural environment while generally allowing one or more activities not usually permitted in a park.
51. A Conservancy is Crown land set aside for protection and maintenance of biodiversity and natural environments, recreational value, and social, ceremonial, and cultural use by First Nations, as well as development or use of natural resources consistent with the other purposes. First Nation Guardians are the primary stewards.

Drone imagery from Parks Canada and Hakai Institute eelgrass mapping at Grice Bay, Long Beach Unit Pacific Rim National Park Reserve. Credit: Hakai Institute

Drone Mapping at Parks Canada's National Park Reserves

As part of Parks Canada's long-term Coastal Health Assessment (Government of Canada, n.d.b.) of the status and condition of indicator ecosystems, staff have been mapping and monitoring eelgrass since 2004 using walking or boat surface surveys which can be time-consuming and difficult to replicate. To try to overcome these limitations, Parks Canada partnered with the Hakai Institute (hakai.org) to test the use of drones (also known as unmanned aerial systems or UAVs)[52] to map and monitor eelgrass, in combination with towed underwater cameras to map subtidal eelgrass beds. Since 2017, the spatial extent of eelgrass beds has been mapped at 21 sites in Pacific Rim National Park Reserve (10 sites in the Broken Group Islands Unit and 11 sites in the Long Beach Unit) (Reshitnyk, 2017a, 2018a) and at 10 sites in the Gulf Islands National Park Reserve (Reshitnyk, 2017b, 2018b). Drone surveys are proving to be low cost and allow for flexible survey timing when conditions are favourable (e.g., low tide, clear water quality) (Nahirnick et al, 2018).

While the 2017 and 2018 drone surveys are helping Parks Canada to establish a baseline, the long-term goal is to reveal trends. To that end, a focussed study at four sites in the Gulf Islands National Park Reserve in 2024, using UAV and fixed wing aerial surveys, combined with towed underwater camera and walking surveys, showed declines in eelgrass extent of 10 per cent at Sidney Spit (compared to 2008), 20 per cent at James Bay (compared to 2017), and 30 per cent at Cabbage Island (compared to 2018), and increased fragmentation at Tumbo Island (Reshitnyk et al., 2024). Continued monitoring with mapping surveys conducted every two to three years is recommended in order to identify changes and inform conservation strategies.

52. also known as remotely piloted aerial systems (RPAS) or unmanned aerial systems (UAS)

BC Parks

All BC Parks in the region with marine zoning are Class A Parks, which are established for environmental protection and recreation under the BC *Park Act* (1996) and the *Protected Areas Act* (2000), with hefty fines and even imprisonment for breaches of the Acts. However, there are some significant weaknesses with the legislation related to the problem of overlapping jurisdiction (Hewson et al., 2023, and references within):

- The province cannot prohibit federally regulated activities including shipping, commercial fishing, offshore oil and gas, and mining from provincial parks. BC Parks can and has requested fisheries closures from DFO for some provincial parks, but action is not guaranteed.
- The Minister has discretionary power over permitting which can result in development activities that cause ecosystem damage, with examples of permitting where recreational values take precedence over environmental values.
- Class A parks established by Order in Council under the *Park Act* rather than a Schedule to the *Protected Areas Act* can be more vulnerable to development.

BC Parks staff oversee mapping and monitoring of eelgrass beds, sometimes in partnership with First Nations and DFO, to learn more about current and historic extent to inform management actions (Baker-French et al., 2024; Baum & Csordas, 2023; Christensen et al., 2023). Examples are mapping initiatives at Háthayim (Von Donop) Marine Provincial Park and Manson's Landing Provincial Park on Cortes Island and Rebecca Spit Marine Provincial Park on Quadra Island by Project Watershed and EcoFish Research Ltd, and mapping at Desolation Sound Marine Provincial Park in partnership with the University of British Columbia (see Chapter 2, Table 2.6).

One area of concern that affects both NPRs and BC Parks with marine zoning is the impact of recreational boating on eelgrass. Both PC and BC Parks are undertaking initiatives to address the problem. Measures taken within both NPRs are the installation of mooring buoys in some anchorages, support for No Anchor Zones in eelgrass beds (although not yet in place or enforceable if boaters drop their anchors in the beds) and education to visitors about the importance of eelgrass and eelgrass conservation (PC staff, personal communication, 2025). Similarly, in some areas, BC Parks is implementing No Anchor Zones and eelgrass bed zone markers, installing mooring buoys and stern ties to encourage boaters to moor outside eelgrass beds, and conducting outreach with educational signage (Erica McLaren, personal communication, 2025; Raymond et al., 2025). Not all of BC's marine provincial parks have implemented these types of programs. Success of the initiatives rely on voluntary compliance by boaters and oversight by park wardens.

Credit: C. Doucet

Indigenous Protected and Conserved Areas (IPCAs)

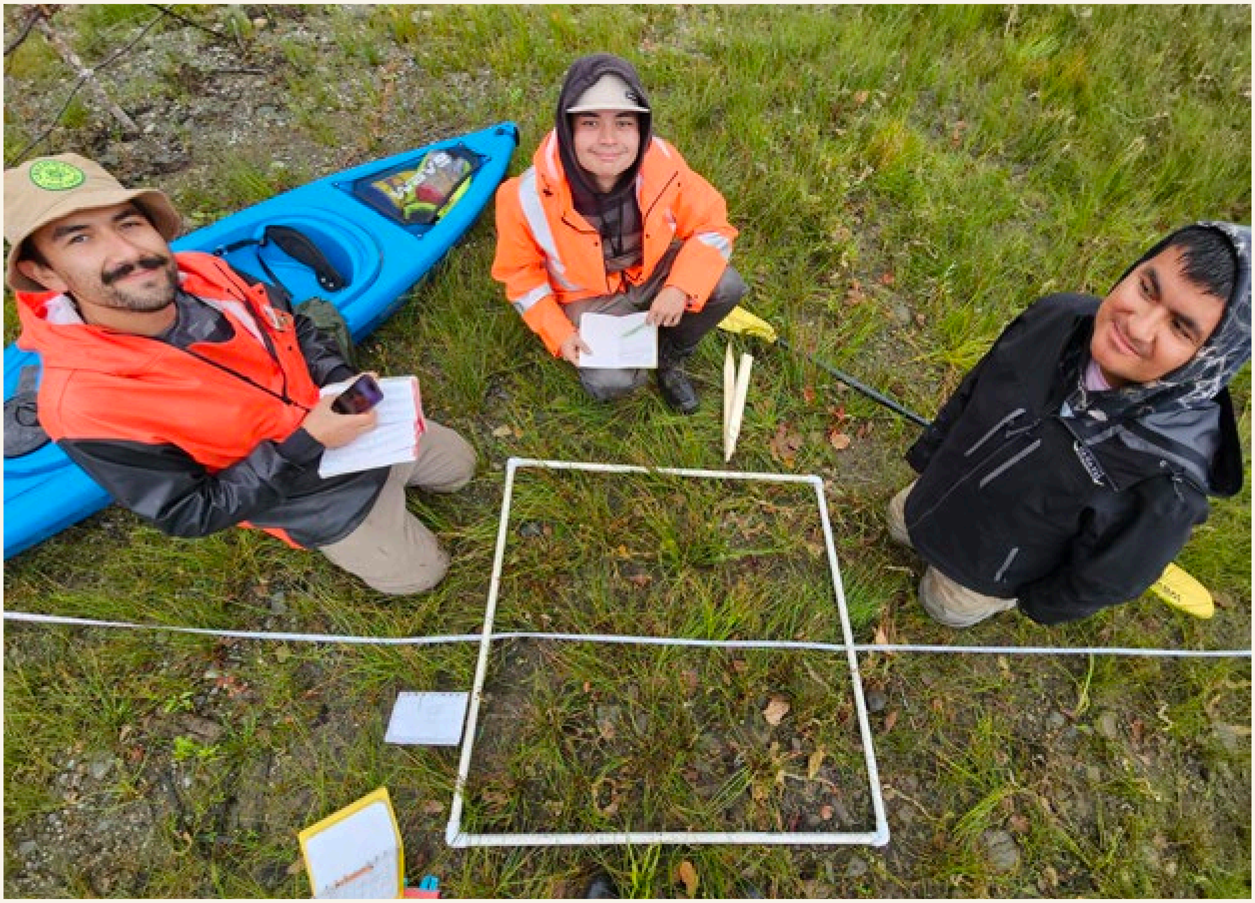
> **Indigenous-led conservation and management is the way forward in BC — the way forward in the world.**
>
> - Tim Clermont; ED. Guardians of our Salish Estuaries (GOOSE). From video Explore Qen, T

Indigenous Protected and Conserved Areas are Indigenous-led conservation initiatives to protect, conserve and steward areas of land and water in their traditional territory to elevate Indigenous rights, sovereignty and responsibilities (The Indigenous Circle of Experts, 2018). Proposed as a concept by the Indigenous Circle of Experts (ICE) in 2017, IPCAs vary in their structure, governance, and management goals, and are governed by the Indigenous laws, traditions and knowledge of the Indigenous group which defines it. Fundamental to IPCAs is a commitment to long-term conservation, and the management and monitoring of ecosystem health and restoration by Indigenous Guardians. IPCAs might be solely governed and managed by the declaring Nation or in partnership with other governments and/or NGOs. One example in the WCVI region of such a partnership was the South Coast European Green Crab Control Project (SCEGCCP) (Coastal Restoration Society, n.d.) to protect eelgrass beds in Tla-o-qui-aht and Ahousaht territory, a project profiled in Chapter 3.

The relationship between IPCAs and provincial and federal governments is guided by the United Nations Declaration on the Right of Indigenous Peoples (2021) (UNDRIP) and, also for BC, the Declaration on the Rights of Indigenous Peoples (2019) (DRIPA). IPCAs in the region frequently overlap with other protected and conserved areas such as National Park Reserves, BC Parks, Ecological Reserves and Conservancies. While IPCAs are not always recognized by other governments, they are often supported by funding from federal and provincial agencies, NGOs, conservation partners and foundations.

Two IPCAs have been declared in the Salish Sea and WCVI region. Tla-o-qui-aht Tribal Parks (www.tribalparks.com) was first declared in Clayoquot Sound in 1984 to stop the logging of ancient forests on Meares Island. The Tribal Park now includes four individual IPCAs in the territory, encompassing 76,000 hectares of critical habitat. QEN, T Marine Protected Area, declared in 2023 by the SȾÁUTW̱ (Tsawout) First Nation on Vancouver Island to protect 155 square kilometres of marine territorial waters, is the second and newest IPCA in the region (Tsawout/ SȾÁUTW̱/ First Nation, n.d).

Credit: Rick Harbo



Wei Wai Kum Guardians Jordan Labbé, Cool Cliffe, and Joey Henderson monitor salt marsh vegetation as a part of the Mill Pond Restoration Project in the Campbell River Estuary. Credit: Greenways Land Trust

Indigenous Guardians: Eyes and Ears on the Land and Water

Indigenous Guardians (also called Guardian Watchmen) are Nation members who act as 'eyes and ears' on the land and waters within their respective territories as a whole, or in their IPCAs, and within other protected areas (e.g. BC Parks and Parks Canada have Guardian programs) (BC First Nations Energy and Mining Council & UVic Environmental Law Centre, 2020; Hewson et al., 2023, and references within). Guardians play a wide range of stewardship roles in support of their Nation's laws and responsibility to the land and water. Their duties include ecological data collection, biodiversity mapping and monitoring, restoration, and maintenance and inventory of cultural and sensitive sites. Guardians play an important role as mentors to their community's youth and a knowledge bridge between their elders and leaders whose obligations may include the enforcement of Indigenous laws and prohibitions within their territory. Most Indigenous Guardians have no official enforcement capability as their powers have been limited by Crown governments. This is starting to change with a recent pilot project between the Kitasoo Xai'xais and Nuxalk Nations and BC Parks that grants Guardians the same enforcement tools within BC protected areas as park rangers. Guardian Programs are becoming a vital component of biodiversity protection in BC and worldwide and a pillar of Indigenous conservation as Canada works to achieve 30 per cent protection targets by 2030.

> **For all of our projects, we try to identify areas where the Guardians could support the work.**
>
> - Caitlyn Pierzchalski, Executive Director, Project Watershed

ALTERNATIVE CONSERVATION MEASURES

Outside of MPAs, eelgrass protection relies on DFO fish habitat legislation and policies and Transport Canada navigation and marine pollution provisions, both which have limitations to address many of the multiple stressors impacting eelgrass. To fill the gap, First Nations, conservation organizations, and local communities are taking the initiative, often with funding support from government agencies, to put voluntary measures into place to protect eelgrass and to educate the public about the ecological, cultural, and social importance of eelgrass ecosystems.

Recreational boating, which is poorly regulated along the BC coast, poses a particular problem to eelgrass everywhere, causing damage to eelgrass habitat from temporary anchorages and permanent moorings, derelict boats washing onto shore or sinking in eelgrass beds, and both legal and illegal dumping of sewage (see Chapter 3). Eelgrass conservation outreach and education directed toward the boating community and the general public is taking the form of printed material, public talks, and signage installed at marinas, docks, and boat ramps (Figure 5.3). Inspired by eelgrass conservation work done in the US Salish Sea by Northwest Straits Commission (n.d.), SeaChange has worked with coastal communities such as Bowen Island in Howe Sound and the District of Oak Bay to install Voluntary No Anchor Zone buoys to alert boaters to stay clear of eelgrass beds when mooring or transiting an area where eelgrass grows. Low impact boat mooring systems, installed in eelgrass beds in places where moorage cannot be prevented, do not scour the seafloor as the moored boats swing. They have been installed in Ford Cove on Hornby Island, Mannion Bay on Bowen Island, Sechelt Inlet, and Clam Bay on Thetis Island (Figure 5.4).

Figure 5.3 Public education is an important component of eelgrass conservation.
Credit: SeaChange Marine Conservation Society

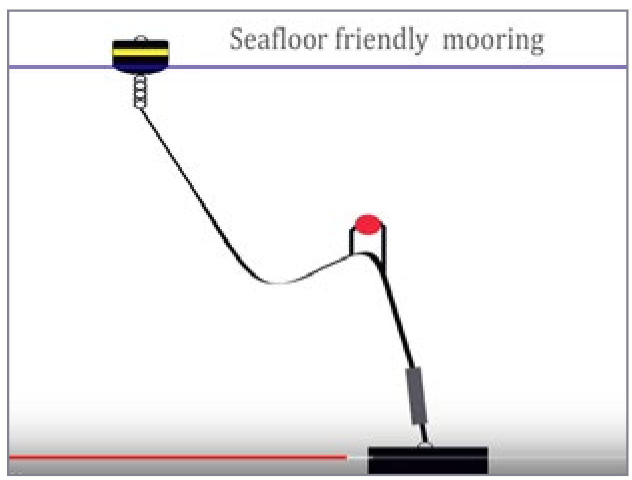
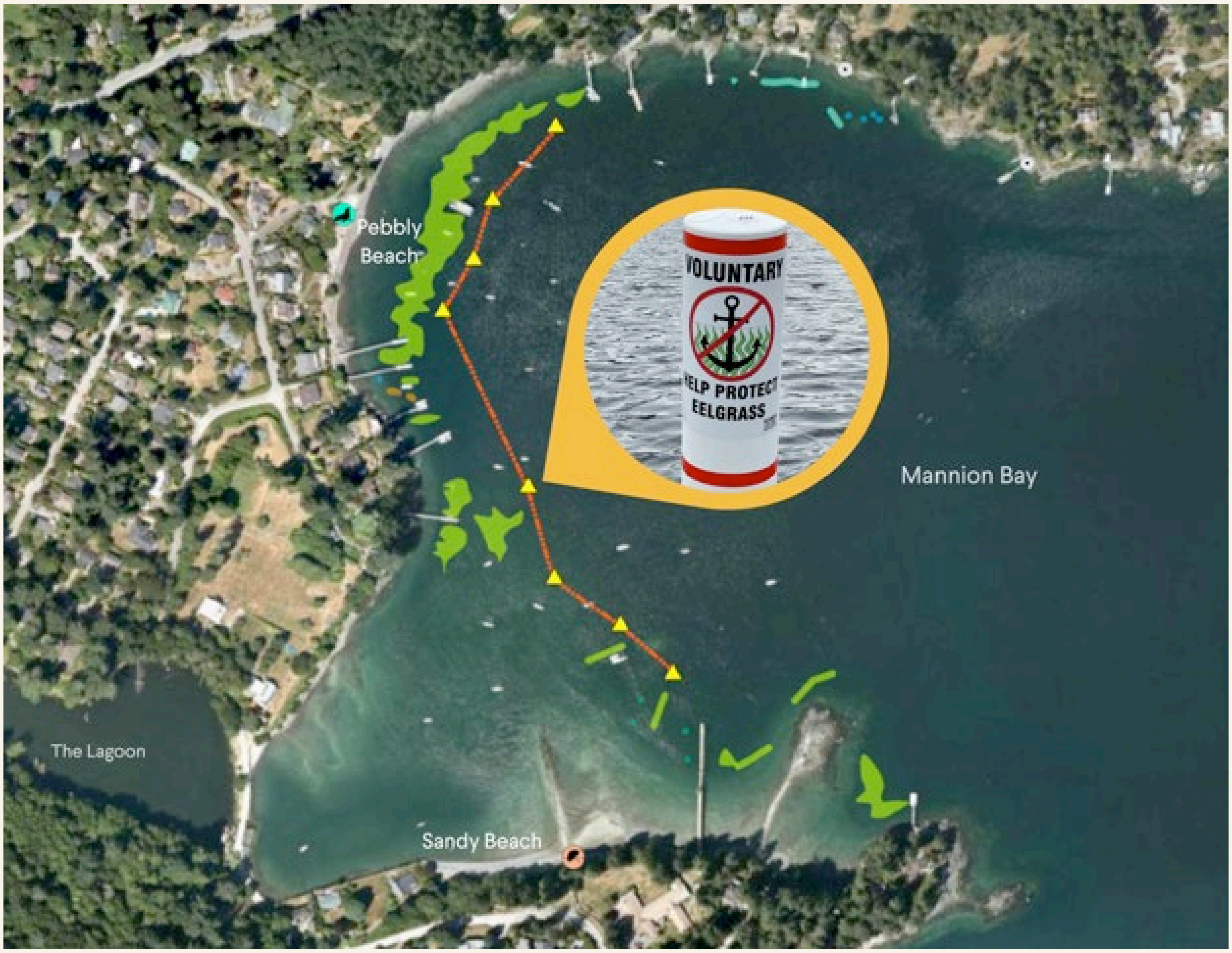


Figure 5.4 Where boat moorage in eelgrass beds cannot be prevented, a low impact boat mooring system is an option that does not damage the eelgrass. Credit: Jamie Smith



In partnership with SeaChange Marine Conservation Society, the Bowen Island Municipality has planted eelgrass and installed a voluntary No Anchor Zone as part of its Mannion Bay Revitalization program. Credit: Carla Skuce

Bowen Island Planning for Eelgrass Conservation

The Bowen Island Municipality in Howe Sound has been proactively protecting marine nearshore areas through the passing of Land Use Bylaws to regulate docks. The Water General (Coastal) Zone, in part, specifically prohibits community docks, and private or group moorage facilities from negatively impacting eelgrass meadows, beds, or patches. Further restrictions on moorage facilities are placed in a specific zone at Cape Roger Curtis. Most recently, in 2018 the Municipality increased these protections to not allow private moorage facilities in areas with eelgrass beds or patches — previously the regulations only prohibited docks in areas of continuous eelgrass meadows.

In addition, the municipality has secured a thirty-year Licence of Occupation from the province in Mannion Bay that allows it to manage mooring buoys for the purpose of restoring marine ecosystems. In partnership with SeaChange Marine Conservation Society, the municipality has planted eelgrass and installed a voluntary No Anchor Zone as part of its Mannion Bay Revitalization program (Bowen Island Municipality, n.d.).

Other actions include beach and subtidal debris removals at Degnen Bay, Gabriola Island and Maple Bay, Lasqueti Island (Figure 5.5) to clean up seafloor garbage from bays and estuaries to allow eelgrass beds to recover naturally.

One of the most critical unofficial protections for eelgrass habitats contributed by informed and engaged local communities, conservation groups and First Nations involved in eelgrass restoration work is to be eyes and ears on the water to prevent damage to eelgrass beds before it happens (Nikki Wright, personal communication, 2025). Marine Guardians are increasingly filling this role (BC First Nations Energy and Mining Council & UVic Environmental Law Centre, 2020), along with local communities and stewardship organizations engaged in eelgrass conservation.

Figure 5.5 Removing debris from damaged eelgrass beds helps them recover naturally.
Credit: Ann Eriksson

THE WILD CARD: CLIMATE CHANGE AND EELGRASS PROTECTION

Whether in a formally protected area, a voluntary protection zone, or under the watchful eye of a Guardian, eelgrass ecosystems are and will be increasingly vulnerable to sea level rise, ocean warming and marine heat waves, and more frequent and intense storms from climate change. The many multiple and cumulative stressors to eelgrass do not stop at MPA boundaries. Marine planning and MPA management plans do not always consider these aspects (Griffiths et al., 2020). To give eelgrass and other nearshore habitats the best chance of survival in the unpredictable future, an expanded climate-smart MPA network design that increases connectivity, identifies and protects refugia where impacts may be less severe, and that minimizes multiple and cumulative impacts, is essential (Arafeh-Dalmau et al., 2023, and references within; Graham et al., 2024). Cooperation among all parties involved in coastal nearshore management is urgently required (Hewson et al., 2023).

CHAPTER FIVE LESSONS LEARNED

- ☑ *Zostera marina* habitat lacks legislated status in BC which makes it vulnerable to declines.
- ☑ BC has lacked overarching coastal and marine legislation, which may be rectified by the implementation of the BC Coastal Marine Strategy, released in 2024 but not yet legislated.
- ☑ While BC has jurisdiction over the seabed, it lacks the authority to regulate most of the activities that have the greatest impact on eelgrass beds (i.e. fishing and boating).
- ☑ Indigenous Conserved and Protected Areas (IPCAs) and Guardian programs are becoming increasingly important for marine protection.
- ☑ While eelgrass is not explicitly mentioned in the federal Fisheries Act, it is protected under fish habitat protection provisions which prevent the harmful alteration, disruption, or destruction (HADD) of fish habitat without prior authorization by the Minister. Authorization of HADD may require habitat offsetting.
- ☑ General habitat protections within existing MPAs have the potential to indirectly protect eelgrass, but overlapping jurisdictions over coastal and marine habitat can hamper the effectiveness of protections.
- ☑ Local governments have the ability to influence coastal and marine protections through their land use planning authority and jurisdiction over shoreline development.
- ☑ Climate-smart MPA design and expansion is necessary in the face of the changing climate and cumulative impacts.
- ☑ Outside of MPAs, conservation groups, First Nations, and local communities are putting voluntary measures in place and educating the public to protect eelgrass habitats.

Next Chapter: Looking Back, Moving Ahead: Gaps in Knowledge and Recommendations for Action.

CHAPTER SIX
LOOKING BACK, MOVING FORWARD: KNOWLEDGE GAPS AND RECOMMENDATIONS FOR ACTION

Explore Eelgrass and Estuaries
(4:11 min) Credit: Nikki Wright and Sarah Verstegen

INTRODUCTION

As the world finds itself in the era of climate change, it is more important than ever to take action to protect nature and to implement nature-based solutions to reduce the impacts of escalating, multiple, and cumulative stressors on ecosystems such as eelgrass. Much needs to be done to fill in the knowledge gaps. Implementing actions, particularly legislation, can take time. Realizing the rights and title of Indigenous Peoples is a complex opportunity. Changing environmental conditions will confront scientists, managers, and practitioners with new avenues of exploration and new problems to solve. However, as expressed by participants at the Eelgrass Symposium held in Campbell River in October 2024, restoration, conservation and management "[must] proceed even in the face of knowledge gaps; a need to know is not an excuse [for inaction]" (Wright, 2024).

> "Eelgrass restoration, conservation, and management **[must] proceed even in the face of knowledge gaps; a need to know is not an excuse [for inaction].**"
>
> - Wright, 2024

This chapter identifies gaps in knowledge about eelgrass ecology as it pertains to salmon conservation, eelgrass distribution, mapping and monitoring, restoration, and protections, and makes recommendations to fill those gaps. Unless cited otherwise, gaps and recommendations are largely sourced from the proceedings of the Eelgrass Symposium hosted at Campbell River (Wright, 2024). The chapter is organized by the five broad topic areas reflecting the previous chapters.

PSF's Greening the Salish Sea project is taking the initiative to fill some of the identified gaps. Recommendations that are already being implemented are marked with an asterisk. This Eelgrass State of Knowledge Report ends with strategies for the sharing of knowledge, a gap clearly identified by symposium participants and echoed in the literature, and which will be instrumental to advancing eelgrass stewardship, conservation, and protection initiatives in the Salish Sea and WCVI region and beyond.


Credit: Angela Spooner

Greenways Land Trust staff and volunteers with Wei Wai Kum Guardians. Credit: Greenways Land Trust

Many Hands: Eelgrass Restoration Through a Socio-ecological Lens

'If you don't build a relationship with the First Nations Guardians, there will not be success.' Katherine Lavoie ED Greenways Land Trust and Jordon Labbe, Wei Wai Kum Stewardship

The Mill Pond Restoration Project in the Campbell River Estuary has been a success because of the many relationships that were developed before the project even applied for funding (Lavoie & Labbe, 2024). The project, to restore two-hectares of saltmarsh, eelgrass, and riparian habitat for salmon at Mill Pond south of Baikie Slough, was started in 2023 as a partnership between Greenways Land Trust and the Wei Wai Kum First Nation and their Guardians. The site lies within an ecological covenant held by the Nature Conservancy of Canada and is co-managed by the Campbell River Estuary Committee which includes Indigenous local Nations, Ducks Unlimited, the Municipality of Campbell River, recreational users, DFO, and others. Under the guidance of Cynthia Durance of Precision Identification, Guardians and community volunteers, including employees of the logging industry, planted 70,000 eelgrass shoots during the restoration. The relationships continue along with the work to restore the Mill Pond and to manage the area going forward, informed by Traditional Ecological Knowledge, community science, and academia. Overall, the goal of the project is to restore 22,000 m^2 of habitat in the estuary. The partners consider outreach to the community and visitors an essential tool for nurturing a positive public perspective about and support for the restoration of nearshore salmon habitat and its ecological and cultural importance.

GAPS AND RECOMMENDATIONS

KNOWLEDGE ABOUT EELGRASS ECOSYSTEMS AND THEIR IMPORTANCE TO PACIFIC SALMON

- **Gap:** Lack of documented Indigenous Traditional Ecological Knowledge about eelgrass stewardship for salmon habitat.
- **Recommendation:** Fund/collect oral histories of eelgrass cultural uses and location according to Indigenous protocols.

- **Gap:** Ability to identify and communicate knowledge gaps.
- **Recommendation:** Increase networking between academia and restoration practitioners.*

- **Gap:** Lack of knowledge comparing use of pre- and post-restoration eelgrass beds by salmon (and other species).
- **Recommendation:** Fund/collect salmon presence information (e.g. using eDNA sampling, underwater wildlife camera surveillance) in reference and transplant sites to compare biodiversity.

- **Gap:** Lack of knowledge about the connectivity between 'eelgrass neighbourhoods' and increased biodiversity in close proximity to one another.
- **Recommendation:** Fund/collect eDNA samples in adjacent and non-adjacent eelgrass sites to compare biodiversity.

- **Gap:** Lack of knowledge about the population genetics of *Z. marina* (Arbeider et al., 2024; Gross et al., 2024).
- **Recommendation:** Fund/conduct research into *Z. marina* population genetics.

- **Gap:** Lack of knowledge about the importance of the microbiome for eelgrass function and plant survival.
- **Recommendation:** Fund/conduct eelgrass microbiome research.

- **Gap:** Lack of knowledge about the possibility to reconstruct growth using rhizomes.
- **Recommendation:** Fund/conduct research into reconstructing growth using rhizomes.

- **Gap:** Lack of mapping of epiphytes on eelgrass leaves.
- **Recommendation:** Fund/conduct research about eelgrass epiphytes.


Credit: Ann Eriksson

EELGRASS DISTRIBUTION

- **Gap:** Lack of knowledge about the health of eelgrass rhizomes in summer as an indicator of winter survival when light levels are low.
- **Recommendation:** Fund/conduct comparisons; record observations during transplants (e.g. photos at different times of year).

MAPPING AND MONITORING OF EELGRASS EXTENT

- **Gap:** Lack of reliable trend data (including historical mapping) and long-term eelgrass monitoring pre- and post-restoration.
- **Recommendation:** Secure multi-year 'Legacy' funds to ensure frequent and long-term monitoring (>five years) into the future.

- **Gap:** Restoration and monitoring vary in quality, methods, and legacy.
- **Recommendation:** Standardize data outputs such as data collecting apps, data sheets, etc., for mapping and monitoring.*

- **Gap:** Lack of guidance for evaluation of success over time.
- **Recommendation:** Provide guidance/guidelines through Practitioner Handbooks, videos and other materials; education (underway; see Networks and Communications below).*

- **Gap:** Need for polygon mapping of all eelgrass beds.
- **Recommendation:** Fund/conduct polygon mapping.

STRESSORS TO EELGRASS ECOSYSTEMS

- **Gap:** Lack of knowledge about the impacts of climate change on eelgrass health.
- **Recommendations:**
    - Investigate whether increases in sea surface temperatures increase the risk of wasting disease.
    - Conduct basic experimental data on responses/tolerance of eelgrass to ocean acidification and hypoxia (OAH).

- **Gap:** Causes of eelgrass decline/change not always evident.
- **Recommendations:**
    - Observe natural processes within a site before restoration begins.
    - Conduct pre-restoration monitoring of sediment and water quality.

- **Gap:** Multi-stressor and cumulative impact knowledge and policies are lacking.
- **Recommendations:**
    - Fund/conduct investigations into multi-stressor/cumulative impacts and mitigations for both.
    - Avoid inflicting damage to eelgrass plants and meadows during sensitive times of year (times of peak growth and greatest photosynthesis (spring, summer) (Murphy et al., 2021).
    - Promote a soft-shores approach to shoreline development.

- **Gap:** Data analysis needed to correlate removal of European Green Crabs with densities of eelgrass, clams and other nearshore species.
- **Recommendation:** Fund data collection /conduct data analysis in consultation with First Nations.

- **Gap:** Lack of knowledge about the effects of intense recreational boat use on eelgrass and its ability to serve as a foundation species.
- **Recommendation:** Fund/conduct analysis of boating impacts on eelgrass.

- **Gap:** Lack of knowledge about the eelgrass microbiota.
- **Recommendations:** Conduct microbiome research into:
  - Whether and how the microbiome mitigates the effects of hydrogen sulphides and low oxygen in sediments.
  - Microbiome differences between failed and successful transplant sites, and between thriving natural meadows and impacted or non-thriving meadows.

- **Gap:** Lack of knowledge about impacts of log dumps on eelgrass (Wright, 2018).
- **Recommendations:**
  - Investigate ways to improve sediment in former log storage sites (Wright, 2018).
  - Investigate whether duration of residence of a log dump in eelgrass habitat affects success of eelgrass recovery (Wright, 2018).

- **Gap:** Consultation process for log lease renewals requires improvements
- **Recommendations:**
  - Encourage BC to switch log dumps from water to land wherever possible in roaded areas.
  - Encourage BC to require fish access to eelgrass from natal streams/rivers.
  - Map areas where logs could be stored to minimize impact on eelgrass and fish survival and migrations.
  - Increase communication between local community members and local forestry operations.
  - Improve access to current LIDAR information for modelling and mapping watersheds and estuaries.

- **Gap:** Lack of TEK about restoration.
- **Recommendation:** Gather TEK about restoration including fish weirs and eco-cultural goose fencing.

Credit: Greenways Land Trust

> **"[T]he future of eelgrass restoration will not be realized/achieved through habitat offsetting for authorized projects; rather, a planning process aimed specifically at eelgrass restoration in the Salish Sea needs to be developed.**
>
> - Scott Northrup, DFO Restoration Centre for Expertise

RESTORATION

- **Gap:** Identification of priority sites for restoration.
- **Recommendations:**
    - Create a Framework for Restoration Priority Sites based on a large-scale eelgrass map of the Salish Sea and WCVI region.
    - Encourage entire watershed approach to restoration.

- **Recommendations:** Increase amount of eelgrass in region by:
    - Setting coast-wide or regional goal for restoration or increase in eelgrass habitat.
    - Using Habitat Suitability Modelling to identify suitable sites that historically had eelgrass but no longer do, or that have suitable habitat but many not have had eelgrass in the past (HSM underway by PSF).

- **Gap:** Efforts to climate-proof restoration efforts are needed.
- **Recommendations:**
    - Prioritize deeper sites that may be resilient to warming.
    - Use disease monitoring to identify individual eelgrass plants that are resistant to pathogens to use for restoration efforts (Graham et al., 2024).
    - Identify high-stress donor sites that may contain plants that are resilient to stressors.
    - Include climate-resilient plants in restoration projects.
    - Locate coastal areas with lower coastal squeeze considerations.

- **Gap:** Lack of guidance to restoration groups for knowledge transfer.
- **Recommendation:** Form Working Groups to share information and resources (see also Networking and Communications).

- **Gap:** Lack of knowledge about harvesting seed and ability to store or culture plants for future restoration.
- **Recommendations:**
    - Establish an eelgrass culturing facility (e.g., Ucluelet Aquarium).
    - Provide seeding protocol training.

- **Gap:** Lack of understanding of how genetic diversity affects restoration success.
- **Recommendation:** Fund/conduct research comparing genetic diversity in successful and failed restoration sites.

PROTECTION

- **Gap:** Too little eelgrass habitat is fully protected.
- **Recommendation:** Create an eelgrass lobby group that will:
  - Encourage federal government to increase the level of protection for eelgrass by legally designating eelgrass habitat as an Environmentally Significant Species (or similar legal status) on the BC coast (now only Atlantic coast);
  - Encourage federal government to specifically include eelgrass and other nearshore ecosystems in the definition of 'fish habitat' in the Fisheries Act;
  - Encourage federal and BC governments to protect the entirety of the Salish Sea;
  - Encourage federal and BC governments to set clear targets for eelgrass inclusion in MPA network planning (Murphy et al., 2021) in consultation with First Nations;
  - Encourage watershed/systems thinking approach by researching and documenting the effects of watershed activities on estuaries;
  - Educate local governments about actions they can take to proactively conserve eelgrass habitats;
  - Increase focus on Special Management Areas such as Indigenous Protected and Conserved Areas;
  - Encourage federal and BC governments to increase capacity for enforcement of regulations and protections (e.g. give more authority to Indigenous Guardians); and
  - Establish eelgrass data on Navionics and other boating navigation maps to alert boaters to the presence of eelgrass and Voluntary No Anchor Zones.

- **Gap:** Identification of climate-resilient eelgrass beds to prioritize for protection as refugia (Graham et al., 2024).
- **Recommendations:**
  - Use disease monitoring to create a climate-smart network of MPAs by protecting deep meadows with low *L. zosterae* severity as indicators of resilience to future warming and pathogen outbreaks (Graham et al., 2024).
  - Target deeper beds for protection.
  - Target beds with greater genetic diversity for protection.
  - Protect upland and promote natural shoreline restoration to allow eelgrass to move shoreward with sea level rise.
  - Protect eelgrass habitats less impacted by climate change (Alefeh-Dalmau et al., 2023).

- **Gap:** Lack of protection for eelgrass climate refugia.
- **Recommendations:**
  - Protect climate refugia from extractive activity (Guijaro-Sabaniel et al., 2023).
  - Establish marine reserves with First Nations where threats can be managed.
  - Incorporate connectivity and protection from cumulative threats and climate resilience into MPA design, with standardized indicators.
  - Encourage federal government to amend Oceans Act to include above recommendation.

- **Gap:** BC has no overarching laws for coastal planning or ecosystem-based planning (Hewson et al., 2023; Curran et al., 2024).
- **Recommendation:** Encourage BC government to legislate, fund and implement the BC Coastal Marine Strategy.

- **Gap:** Overlapping jurisdictions lead to confusion, conflicting decisions, and inaction that can result in eelgrass declines (Hewson et al., 2023).
- **Recommendations:**
  - Include eelgrass habitat within integrated coastal and marine spatial planning and management for the Salish Sea region.
  - Include eelgrass habitat in estuary planning.
  - Promote cooperation between Indigenous and other government agencies to protect eelgrass.

KNOWLEDGE SHARING

Cultural

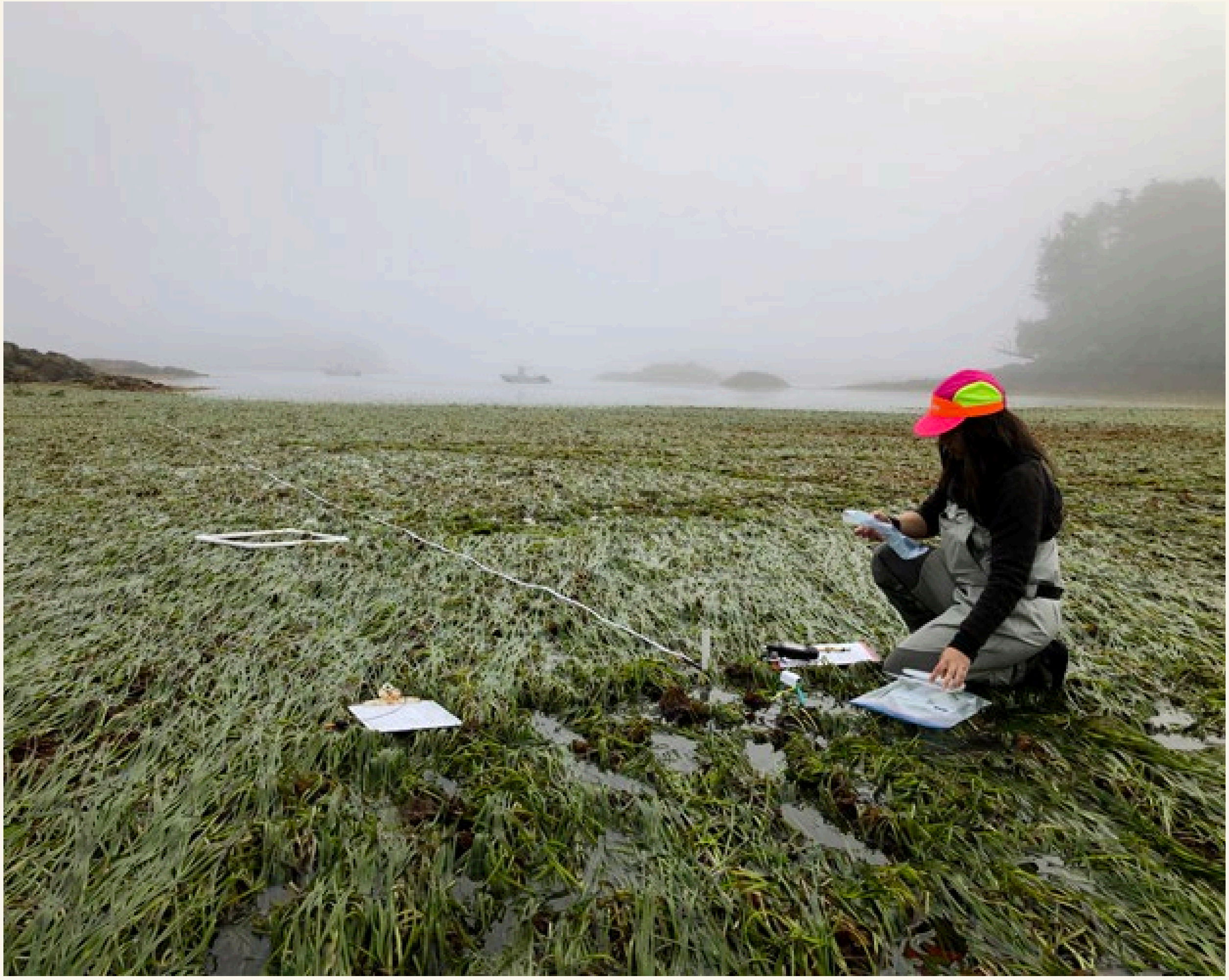
- **Gap:** Understanding of TEK as it relates to restoration and stewardship.
- **Recommendation:** Fund First Nations to collect and disseminate knowledge according to their protocols.

Public Education

- **Gap:** Lack of support, knowledge by public for eelgrass conservation.
- **Recommendations:**
    - Increase capacity of groups for outreach;
    - Increase lobby for habitat protection;
    - Share successes and failures; and
    - Improve communication and direct engagement with community members to reduce back-lash against restoration projects

Networking and Communications

- **Gap:** Restoration groups need guidance for knowledge transfer; and
- **Gap:** Restoration/conservation/and monitoring projects vary in quality control, methods and legacy
- **Recommendations :**
    - Develop a provincial Seagrass Coordination Framework funded by government and foundations.
    - Form regional Working 'Super' Groups of partners for implementing/promoting protections, restoration and monitoring (or revitalize the Seagrass Conservation Working Group and website).
    - Create a centralized, accessible, curated (and fully funded) BC coast-wide 'Restoration Hub' that provides (for example):
        - > A centralized databank of past and present restoration and conservation projects including those listed in the Provincial Front Desk BC database of projects that have been issued permits/approvals;
        - > A centralized databank of environmental data;
        - > A library of standardized protocols/best practices for restoration, mapping, and monitoring;*
        - > Sharing of information, knowledge and resources;*
        - > A list of experienced practitioners to advise site selection;
        - > Accessible Habitat Suitability models with detailed information to guide site selection;*
        - > Regularly updated contact list;
        - > Inclusive roundtable events between Indigenous, federal, provincial and local governments, industry, conservation groups, and community members;
        - > Engagement with the 'Seagrass Collective'; and
        - > Networking with other Canadian, US, and international eelgrass restoration and conservation practitioners and science groups (e.g., Seagrass Net).



Angeleen Olson conducting annual Hakai Institute seagrass monitoring.
Credit: Margot Hessing-Lewis, Hakai Institute.

Join the 'Seagrass Collective'

Contributed by Margot Hessing-Lewis, Hakai Institute

The "Seagrass Collective' is an emerging network of seagrass scientists and practitioners in BC and Washington State who are coming together to share information and knowledge on seagrass work that is happening in our region, with an aim of building more integrative science and management that spans this transboundary coastline. To get involved or for more information contact the Seagrass Collective at seagrass@hakai.org.

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