BUILDING CONNECTIONS FOR BLUE CARBON ACROSS CANADA

Restoration and Monitoring Workshop Report

Building Connections For
Blue Carbon Across Canada
Restoration and Monitoring Report
February 3rd, 2021
2nd in a Five Part Series
Summary Report
Prepared by WWF-Canada

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Cover photo: A causeway-aboiteau was upgraded with a causeway-bridge to restore a more natural hydrological regime and 82 hectares of tidal wetland, at Abrams River, Nova Scotia. The project included six years of pre- and post-restoration monitoring. Project partners include Nova Scotia Transportation and Infrastructure Renewal, CBWES Inc., and Saint Mary's University. © CBWES Inc.

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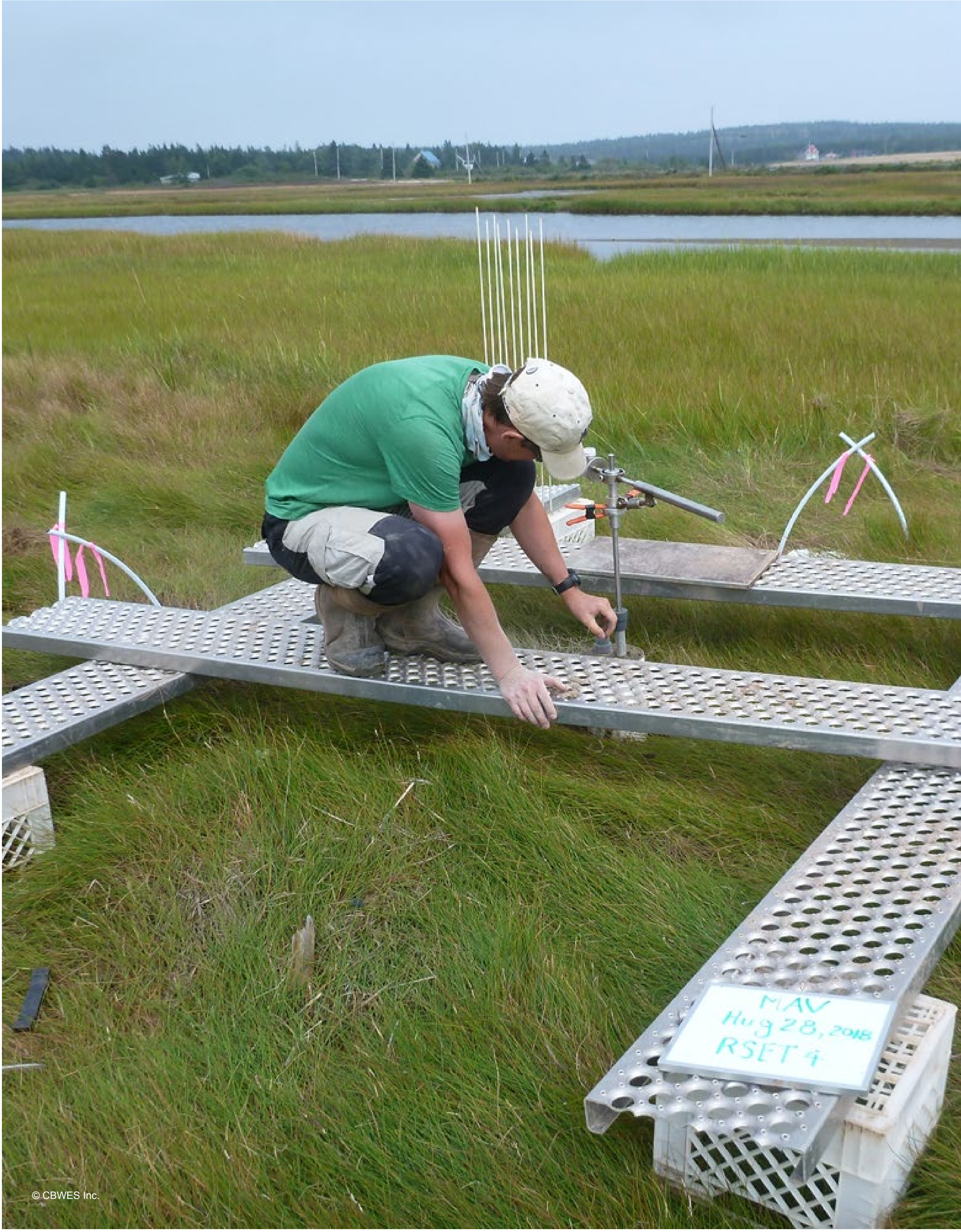
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SUMMARY

The restoration of blue carbon habitats can provide a variety of benefits and ecosystem services including carbon storage and climate change mitigation. A growing number of individuals and organizations are working on research, restoration, conservation and policy related to blue carbon ecosystems in Canada. To bring the community of practice together and identify knowledge gaps and opportunities for collaboration, WWF-Canada is hosting a five-part virtual workshop series.

This report summarizes the second workshop in the series, Restoration and Monitoring, which took place on February 3, 2021 and had over 75 attendees. This workshop aimed to tackle the question **How can we restore and monitor blue carbon systems to sequester carbon, increase biodiversity and be resilient to climate change?**

The major key takeaways from the second workshop were:

- Blue carbon ecosystems are highly variable within and among sites, which creates challenges for choosing and designing suitable restoration sites and monitoring programs.
- Key challenges to restoration and monitoring work are the cost, time and resource intensive nature of blue carbon field and lab work. Well-designed funding opportunities, training programs to increase capacity within the blue carbon community of practice and collaboration with a wide range of knowledge holders and skilled personnel can help address these challenges.
- Engagement with Indigenous governments and Indigenous conservation groups needs to happen very early on in project development, before grant applications are submitted. Working to understand the needs and priorities of Indigenous communities and supporting capacity building in Indigenous governments and organizations will help to build meaningful and lasting relationships.

Contact information for the attendees is provided, as well as additional links to blue carbon initiatives and resources, data and portals, and a copy of invited and speed talk presentations.

Photo: Tony Bowron taking measurements at one of six Rod Elevation Table stations at the Mavillette tidal wetland restoration site, Nova Scotia. The project replaced a failing bridge, restoring 99 hectares of wetland. Project partners include Nova Scotia Transportation and Infrastructure Renewal, CBWES Inc., and Saint Mary's University.

INTRODUCTION

Blue carbon – carbon stored in coastal ecosystems, such as seagrass meadows, salt marshes and kelp forests – can play an important role in the fight against climate change. However, blue carbon habitats have been and continue to be degraded or destroyed as a result of human activities and coastline development. Restoring blue carbon ecosystems, where feasible, could increase the amount of carbon stored along our coastlines. Yet, to maximize the carbon storage potential of our blue carbon habitats, we need a deep understanding of carbon cycling in these ecosystems.

The carbon dynamics in coastal ecosystems are highly variable, both within habitats and across regions. Blue carbon habitats can be a source of carbon emissions as well as a sink for carbon storage. Understanding carbon dynamics in our ecosystems requires long-term monitoring using robust and comparable methods. Gaining this understanding will facilitate the tracking of carbon storage along our coasts and support the design of effective restoration projects.

There are many restoration practitioners working across Canada in the marine environment. Restoration projects are designed to provide a wide range of benefits and increased carbon storage could be included as an objective in restoration projects where appropriate. To bring the community of practice together and identify knowledge gaps and opportunities for collaboration, WWF-Canada is hosting a five-part virtual workshop series. The objectives of the sessions are to:

- Facilitate connections within the blue carbon community and share information on ongoing blue carbon work;
- Discuss key questions on blue carbon research, policy and application; and
- Identify areas of opportunity to advance collaboration on blue carbon across Canada.

The second workshop in the series focused on restoration and monitoring and aimed to tackle the question: **How can we restore and monitor blue carbon systems to sequester carbon, increase biodiversity and be resilient to climate change?** At the workshop, participants were asked to name the benefits that come to mind when thinking of blue carbon restoration and monitoring projects. The following diagram displays participant answers; larger font sizes indicate words more frequently mentioned.

Photo: Jennie Graham from CBWES conducting an elevation survey within a tidal salt marsh channel, Bay of Fundy. The data from research and monitoring activities like this helps CBWES understand the form and function of these dynamic coastal systems and improves the ability to design habitat restoration and climate change adaptation projects.

At the workshop, a series of four invited speakers provided talks to set the stage for a breakout group discussion session. Following the discussion session there was a series of three speed talks aimed at introducing members of the blue carbon community.

During the breakout group discussion session, participants chose one of the following questions to explore with their fellow group members:

1. What are the current **best practices for collecting carbon accumulation, sequestration and flux data**, what are the limitations and how do we incorporate these measurements into restoration projects?
2. How do we determine the **suitability of a site for restoration** and what are the **baseline knowledge needs**?
3. How do we **design** restoration projects to ensure we maximize **social, economic, ecological and cultural benefits**?
4. How do we **develop and implement effective monitoring plans** for restoration projects?
5. How can we ensure we include **multiple sources of evidence including local, Indigenous and scientific knowledge** to strengthen our restoration projects?

This report summarizes the invited talks and discussion sessions from the restoration and monitoring workshop, highlighting key takeaways as identified by participants. The restoration and monitoring workshop will be followed by workshops focused on policy, ecosystem approach and next steps.


Soil core with depth increasing to the right. The knife blade indicates the agricultural horizon. © Gail Chmura


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INVITED TALK SUMMARIES

Allen Beck, Clean Foundation

Clean Coasts – Coastal restoration and blue carbon

The Clean Foundation works towards a clean climate and clean water. To achieve their goals, the Foundation fosters, educates and supports clean leaders in the community. Within the Clean Foundation, the Clean Coasts Team uses Nature-based Solutions to create healthy, resilient coastlines that help protect ecosystems, built environments and livelihoods from the risks of climate change. They monitor and assess ecosystem health by gathering information from existing research studies and generating new data on water quality, hydrology, typography, flora, fauna, and soil. The Clean Coasts Team takes a Two-Eyed Seeing (Etuaptmumk) approach to their work by interviewing Elders, incorporating Traditional Knowledge, specifically Mi'kmaw Ecological Knowledge (MEK), engaging with Crown and Indigenous governments and communities, and working with technical partners. They also work to make the data they generate accessible and free through the CLEAN Dataverse repository on their website and their Online Atlas. Building capacity is an important part of the Clean Coasts Team's work. They do this through public events, online workshops and webinars, newsletters and social media and through engaging and training volunteers in coastal restoration initiatives.

One example of the Clean Coast Team's Nature-based Solutions approach is the restoration of the natural flow of a tidal river and adjacent salt marsh habitat, enabling fish passage, at their Marshall's Crossing site. This involved replacing undersized, failing culverts, which were obstructing the tidal river flow, with a bridge. To address erosion on one side of the bridge they implemented a living shoreline approach using natural materials to stabilize the bank, enabling the migration of native plants and the rebuilding of salt marsh habitat in a way which will be resilient to sea level rise.

The Clean Coasts Team's current work on blue carbon is focused on sample collection at their restoration sites. However, they are facing funding restrictions which prevent the analysis of these samples. Moving forward the Clean Coasts Team would like to incorporate blue carbon work into all their projects, contribute to a gear library to facilitate blue carbon work, and provide training on blue carbon sampling techniques to enable the collection of standardized data.

Including communities in blue carbon projects and in the data collection process is essential for success. For example, 86 per cent of the Nova Scotian coastline is privately owned. Therefore, considering public perceptions and land-use practices, providing information on the importance of maintaining coastal health, and including community science in project design and implementation is very important.

Animations are an effective way to communicate complex ideas to the public and demonstrate the planned impact of shoreline restoration projects. For example, the Clean Coasts Team has used a 3D model and animation, based on drone imagery, to demonstrate the hydrology, sediment dynamics and plant colonization at the Sitmu'k reef ball site in partnership with The Mi'kmaw Conservation Group (MCG). The animation provides information to the public on how the project works, what the reef ball deployment looks like, and the impact of the project to the coastline.

KEY TAKEAWAYS

- We need to ensure that going forward blue carbon objectives and metrics will be considered as eligible for funding under calls for proposals for restoration projects.
- Effectively communicating complex ideas to the public and involving them where possible in skill-building workshops and training is essential to gaining support for healthy coastal ecosystems and integrating community science into restoration and monitoring projects.

Dr. Gail Chmura, McGill University

Reflooding Drained Salt Marshes Has Immediate Carbon Storage Benefits

Recent research by Gail and her colleagues[1] shows that managed realignment of coastal dyke systems can lead to the storage of a significant amount of carbon. The rebuilding of a dyke system inland, combined with breaches of the outer marsh, resulted in the recovery of 16.5 hectares of salt marsh along the Bay of Fundy coast. After just 9 years, the recovering salt marsh had stored the equivalent CO_2 emissions from over 2,000 passenger vehicles. Based on 2017 numbers, these CO2 equivalents would have generated $30,000 USD in the voluntary carbon market and $124,000 USD in the regulated California carbon market. However, the Bay of Fundy has a high tidal range and a large sediment supply relative to other environments, which could be driving high carbon accumulation rates. As well, to be eligible for the carbon market, restoration projects need to meet the requirement of permanence (the carbon sequestration has to continue for 100 years).

To further evaluate the effect of tidal amplitude on carbon accumulation and the long-term storage of carbon, google earth images and historical aerial photos were examined to identify reflooded agricultural areas. Thirteen reflooded sites were identified for sampling with tidal amplitudes ranging from two to 12 meters and time periods since reflooding ranging from 9 to 92 years. Soil cores revealed a recognizable ‘agricultural horizon’, a layer of dense organic matter resulting from the flooding of vegetated agricultural lands and the subsequent anoxic environment. Core sections from the post-flooding period were analyzed for organic matter content through the loss on ignition method and converted to an organic carbon amount using a conversion factor[2]. (Gail is now using soil samples from New Brunswick marshes to develop a regionally specific factor for converting organic matter to organic carbon that should apply to Nova Scotia and Prince Edward Island.)

Results show that tidal amplitude does matter for the rate of organic carbon accumulation (g m^{-2} yr^{-1}) on reflooded dykelands. However, the recovery period itself is a much better predictor of organic carbon storage. As well, the amount of carbon stored per year decreases over time. This work has provided a formula for estimating the carbon storage potential of restored dykelands over time. Yet, to ensure the permanence of carbon storage, the potential for coastal squeeze also needs to be taken into account.

Increased rates of sea level rise can cause extended submergence of the lower elevations of a tidal marsh, causing loss of marsh on its seaward side. However, as adjacent uplands become flooded, a marsh can migrate inland. If barriers such as sea walls or steep slopes limit this migration, the marsh is in a “coastal squeeze.” Digital elevation models from LiDAR data and remote sensing imagery of impermeable surfaces were used to map the potential for coastal squeeze along Chaleur Bay, and this technique is now being used to map the rest of the New Brunswick coast. This work will inform coastal management decision-making, including identifying cost-effective locations for salt marsh restoration projects as well as areas in need of dyke repair.

KEY TAKEAWAYS

- Drained salt marshes can store large amounts of carbon when tidal flooding is returned.
- The carbon accumulation rates of reflooded agricultural lands depend on the length of recovery time. The rate of carbon accumulation decreases as recovery time increases.
- Salt marsh restoration projects need to consider potential for coastal squeeze to ensure cost-effective carbon sequestration

[1] Wollenberg JT, Ollerhead J, Chmura GL. 2018. Rapid carbon accumulation following managed realignment on the Bay of Fundy. Plos One. doi.org/10.1371/journal.pone.0193930.

[2] Craft, C. B., Seneca, E. D., & Broome, S. W. (1991). Loss on ignition and Kjeldahl digestion for estimating organic carbon and total nitrogen in estuarine marsh soils: calibration with dry combustion. Estuaries, 14(2), 175-179w.

Lynn Lee, Gwaii Haanas Parks Canada
Dan McNeill, Council of the Haida Nation

Chiixuu Tll iinasdll: Nurturing seafood to grow

Collaborative Kelp Forest Restoration Within an Indigenous Cooperative Management Context in Gwaii Haanas, Haida Gwaii

Gwaii Haanas Parks Canada and the Council of the Haida Nation Haida Fisheries Program have been working together to transform urchin barrens into kelp forests for the purpose of improving habitat for culturally important species such as abalone, rockfish and herring. The restoration of kelp forests also has implications for habitat conditions and potential mitigation of climate change impacts. For example, deeper and larger kelp forests could result in increased physical protection for shorelines, increased carbon cycling and sequestration, increased dissolved oxygen levels, mitigation of acidification effects, and contribution of nutrient subsidies to coastal and deepwater habitats. The implications for blue carbon storage are less clear than salt marshes and seagrass meadows, but there is the potential for storage of carbon from kelp biomass in coastal and deepwater habitats.

Motivation behind the kelp restoration project includes the complex and dynamic interactions between people and place. Indigenous peoples have been hunting sea otters and harvesting coastal shellfish and fish for millennia. In the late 1700s and early 1800s, the maritime fur trade locally extirpated sea otters in some parts of the BC coast within 50 years, which changed both ecological and cultural relationships among species. Before the industrial fur trade, sea otters consumed abalone and urchins, which kept their populations generally lower and reduced grazing pressure on kelp. However, after the extirpation of sea otters, shellfish prey numbers increased and resulted in higher levels of grazing and a general decrease in kelp forests. As well, commercial overfishing of shellfish has resulted in a decrease of some culturally important species like abalone. This history has led to the need for restoration of these diminished kelp forest communities.

In Haida Gwaii, overgrazing of kelp by urchins has resulted in urchin barrens. In areas without sea otters, abalone recovery has been observed, while in parts of British Columbia where sea otters were reintroduced, there has been substantial kelp recovery. Within one to five years of sea otter reintroduction, the kelp resembles secondary forests on land and after about 10 years, the succession resulted in a greater diversity of kelp, invertebrates and fishes.

To restore kelp forests in Gwaii Haanas, commercial urchin fishermen and a Haida dive team mimicked the effect of sea otters foraging in the nearshore ecosystem by removing and cracking sea urchins from a 3 km stretch of shoreline. The commercial fleet harvested urchins where possible for commercial purposes, as well as for provision of food to Haida communities as a traditionally important food. In the fall of 2018 and spring of 2019, 75-90 percent of sea urchins were removed from the restoration site. Aerial drone footage collected in collaboration with the Hakai Institute and by Parks Canada showed that, although kelp canopy cover is variable year to year, there was incredible kelp growth recorded in just 8 months after restoration at the restored site relative to the control site.

Gwaii Haanas is continuing to pursue innovative management actions, working with industry to try and maintain the gains of restoration by continuing to harvest and crack sea urchins at the site each fishing year. They hope to work together to create recovery strategies in other areas around the island, as well as continuing to expand their knowledge base on diverse responses of the rocky reef community to kelp restoration efforts, as well as supporting the training of new Haida divers in the community. This project's success is due to the long-standing collaborative and cooperative relationships between First Nations, the federal government, researchers and commercial fishing industry, as well as the high level of community interest and support, and implementation of outreach activities such as introducing youth to kelp, urchins and nearshore ecosystems.

KEY TAKEAWAYS

- Restoration can improve habitat for culturally important species (e.g., abalone, rockfishes, herring), provide access to culturally important food (e.g., urchin roe) and expand the knowledge base on kelp and coastal ecosystems.
- Restoration of kelp forests overgrazed by sea urchins requires a collaborative effort with communities, researchers, industry and government agencies. Restoration of kelp forests can result in increased physical protection for shorelines, increased carbon cycling and sequestration, increased dissolved oxygen, mitigation of acidification effects, and contribution of nutrient subsidies to coastal and deepwater habitats.
- The implications of kelp forest restoration for blue carbon are less clear than for salt marshes and seagrass meadows, but there is potential for the storage of kelp biomass in coastal and deepwater habitats.

Carolyn Prentice, Hakai Institute

Variability in Carbon Storage in Temperate Eelgrass (*Zostera marina*) Meadows

Research by Carolyn Prentice and collaborators[3] highlights the variability of carbon storage within and among seagrass meadows at different scales. The traditional territories of the Heiltsuk Nation and the Wuikinuxv Nation on the Central Coast of British Columbia are well suited to study variability in seagrass carbon storage because of the range of physical characteristics along the coastline. The drivers of carbon storage in seagrass meadows include the hydrodynamic regime (e.g., exposure, currents), size and patchiness, density and canopy height, and sediment characteristics. The local seagrass species, *Zostera marina*, can thrive in the outer coasts exposed to large waves and currents as well as in the inner, sheltered coasts.

The first study sampled the meadow interior, the meadow edge, and the adjacent unvegetated sediments in triplicate in six different seagrass meadows. Cores (20-30 cm in depth) were collected by scuba divers, sliced into 5 cm sections and then subsampled. The subsamples were analyzed for percent total carbon using elemental analysis as well as percent inorganic carbon using a CO_2 coulometer. Inorganic carbon was subtracted from total carbon to determine percent organic carbon (OC content). Carbon stocks (g OC m^{-2}) over various sediment depths (5 cm, 20 cm) were calculated by multiplying dry bulk density by per cent organic carbon. There was high variability in OC content among the sediment core subsections (minimum and maximum values from the five cm sections were 185 and 5,147 g OC m^{-2}, respectively). In four of the six meadows, the carbon stocks were greatest in the interior of the seagrass meadows but vegetated areas (interior and edge) were usually not significantly different from the adjacent unvegetated mudflats. By pairing this data with the Hakai Institute's annual seagrass monitoring data and using a mixed effects model, the hydrodynamic environment (i.e. water motion) was found to explain the most variation in carbon stocks, with higher carbon stocks in seagrass meadows with lower water motion.

Another study[4] in collaboration with researchers from Alaska to Oregon synthesized carbon values from 30 seagrass meadows in the Pacific Northwest, including percent organic carbon, carbon stocks and carbon accumulation rates. These values were compared with other temperate seagrass meadows, as well as other seagrass species around the world. Sediment percent organic carbon and carbon accumulation rates in *Z. marina* meadows in the Pacific Northwest were comparable to *Z. marina* meadows in other

[3] Prentice, C., Hessing-Lewis, M., Sanders-Smith, R., & Salomon, A. K. (2019). Reduced water motion enhances organic carbon stocks in temperate eelgrass meadows. Limnology and Oceanography, 64, 2389-2404. https://doi.org/10.1002/lno.11191

[4] Prentice, C., Poppe, K. L., Lutz, M., Murray, E., Stephens, T. A., Spooner, A., et al. (2020). A synthesis of blue carbon stocks, sources, and accumulation rates in eelgrass (Zostera marina) meadows in the Northeast Pacific. Global Biogeochemical Cycles, 34, e2019GB006345. https://doi.org/10.1029/2019GB006345.

temperate regions and showed similarly high variability. However, temperate seagrass meadows have lower sediment organic carbon content and much lower carbon accumulation rates when compared to seagrass meadows from across the globe. This is mostly due to the prevalence of Posidonia species in tropical environments that are especially good at storing carbon. Finally, percent organic carbon in the unvegetated sediments was not significantly different from seagrass meadows themselves across meadows in the Pacific Northwest, which highlights that bare mudflat areas should not be overlooked, especially when they are surrounded by productive ecosystems, like kelp forests or seagrass meadows.

KEY TAKEAWAYS

- Not all seagrass meadows can be considered equal due to the high variability in carbon storage and accumulation rates at local (i.e., within meadow), regional (i.e., among meadows in BC and in the Pacific Northwest) and global (i.e., among species) scales. Use caution when scaling up values from the local to regional level as well as when comparing among seagrass species.
- Landscape factors (e.g., water motion) may influence carbon stocks more than meadow-scale factors (e.g., seagrass density), so it is important to consider these larger physical factors when designing restoration projects.
- The high variability in carbon stocks within a given seagrass meadow may have implications for monitoring – when collecting sediment cores, take as many cores as possible and from as many locations within a meadow as possible.
- The carbon content in bare sediments can be similar to vegetated sediments.
- Carbon storage of seagrass meadows is only one of many important functions or ecosystem services.


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Photo: Managed dyke realignment and 9.7 hectare tidal wetland restoration project, Cornwallis River, Nova Scotia. The project included four years of pre- and post-restoration monitoring. Project partners include the Nova Scotia Department of Agriculture, Saint Mary's University, CBWES Inc., and the DFO Coastal Restoration Fund.


K'ómoks Estuary, Vancouver Island BC, August 2020 © Cornelia Rindt

GROUP DISCUSSIONS

Restoration

Quantifying the potential carbon value of restoration projects is essential for understanding the benefits that these projects provide. Key knowledge gaps in the restoration of blue carbon ecosystems include the extent to which measurements of carbon dynamics in natural systems apply to restored systems and how carbon accretion rates may change over time. For example, recent research shows that carbon accretion rates can decrease over time in reflooded dykelands. However, not many studies have measured carbon storage in seagrass beds pre- and post-restoration. **Building our knowledge and understanding of carbon dynamics in natural and restored ecosystems will facilitate the development of more effective restoration projects**.

Restoration projects provide many ecosystem benefits beyond carbon storage and not all restoration projects are designed to incorporate carbon measurements. If resilient marine habitat and ecosystem services is the goal of a restoration project, then care should be taken to avoid disturbing the restored area to accurately document carbon accumulation and storage. By working together collaboratively, **practitioners and researchers should strive to find a balance between collecting valuable data and preserving the integrity of the restored ecosystem**.

When designing restoration projects, it is important to **understand the baseline conditions of the ecosystem and how the system has changed over time** (e.g., with colonization, agriculture, compaction). Projects should be designed for the long-term and should have clear goals related to ecosystem restoration and to building trust and capacity within local communities. Conducting vulnerability assessments of the site to predict impacts from climate change such as coastal squeeze, sea level rise and wave energy are also important. Working with a long-term view, gaining an understanding of how the site has changed in the past, how the site is likely to change in the future, and building strong relationships with the community will help ensure restoration projects are successful.

Choosing suitable restoration sites

Identifying suitable sites for restoration is challenging. Factors to be considered when choosing restoration sites include:

- hydrology,
- tidal and sedimentation patterns,
- areas of erosion,
- the plant community,
- land use and current infrastructure,
- landowners associated with the site,
- historical importance to community members and Elders,
- cost,
- future development plans, and
- sea level rise and coastal squeeze

Prior to beginning a restoration project, it is necessary to gain permission from the Indigenous government within whose territory the project will be undertaken. Many projects prioritize getting permission from the provincial and federal governments but should obtain permission from Indigenous governments first. Indigenous guidance can also assist in the identification of suitable sites for restoration by providing the historical understanding of ecosystems and habitats, how shorelines have changed over time (e.g., the addition of man-made structures, dredging) and the availability of baseline information.

Obtaining support from Indigenous governments, landowners, and the community is essential to the success of a restoration project. Gaining support can be achieved by understanding and addressing concerns held by community members. For example, the Clean Foundation's project at the Marshall's Crossing site in Nova Scotia addressed a major infrastructure concern, which resonated with the community, while also restoring salt marsh habitat. Clear communication of the intentions of the restoration project, using unique and creative ways to present the message (e.g., animations, videos) and listening to the community's concerns are all strategies to gain support for restoration projects.

A key challenge to identifying suitable restoration sites is obtaining local information with which to evaluate the conditions and characteristics of a site. **Local knowledge, expert information and baseline data are required** to determine if restoration of a site is needed, or if the present conditions are due to natural events. For example, seagrass beds can be highly affected by storms but return naturally to pre-disturbance conditions over time. Engagement and relationship building with local residents, such as fisherfolk and Indigenous peoples, can help to fill knowledge gaps and determine the need for restoration at specific sites.

Expectations for the long-term resilience of restoration projects can be high, such as the requirement of permanence to qualify for carbon credit programs. Climate change driven shifts in shoreline characteristics and species distribution can threaten the long-term viability of restoration projects. As well, private land ownership can constitute a risk for projects as restoration sites may not be preserved with landowner changes. Working to restore the ecological functioning of a site and the accompanying ecosystem services could be a way to build long-term resilience into restoration projects amidst a changing climate.

Monitoring

Developing and standardizing monitoring programs for blue carbon metrics is challenging as blue carbon dynamics differ across regions. However, **developing a monitoring protocol specific to Canada's blue carbon ecosystems could be a valuable next step** for the community of practice. Best practice documents have been developed for monitoring stream and riparian habitats and underwater ecosystems, and a blue carbon protocol could build on that work. However, a Canada-wide protocol would need to include methods that are adapted for regional conditions and ecosystem types and would ideally include methods for monitoring a range of ecosystem services.

Developing simple and cost-effective proxies for blue carbon metrics could be a way to facilitate the monitoring blue carbon ecosystems. However, collecting data to create a robust baseline and/or reference library across regions is necessary prior to attempting to develop proxies. It is also important to understand the range of different characteristics within ecosystem types when building a data reference library. Identifying the range of blue carbon ecosystem characteristics present in Canada across regions and within ecosystem types could be a valuable first step to understanding the blue carbon habitats along our coastlines.

Carbon fluxes and emissions

While blue carbon ecosystems can sequester substantial quantities of carbon, they can also be a source of carbon emissions. For example, salt marshes produce methane, the quantity of which can vary along salinity gradients. It is unclear whether methane emissions are high enough to counteract the long-term carbon sequestration value of these systems. We need to ensure we collect field measurements of greenhouse gas emissions and that we understand the suite of physical, chemical and biological interactions which influence them. **Understanding carbon fluxes and greenhouse gas emissions in blue carbon ecosystems will provide a greater understanding of the carbon value of restoration projects within and across ecosystems**.

Incorporating social, economic, ecological and cultural benefits into restoration projects

Many groups across the country are designing and implementing projects that produce a diversity of benefits, including:

- flood mitigation,
- temperature regulation,
- habitat conservation,
- social benefits,
- erosion control,
- recreational opportunities,
- wildlife conservation,
- coastal infrastructure protection,
- fish habitat conservation,
- nutrient management, and
- biodiversity gains.

Incorporating social, economic, ecological and cultural values into restoration projects should be addressed at an early stage in the project design. Co-designing projects with communities is an ideal way to integrate diverse benefits into project design. However, it is important to recognize and respect capacity limitations, time constraints and the specific histories and needs of the communities we would like to work with. Being flexible, welcoming scrutiny and adapting projects to meet community needs is essential. Being accountable and transparent in the planning, implementation, monitoring and reporting of projects is also important and will help ensure the success of the project.

A key challenge to undertaking projects that integrate social, economic, ecological and cultural values is the specificity of funding opportunities. Currently national, provincial and municipal governments have different mandates and priorities which are reflected in their calls for proposals. **Communicating the importance of the diverse range of benefits associated with restoration projects to different government levels may help gain support and encourage governments to include a wider range of benefits in their commitments**.

Including multiple sources of evidence in restoration projects

Relationship-building is a key part of restoration projects. Engagement with Indigenous governments and communities should happen early in the project design process, prior to submitting grant applications. Conversations with Indigenous communities should be open-ended and collaborative to achieve restoration goals that are important and meaningful for these communities. Relationships should be built based on a genuine interest in knowledge sharing and producing a restoration or monitoring plan that benefits the community.

A misalignment of goals between Indigenous and non-Indigenous communities can create a barrier to impactful restoration projects. Solving conflicts between communities may include identifying core values and working to address multiple needs through the design of the project. It is important for non-Indigenous organizations and communities to understand how Indigenous communities gather knowledge and make decisions (e.g., tribal councils, governing bodies, Elders). It is also important to remember that there are capacity limitations in Indigenous governments and organizations; Indigenous groups can struggle with responding to numerous partnership requests and experience interview and engagement fatigue. Working to understand the needs and priorities of Indigenous communities and supporting capacity building in Indigenous governments and organizations will help to build meaningful relationships and facilitate collaborative projects.

Engagement with landowners, land users and Indigenous communities is important for collecting data, as they will have knowledge of local ecological trends and past projects. Many different groups hold important scientific data and Indigenous Knowledge. Compiling these data and knowledge sources in a respectful way can help facilitate restoration and monitoring projects. Connecting landowners and practitioners with Indigenous communities is important for facilitating the inclusion of Indigenous Knowledge into restoration projects. Opportunities to collect community science data from events such as Bioblitz and apps like iNaturalist and eBird are also valuable sources of information.

Knowledge of historical land use and culturally significant areas should be included into restoration project design. For example, the reflooding of drained areas in eastern Canada can result in a loss of history relevant to local communities. Therefore, we need to **include historians, archaeologists and geographers at the outset of a project** to gather all relevant historical information to include in project planning. Historians and archaeologists are now being included through both the regulatory and non-regulatory processes in Nova Scotia for any work on dykelands.

Prior to Covid-19, building capacity in coastal communities and designing resilient projects was accomplished through in-person workshops, engagement with Elders and the inclusion of communities in project implementation. Workshops that are held prior to restoration help to co-develop research priorities and make sure that there is an opportunity to hear from all voices, address concerns, and make compromises where appropriate. However, working virtually has brought new challenges to designing and implementing projects, especially where access to technology and online platforms is a barrier.

Challenges and limitations

A key challenge to restoration and monitoring work is the cost, time and resource intensive nature of blue carbon field and lab work. For example, access to restoration sites and equipment can be a limitation, especially given that equipment needs vary by site. Personnel capacity can also be a limitation, as some blue carbon sampling requires highly trained individuals, such as scuba divers, to complete the work. Access to specialized expertise, such as geochemists, is also important for properly designing studies and analyzing samples. **Well-designed funding opportunities, training programs to increase capacity within the blue carbon community of practice and collaboration with a wide range of knowledge holders and skilled personnel can help address these challenges**.

The **high variability of conditions within blue carbon ecosystems**, and within individual sites, is also a challenge. It is unclear how many replicates of a particular sample type are needed to get an accurate understanding of carbon dynamics. One approach is to collect as many samples as possible, analyzing them as funds become available. The purpose of the sample collection may also dictate the number and type of samples required. For example, an academic study may require more involved sampling to fully understand accretion rates and variability at a site, while fewer samples may be required if simply confirming carbon storage is the goal. Designing a sampling approach to directly meet the goals of the project could save time and costs. However keeping in mind the development of regional sampling protocols and standards is also important to facilitate comparison of data across sites and projects.

Funding Challenges

Obtaining appropriate funding for monitoring programs is a key challenge. **Most funding awarded for projects is short-term** (1 to several years). It can take years to engage with communities, build meaningful relationships and plan impactful projects. The availability of short-term funding can therefore result in project leads choosing a restoration site that already has community support but may not provide the most ecological benefit. A mismatch in the timing of funding can also pose challenges since field work in many areas needs to be completed at particular times of year. And while monitoring of a restoration site can begin shortly after the project is complete, early results typically do not suggest success, even if the project goals are achieved in the long-term. **Without long-term funding it isn't possible to continuously return to sites to monitor over time**.

To address the current gaps and mismatches in funding for restoration and monitoring work, we need to:

- Convince funders to recognize the importance of multi-year projects and long-term monitoring,
- Communicate the value of building meaningful relationships with communities,
- Expand the metrics of success for evaluating restoration projects beyond 'area of habitat restored,'
- Communicate the importance of adaptive management to ensure long-term restoration success, and
- Work with community volunteers who can participate in long-term monitoring activities.

Methodological Challenges

^{210}Pb dating is the main method used to estimate sediment accumulation rates in blue carbon ecosystems (although ^{137}Cs and ^{14}C are also used for longer time scales). Coupled with carbon content analysis from the same sediment or soil core, it is possible to obtain estimates of carbon accumulation rates. While the ^{210}Pb method is widely used, there are multiple challenges with it. The method is expensive and time consuming. Single ^{210}Pb samples can take 2-3 days to analyze, necessitating weeks to date one core. There is also error associated with estimates of carbon accumulation as seagrass sediments can shift and mix, complicating the interpretation of ^{210}Pb profiles. **Setting up blue carbon monitoring nodes and increasing analysis capacity at labs across the country** could help alleviate the technical, time and cost challenges associated with ^{210}Pb analysis.

Kelp at Chesterman Beach, Tofino BC, October 2020 © Cornelia Rindt

KEY POINTS

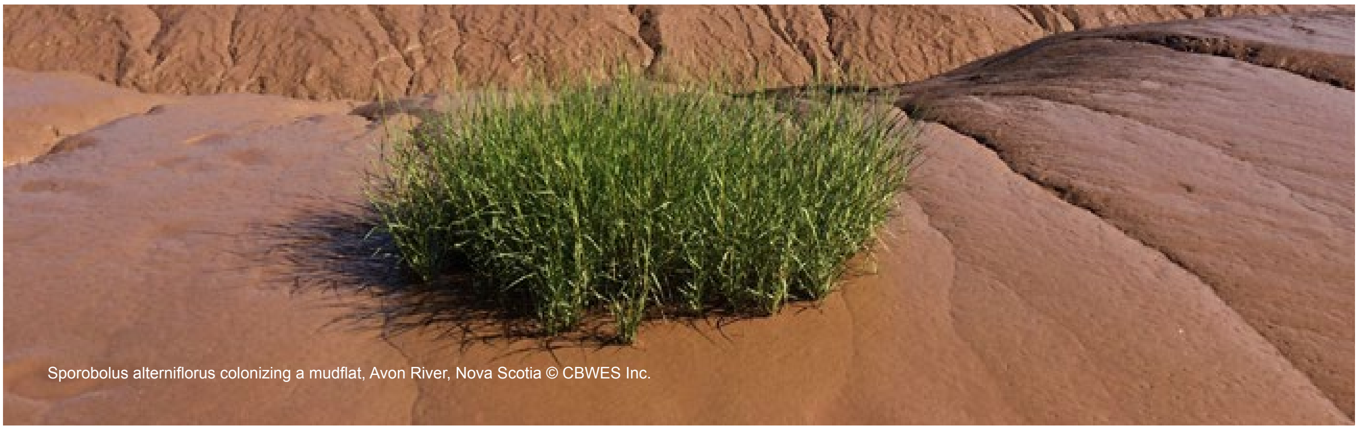
Participants in the breakout sessions were asked to highlight key points that arose during their discussion. Included below is a summary of those key points.

What are the current **best practices for collecting carbon accumulation, sequestration and flux data**, what are the limitations and how do we incorporate these measurements into restoration projects?

- Carbon storage and climate mitigation can be co-benefits of habitat restoration. To realize these benefits, we need funding mechanisms that enable the collection and analysis of carbon samples as part of restoration projects. We also need to connect blue carbon researchers with habitat restoration practitioners to facilitate sample collection and analysis. This is especially important given that understanding carbon dynamics is often not the primary purpose of a restoration project.
- Limitations to collecting blue carbon data include cost, capacity, lack of standard protocols for sampling, and the high variability among and within blue carbon habitats. A key question we need to answer is: What is a sufficient sample size to say something meaningful about carbon dynamics at a particular site?
- Building a network for equipment and expertise sharing can help to address the challenges of blue carbon sampling related to cost and capacity.

How do we determine the **suitability of a site for restoration** and what are the **baseline knowledge needs**?

- Site suitability depends on several factors, including landowner and community support, current land use and infrastructure, future development plans, historical importance to community members and Elders, sea level rise and coastal squeeze, site access and baseline conditions (e.g., erosion, vegetation).
- Identification of suitable sites can be difficult depending on private land ownership, community support and a lack of baseline data and/or expert knowledge of the conditions of a site.
- Baseline data collection is limited by cost, landowner support and land access. Historic information is important and can be obtained by asking Indigenous governments and private landowners about areas of significance for communities. It is important to consult with fisherfolk, Indigenous groups and landowners to determine if a site needs to be restored or if conditions are a result of natural disturbance (e.g., storms).



Sporobolus alterniflorus colonizing a mudflat, Avon River, Nova Scotia © CBWES Inc.

How do we **design** restoration projects to ensure we maximize **social, economic, ecological and cultural benefits**?

- Start conversations and engagement early during the design phase of projects, especially with communities, and include the co-design of projects. Collaborate with diverse peoples and groups to bring many different perspectives, priorities and funding opportunities into the project.
- Current restoration project designs include many co-benefits, such as biodiversity, and are now starting to include carbon storage.
- Consider and recognize ecosystem services at national and local levels, as part of project design and communication.
- Communicate the value of blue carbon with governments and potential stakeholders to gain support for including blue carbon in funding proposals (e.g., green infrastructure funding could better include blue carbon). This will allow us to develop common tools, co-design projects, and build long-term collaborations.

How can we ensure we include **multiple sources of evidence including local, Indigenous and scientific knowledge** to strengthen our restoration projects?

- Engage with historians, archaeologists and Indigenous governments and communities at the beginning of restoration projects (before grant applications are submitted) to co-develop priorities before the project has taken off. Engage with landowners and land users, as they know the landscape well and can provide insight into trends in degradation or regeneration, as well as strategies that have worked or failed in the past.
- Capacity limits Indigenous government and organizations. Indigenous groups are doing their best to promote capacity building to improve partnerships but are experiencing interview and engagement fatigue due to the number and repetitive nature of requests.
- Work with the funding community to lengthen funding timeframes to allow for proper engagement and relationship building (i.e. longer than the typical funding periods of 1-2 years or post-doc positions). Building relationships with local, Indigenous and scientific communities is valuable and should be incorporated into funding opportunities and job tenure.

How do we **develop and implement effective monitoring plans** for restoration projects?

- We need to develop clear goals for monitoring efforts that align with stakeholder and rightsholder needs.
- The biggest challenge to monitoring is financial limitations. To solve this, we need a funding mandate in place that requires monitoring to be tied into restoration projects.
- We need a national-level strategy to design monitoring protocols, create a reference library, and align datasets. The protocols should account for regional specificities in blue carbon habitats.

APPENDICES

Workshop Agenda

Building Connections for Blue Carbon Across Canada

Restoration and Monitoring – February 3rd 2021

10am-12:30pm PST, 1pm-3:30pm EST, 2pm-4:30pm AST, 2:30pm-5pm NST

How can we restore and monitor blue carbon systems to sequester carbon, increase biodiversity and be resilient to climate change?

Workshop Objectives

Through a series of focused workshops, these sessions will bring together a range of blue carbon researchers and practitioners from across Canada to:

- Facilitate connections within the blue carbon community and share information about ongoing blue carbon work
- Discuss key questions on blue carbon research, policy and application
- Identify areas of opportunity to advance collaboration on blue carbon across Canada

1:00 – 1:15pm EST	**Welcome**
1:15 – 2:05pm EST	**Invited Speakers** • Allen Beck, Clean Foundation • Dr. Gail Chmura, McGill University • Dan McNeill, Council of the Haida Nation and Lynn Lee, Gwaii Haanas Parks Canada • Carolyn Prentice, Hakai Institute
10 minute break	
2:15 – 3:05pm EST	**Breakout Groups – focused discussions**
3:05 – 3:25pm EST	**Speed Talks – getting to know our community** • Tony Bowron, CBWES Inc. • Dr. Danielle Denley, Simon Fraser University • Dr. Rebecca Goldman Martone, Province of British Columbia
3:25 – 3:30pm EST	**Wrap Up**

Discussion questions:

1. What are the current best practices for collecting carbon accumulation, sequestration and flux data, what are the limitations and how do we incorporate these measurements into restoration projects?
    - What are the priorities for the development and refinement of methods?
2. How do we determine the suitability of a site for restoration and what are the baseline knowledge needs?
3. How do we design restoration projects to ensure we maximize social, economic, ecological and cultural benefits?
    - What factors need to be included in project design to ensure long-term resilience to climate change?
    - How do we build ecosystem services and biodiversity gains into the design of blue carbon restoration projects?
4. How do we develop and implement effective monitoring plans for restoration projects?
    - How can we connect and standardize monitoring programs regionally?
    - How can we develop proxies for blue carbon metrics that reduce technical and financial barriers to monitoring?
5. How can we ensure we include multiple sources of evidence including local, Indigenous and scientific knowledge to strengthen our restoration projects?
    - How can we facilitate and integrate community science to improve baseline knowledge, restoration and monitoring of blue carbon?


© Carolyn Prentice

Next up:

Policy, February 24th

Ecosystem Approach, March 24th

Next Steps, April 14th

Participant List

Participants were asked upon registration if they would like their names, organizations and emails included in a summary report to facilitate connections within the blue carbon community. The participants who answered 'yes' to that question appear in the table below.

Name	Organization	Email
Hosts		
Brianne Kelly	WWF-Canada	bkelly@wwfcanada.org
Caroline Martin	WWF-Canada	cmartin@wwfcanada.org
Facilitation Team		
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Barb Sweazey	Stratos Inc.	bsweazey@stratos-sts.com
Izak Weinstein	Stratos Inc.	iweinstein@stratos-sts.com
Discussion Leads and Note Takers		
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Jacklyn Barrs	WWF-Canada	jbarrs@wwfcanada.org
Aurelie Cosandey-Godin	WWF-Canada	acosandeygodin@wwfcanada.org
Heather Crochetiere	WWF-Canada	hcrochetiere@wwfcanada.org
Jessica Currie	WWF-Canada	jcurrie@wwfcanada.org
Kim Dunn	WWF-Canada	kdunn@wwfcanada.org
Emily Giles	WWF-Canada	egiles@wwfcanada.org
Ryan Godfrey	WWF-Canada	rgodfrey@wwfcanada.org
Victoria Neville	WWF-Canada	vneville@wwfcanada.org
Sarah Saunders	WWF-Canada	ssaunders@wwfcanada.org
Invited Speakers		
Allen Beck	Clean Foundation	abeck@clean.ns.ca
Gail Chmura	McGill University	gail.chmura@mcgill.ca
Lynn Lee	Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site	lynn.lee2@canada.ca
Dan McNeill	Haida Nation	
Carolyn Prentice	Hakai Institute	carolyn.prentice@hakai.org
Speed Talkers		
Tony Bowron	CBWES Inc. & TransCoastal Adaptations: Centre for Nature-Based Solutions	tony.bowron@cbwes.com
Danielle Denley	Simon Fraser University	danielle_denley@sfu.ca

Rebecca Goldman Martone	Province of British Columbia	rebecca.martone@gov.bc.ca
Participants		
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Bailey Brogan	ACAP Saint John	roxanne@acapsj.org
Erin Burbidge	Clean Foundation	eburbidge@clean.ns.ca
Marie Cadieux	SNAP Québec	marie@snapquebec.org
Deborah Carlson	West Coast Environmental Law	dcarlson@wcel.org
James Casey	Birds Canada	jcasey@birdscanada.org
Megan Chen	Wildlands League	meganc@wildlandsleague.org
Matt Christensen	University of British Columbia	msc01@zoology.ubc.ca
Sarah Cook	Coastal & Ocean Resources	sarah@coastalandoceans.com
Julie Cormier	Vision H2O	info@visionh2o.com
Angela Danyluk	City of Vancouver	angela.danyluk@vancouver.ca
Kirsten Ellis	CBWES Inc.	kirsten.ellis@cbwes.com
Mark Gloutney	Ducks Unlimited Canada	m_gloutney@ducks.ca
Al Hanson	Canadian Wildlife Service	al.hanson@canada.ca
Margot Hessing-Lewis	Hakai Institute	margot@hakai.org
Robyn Holwell	NunatuKavut Community Council	rholwell@nunatukavut.ca
Fiona Hood	Tsleil-Waututh Nation	fhood@twnation.ca
Hillary Hyland	Tsleil-Waututh Nation	hhyland@twnation.ca
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Hali Moreland	Parks Canada	hali.moreland@canada.ca
William Nelson	Metlakatla Stewardship Society	wnelson@metlakatla.ca
Candace Newman	Parks Canada Agency	candace.newman@canada.ca
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Sachiko Ouchi	Kitselas First Nation	mrso@kitselas.com
Kylee Pawluk	MaPP	kpawluk@mappocean.org
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Troy Pretzlaw	Parks Canada	troy.pretzlaw@canada.ca
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Trevor Reid	The Nature Conservancy of Canada	reid.trevor@gmail.com
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Cornelia Rindt	NatureBank	cornelia.rindt@naturebank.com
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Edith Tobe	Squamish River Watershed Society	srws@shaw.ca
Chantal Vis	Parks Canada	chantal.vis@canada.ca
Nikki Wright	SeaChange Marine Conservation Society	nikki@seachangelife.org
Jennifer Yakimishyn	Pacific Rim National Park Reserve	jennifer.yakimishyn@canada.ca

Photo: The Cheverie Creek, Nova Scotia, tidal river and salt marsh restoration project replaced an old wooden culvert in 2005, restoring tidal flow and fish passage to 43 hectares of tidal wetland habitat. The project included 7 years of post-restoration monitoring. Project partners include Nova Scotia Department of Transportation and Infrastructure Renewal, CBWES Inc., Saint Mary's University, DFO Small Craft Harbours, and the local community.

Blue Carbon Initiatives and Resources

Below is a list of blue carbon initiatives and resources mentioned by participants during the workshop.

- Two-Eyed Seeing approach (Etuaptmumk). Hear from Elder Albert Marshall and learn more about Etuaptmumk in-practice.
- Reefball deployment at Sitmu'k animation
- The Bay of Fundy Blue Carbon Story https://arcg.is/0DqLzm
- Le Maritime Ringlet et ses Marais
- The Maritime Ringlet and Its Marshes
- Sea2City – a coastal design challenge focused on False Creek, Vancouver
- Literature:
  - Arias-Ortiz, A., Masqué, P., Garcia-Orellana, J., Serrano, O., Mazarrasa, I., Marbà, N., ... & Duarte, C. M. (2018). Reviews and syntheses: 210 Pb-derived sediment and carbon accumulation rates in vegetated coastal ecosystems–setting the record straight. Biogeosciences, 15(22), 6791-6818.
  - Greiner, J. T., McGlathery, K. J., Gunnell, J., & McKee, B. A. (2013). Seagrass restoration enhances "blue carbon" sequestration in coastal waters. PloS one, 8(8), e72469.
  - Oreska, M. P., McGlathery, K. J., Aoki, L. R., Berger, A. C., Berg, P., & Mullins, L. (2020). The greenhouse gas offset potential from seagrass restoration. Scientific reports, 10(1), 1-15.
  - Wollenberg, J. T., Biswas, A., & Chmura, G. L. (2018). Greenhouse gas flux with reflooding of a drained salt marsh soil. PeerJ, 6, e5659.

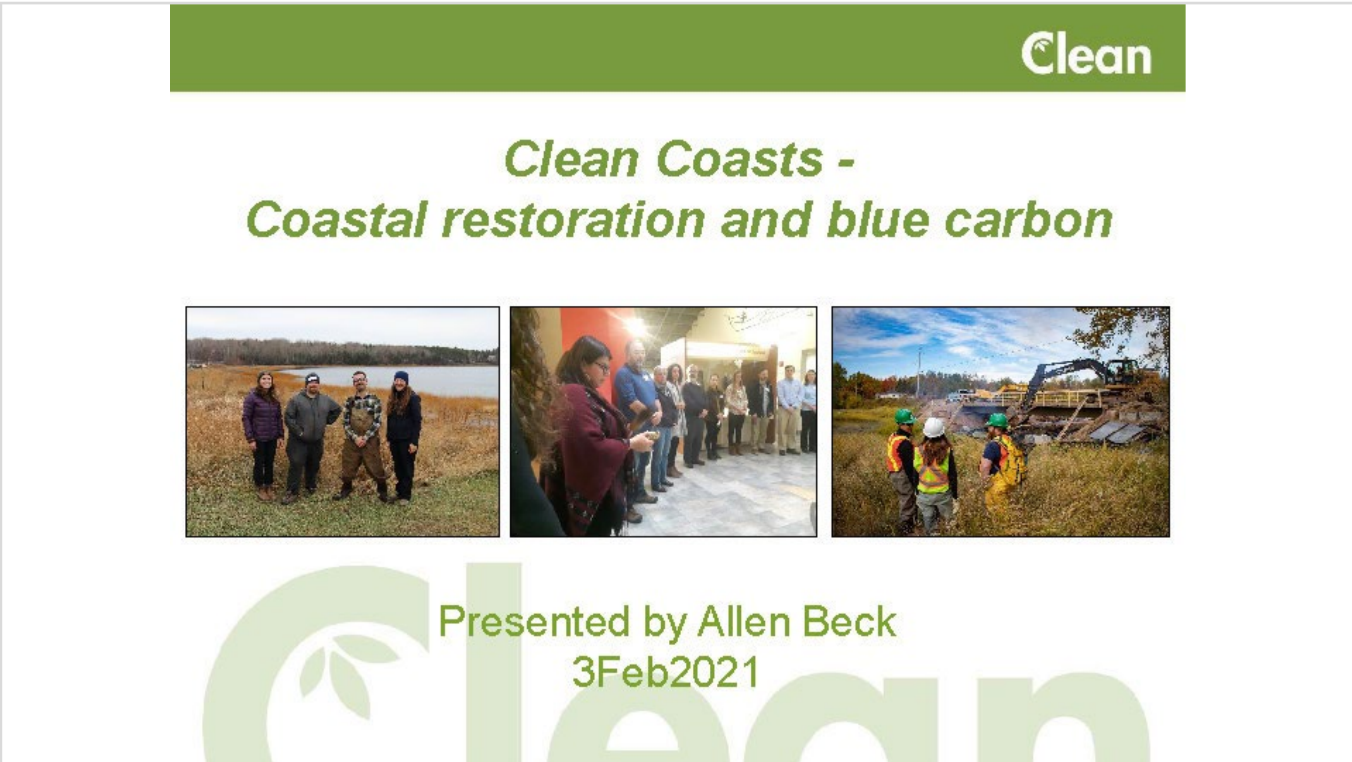
Data Sources and Portals

Below is a list of data sources and portals mentioned by participants during the workshop.

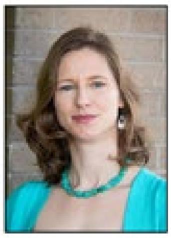
- Canadian Integrated Ocean Observing System (CIOOS)
- Clean Foundation CLEAN Dataverse
- Clean Foundation Online Atlas
- eBird
- Hakai Institute
- iNaturalist

Presentation pdfs

Invited talks



The Clean Coasts Team





Erin Burbidge *Director of Programs and Regulatory Affairs*	**Charlynne Robertson** *Project Manager*	**Allen Beck** *Restoration Specialist*	**Logan Horrocks** *GIS Specialist*	**Julia Stoughton** *Engagement Specialist*

The Clean Coasts Project

Our mission is to use **nature-based solutions** to create healthy, resilient **coastlines** that help **protect our ecosystems**, **built environments,** and **livelihoods** from the risks of a changing **climate**.

Monitor and assess ecosystem health

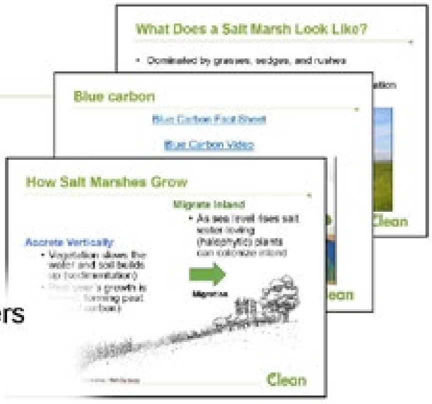
- Research existing studies and data
- Generate new data
- Approach projects with Two-Eyed Seeing
  - Talk to technical partners
  - Talk to community members
- Share all data collected
  - Dataverse repository
  - Online atlas

Restore coastal habitat

- Collaborative site and approach selection
- Consider nature-based solutions where possible
- Ongoing monitoring and adaptive management

Build capacity

- Public events
  - On-site workshops
  - Online webinars
- Special events
  - Presenting to municipality leaders
  - Share with public
- Newsletters and social media
- Volunteers



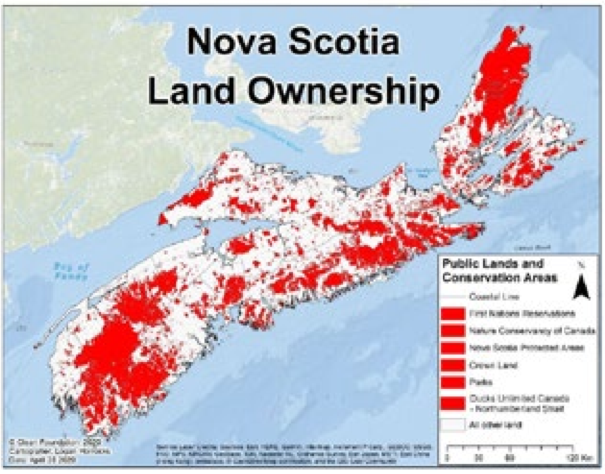
Where we are now

- Collecting samples as we go
  - Funding restrictions
- Gearing and training up
- Finding blue carbon research and data availability needs

Where we want to be

- Incorporate blue carbon into new projects
- Build or contribute to a gear library
- Train others (community groups) to collect blue carbon in standardized manners

The importance of communication and outreach



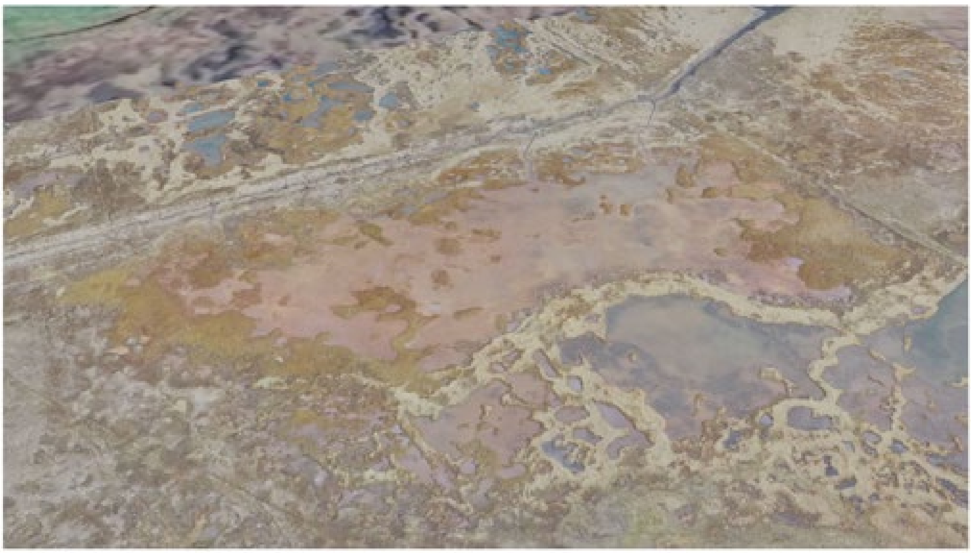
86% of Nova Scotia's coastline is privately owned
(*State of the Coast Report*, NS Government, 2009)

Clean

Thanks!

Questions?

Saltmarshes.ca
abeck@clean.ns.ca



Coastal Resilience Matters

- **70% of Nova Scotia's population lives in coastal communities along 13,300km of coastline** (*State of the Coast Report*, NS Government, 2009)

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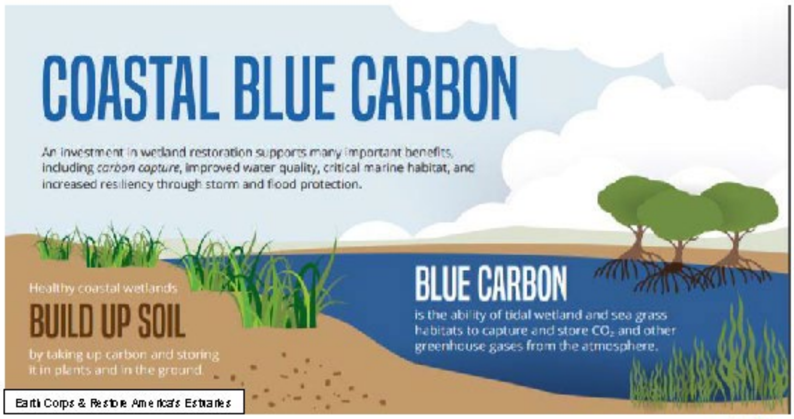
Blue carbon

Blue Carbon Fact Sheet

Blue Carbon Video



Earth Corps & Restore America's Estuaries

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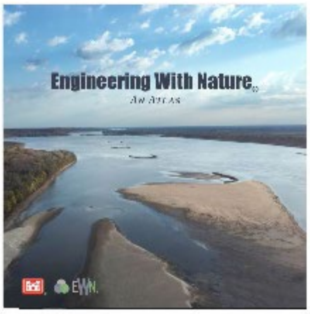
Valuing Nature-Based Solutions

There are four critical elements that define the EWN approach:

- Using science and engineering to produce operational efficiencies
- Using natural processes to maximize benefit
- Increasing the value provided by projects to include social, environmental, and economic benefits
- Using collaborative processes to organize, engage, and focus interests, stakeholders, and partners



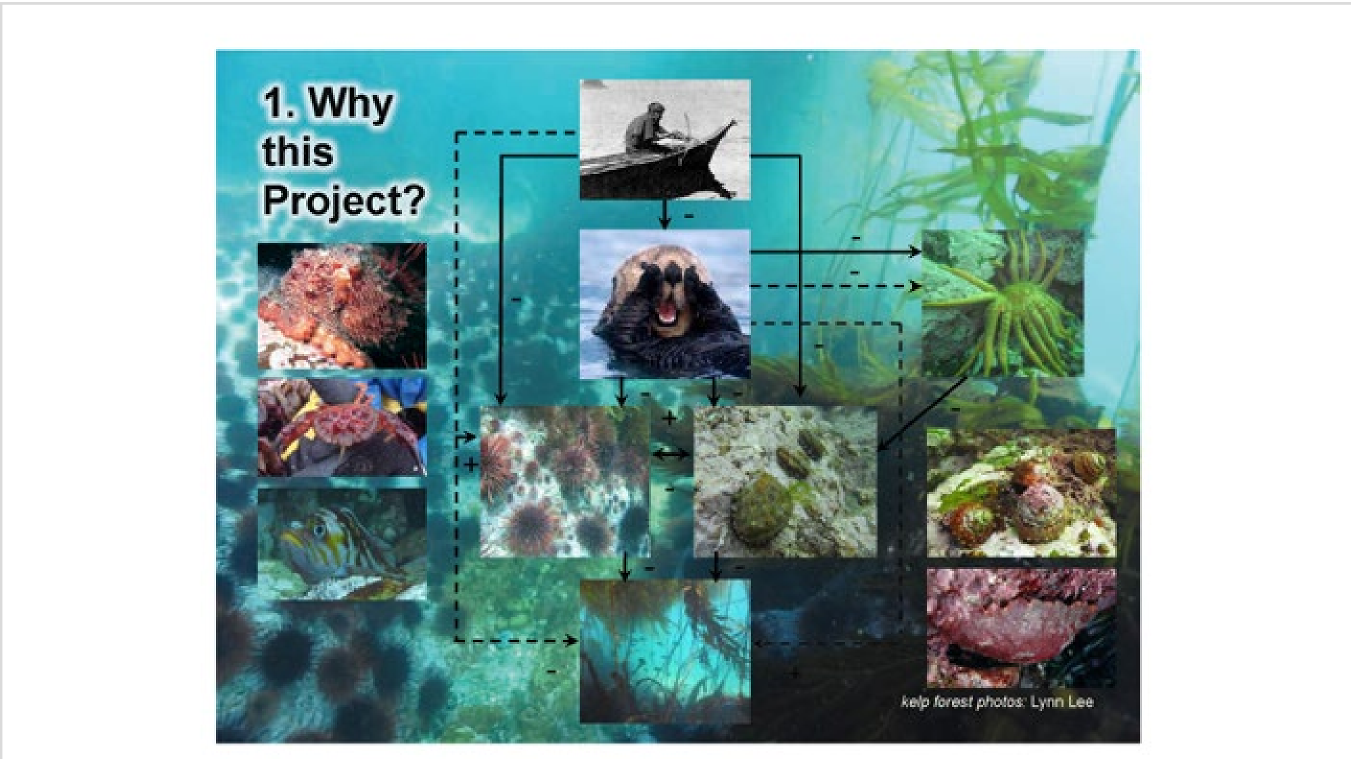
Download your own copy of "Engineering With Nature: An Atlas" by the US Army Corps of Engineers for free online!

Clean


Canada
HAIDA NATION
Chiixuu Tll iinasdll
Collaborative kelp forest restoration within an indigenous cooperative management context in Gwaii Haanas, Haida Gwaii
WWF Blue Carbon Workshop . 03 Feb 2021
Lynn Lee (Gwaii Haanas) & Dan McNeill (Haida Fisheries)
& many many more collaborators
photos: Lynn Lee


Chiixuu Tll iinasdll
Transforming urchin barrens to kelp forests
herring photo: Mark Hiebert
other photos: Lynn Lee
Canada
HAIDA NATION


A swim over…
1. Why this Project?
2. Good People Working Together
3. Restoring Balance in the Sea
photo: Lynn Lee
Canada
HAIDA NATION


1. Why this Project?
kelp forest photos: Lynn Lee

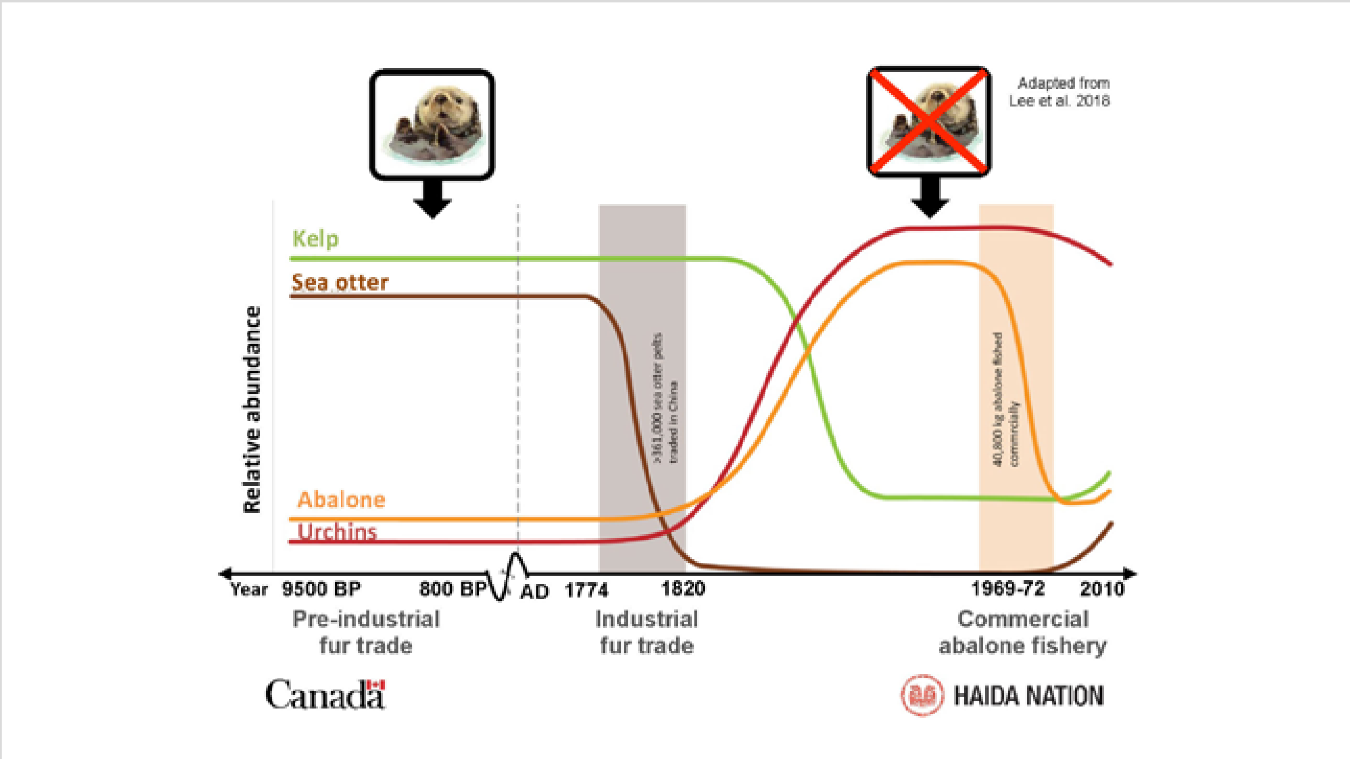

Adapted from
Lee et al. 2018
Kelp
Sea otter
Abalone
Urchins
Relative abundance
>161,000 sea otter pelts traded in China
40,800 kg abalone fished commercially
Year
9500 BP
800 BP
AD
1774
1820
1969-72
2010
Pre-industrial
fur trade
Industrial
fur trade
Commercial
abalone fishery
Canada
HAIDA NATION


photo: Lynn Lee
Canada
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Canada

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Canada

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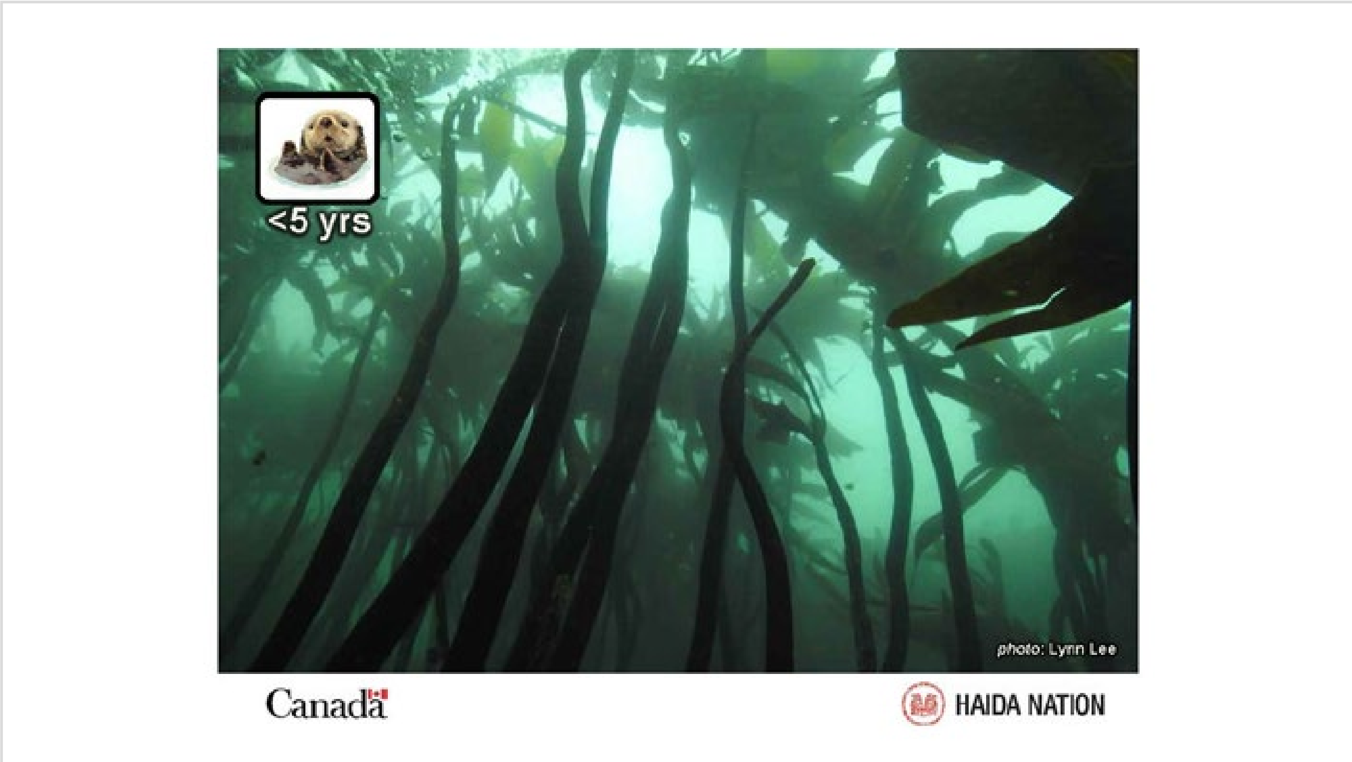
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photo: Lynn Lee
Canada
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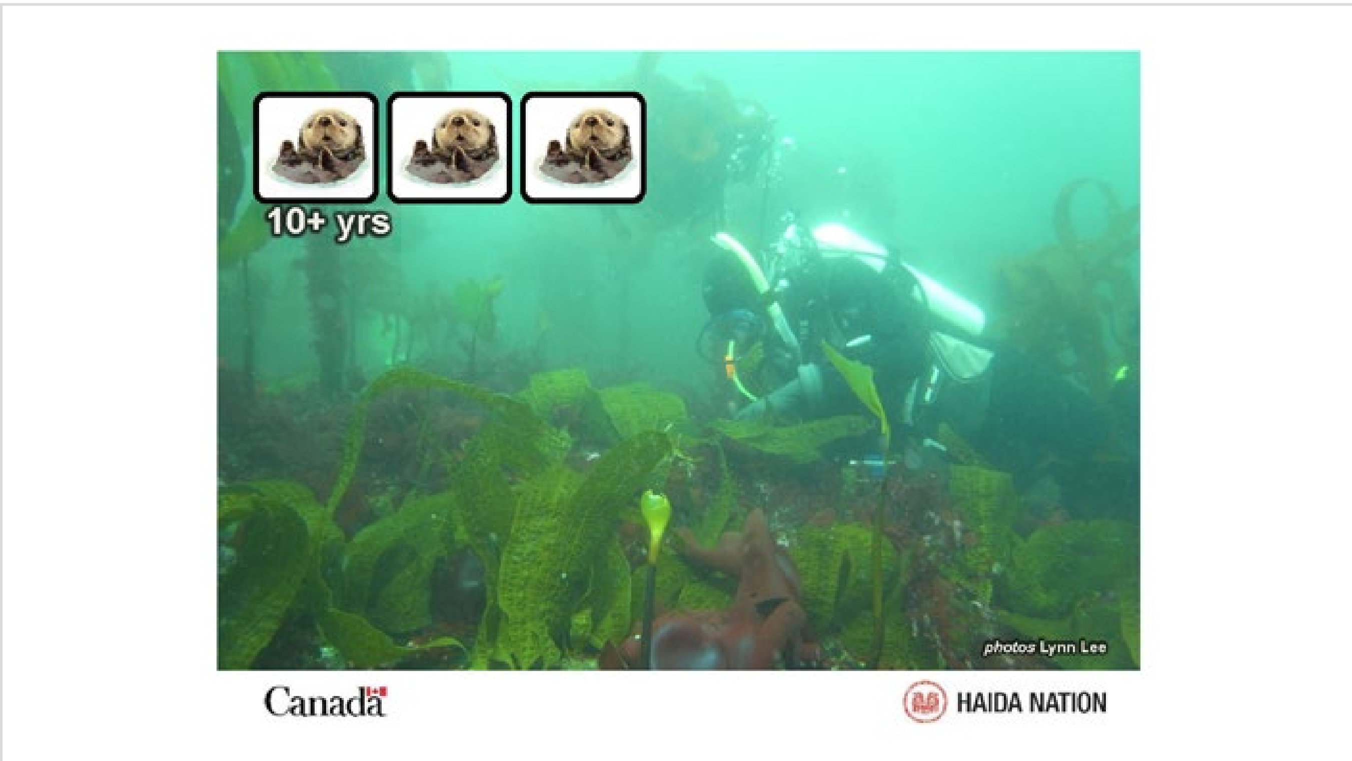
10+ yrs
photos Lynn Lee
Canada
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Canada

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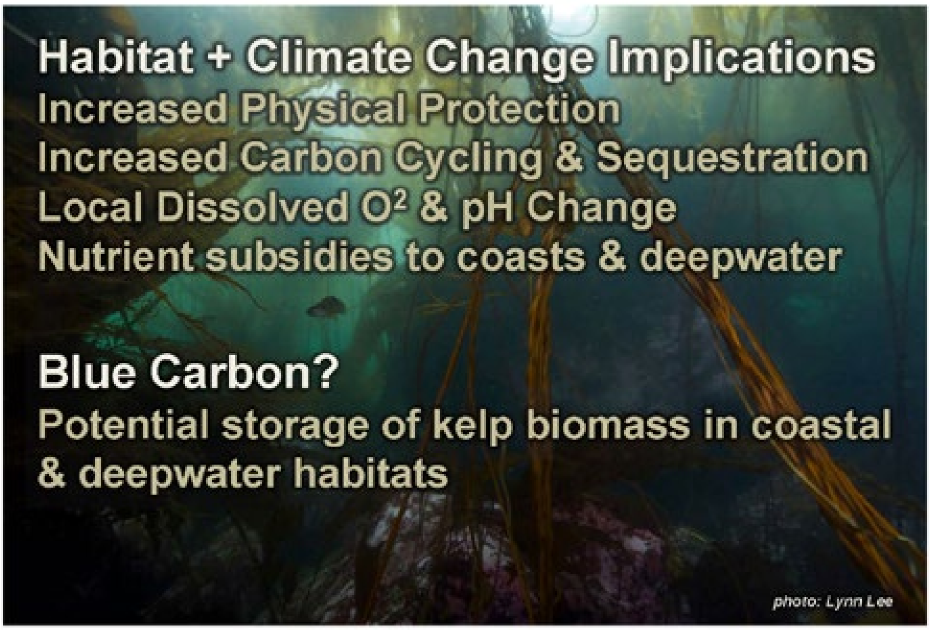

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Herring Spawning
Photo: Lynn Lee
Canada
HAIDA NATION


Cultural Importance
K'aaw – Herring roe-on-kelp
background photo: Lynn Lee
inset: photo from Gwaag̱anad in Haida Marine Traditional Knowledge Calendar, Council of the Haida Nation
Canada
HAIDA NATION

Canada

Fisheries and Oceans Canada

Hakai

UNIVERSITY OF OREGON

UBC

UNB

Canada

HAIDA NATION

Gwaii Haanas Archipelago Management Board

Parks Canada

Haida Nation

Fisheries and Oceans Canada

Canada

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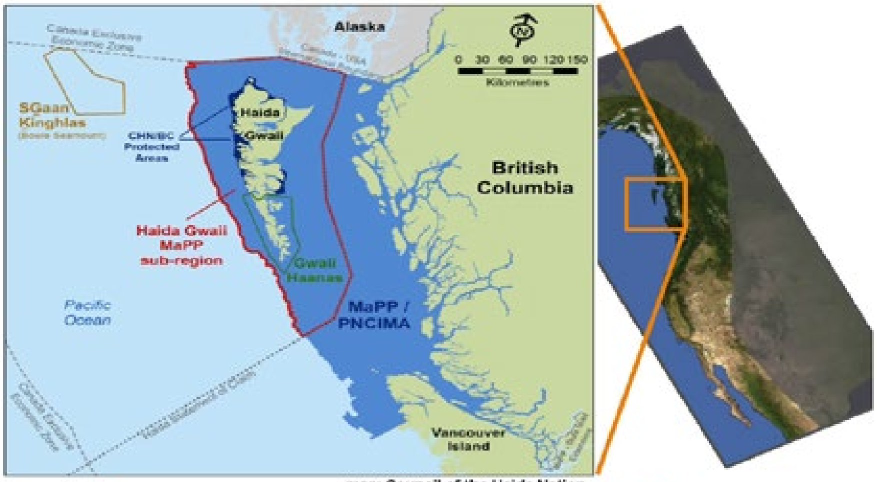
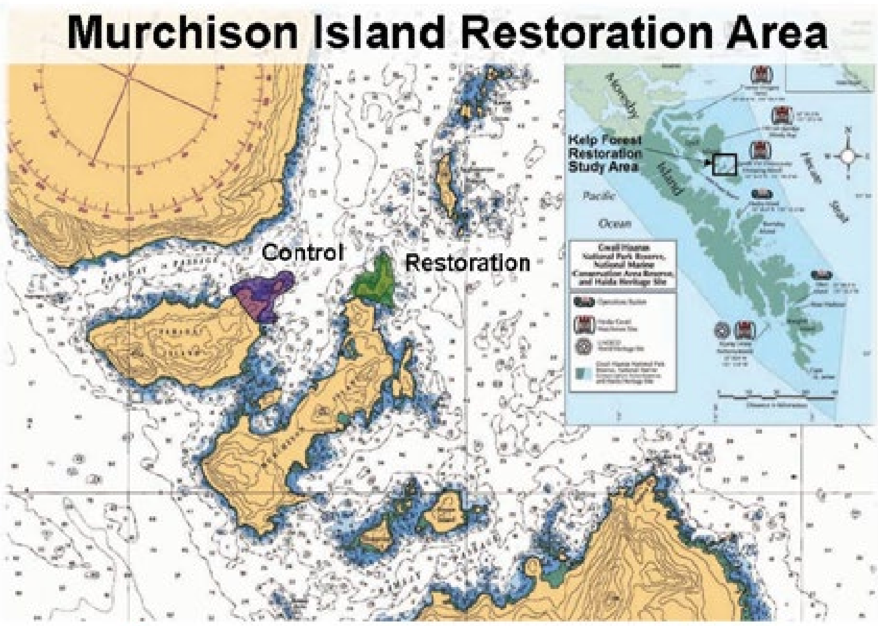


map: Council of the Haida Nation

Canada

HAIDA NATION



Canada

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Remote field camp

Canada

HAIDA NATION

Community Food & Urchin Cracking by commercial fishing & Haida crews

Canada

HAIDA NATION


Community Food & Urchin Cracking by commercial fishing & Haida crews
photo: Parks Canada/C.Houston
photo: Parks Canada/L.Lee
Canada
HAIDA NATION


Delivery of urchins for community food
photo: Parks Canada/C.Houston
Canada
HAIDA NATION

Delivery of urchins for community food

Canada

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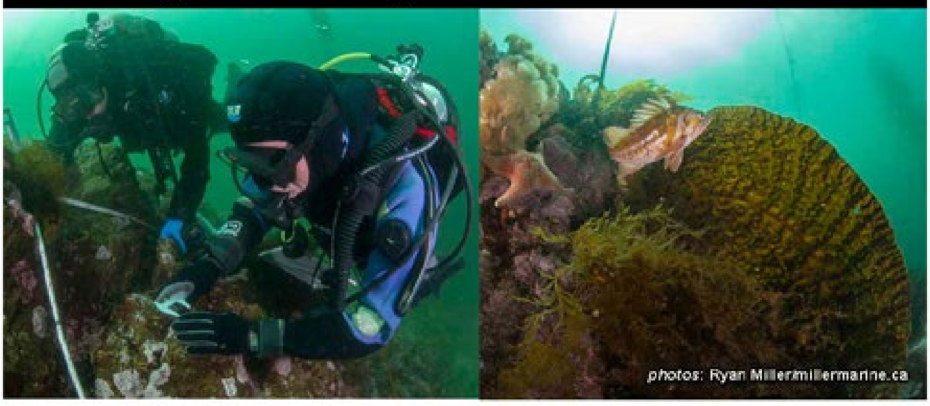
3. Restoring Balance in the Sea

- Training Haida divers in kelp community survey methods
- Subtidal kelp forest monitoring by Haida Fisheries divers
- Funding to assist training new Haida commercial divers



Canada

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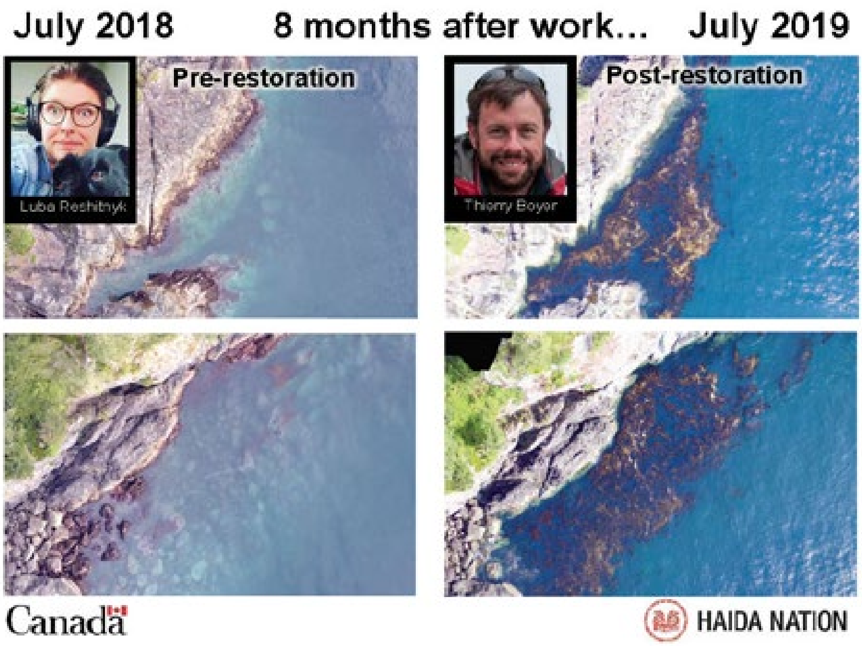
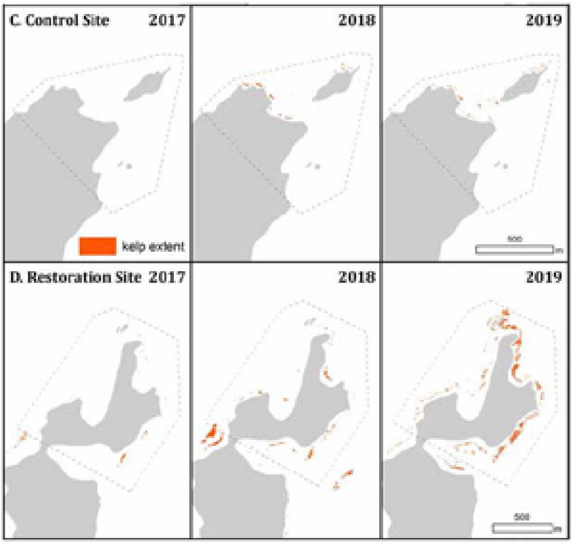
Fall 2018 & Spring 2019 Restoration Work
• Commercial urchin divers harvest marketable urchins
• Haida Fisheries & commercial urchin divers crack non-marketable urchins underwater
• At least 75-95% of urchins removed or cracked
photo: Ryan Miller/millermarine.ca
photo: Pacific Urchin Harvesters Association
Canada
HAIDA NATION


July 2018
8 months after work…
July 2019
Pre-restoration
Luba Reshitnyk
Post-restoration
Thierry Boyer
Canada
HAIDA NATION

Kelp Canopy Change

2017 & 18 Pre-restoration



2019 Post-restoration

analysis & maps: L. Reshitnyk, Hakai Institute

Canada

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Innovative Management Implications

- Continued work with industry to maintain restoration area
- Alternative urchin fishing strategies to assist kelp recovery

Canada

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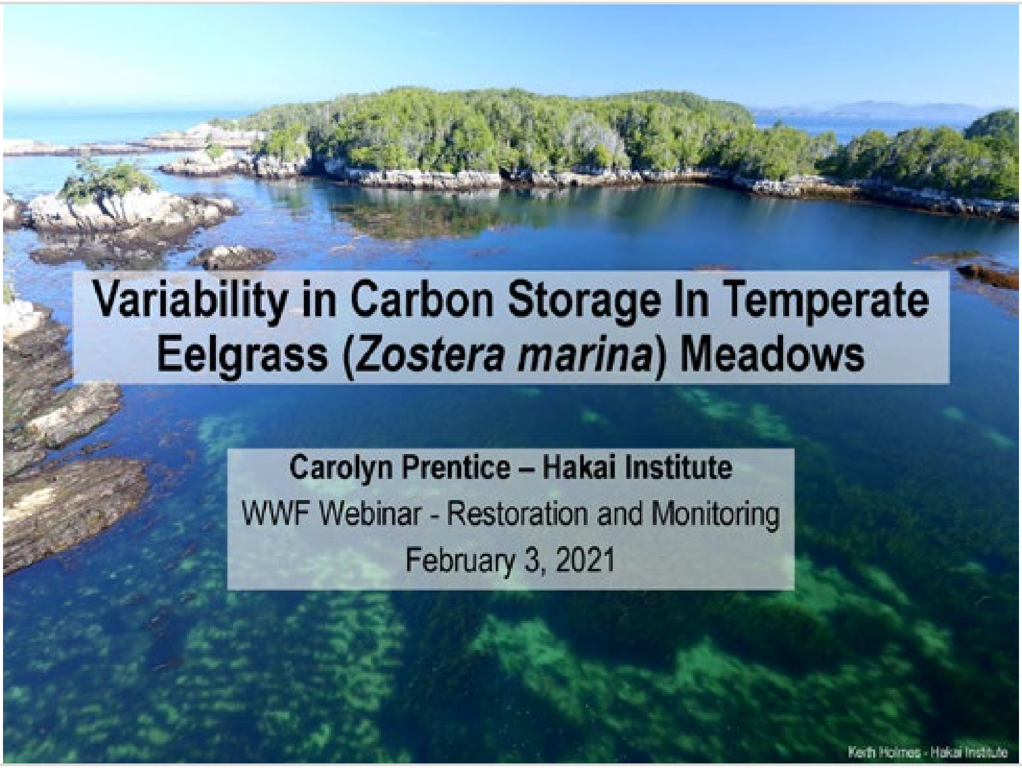
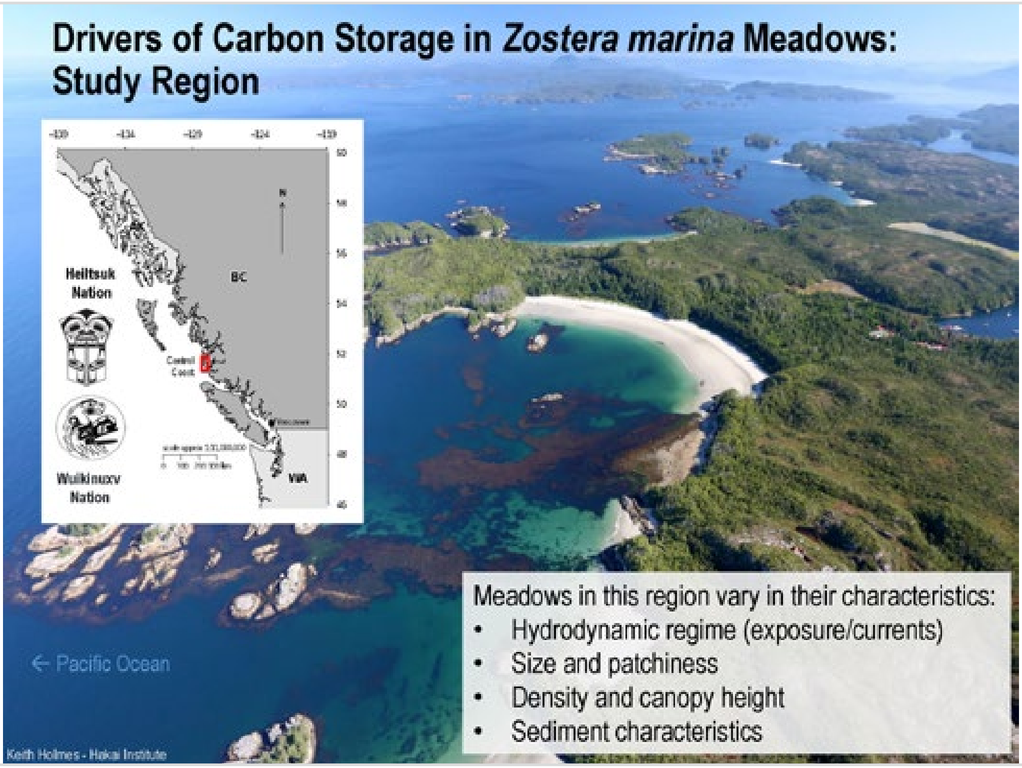
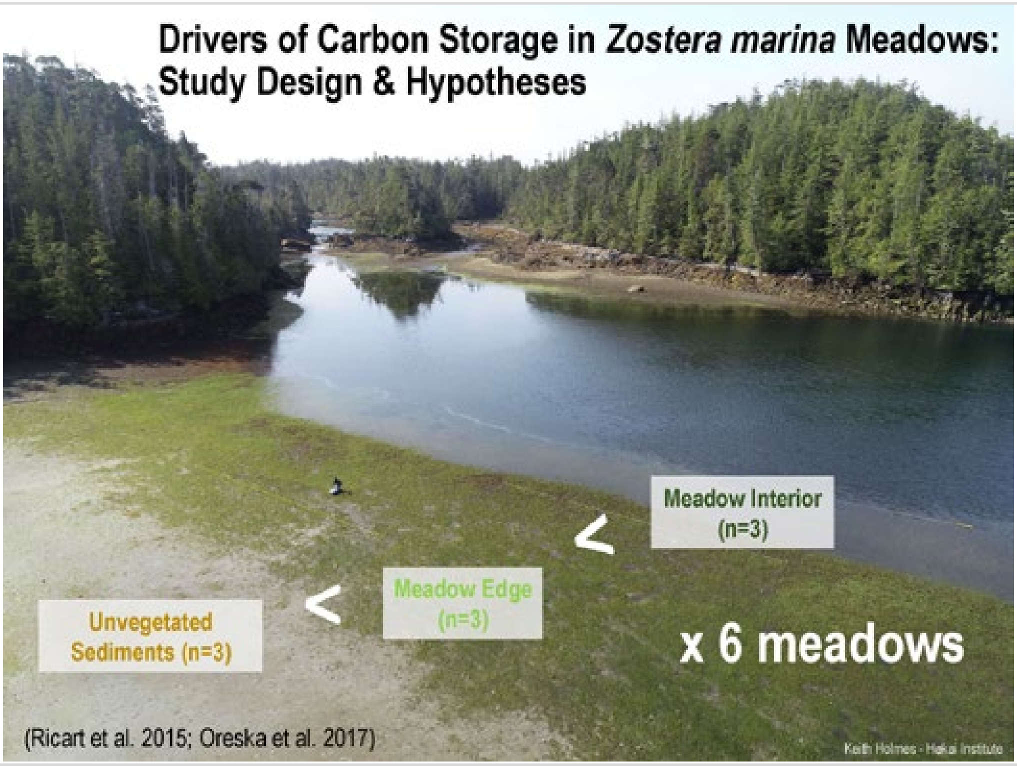
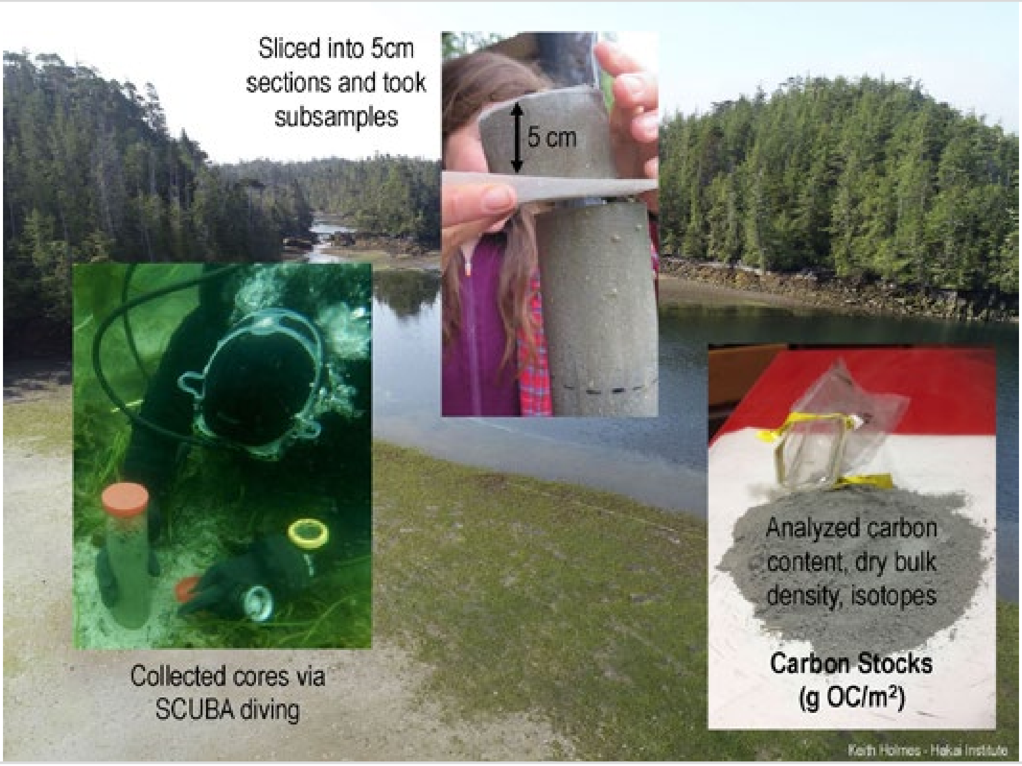
Kelp
Rocks!!
photo: Lynn Lee
Canada
HAIDA NATION

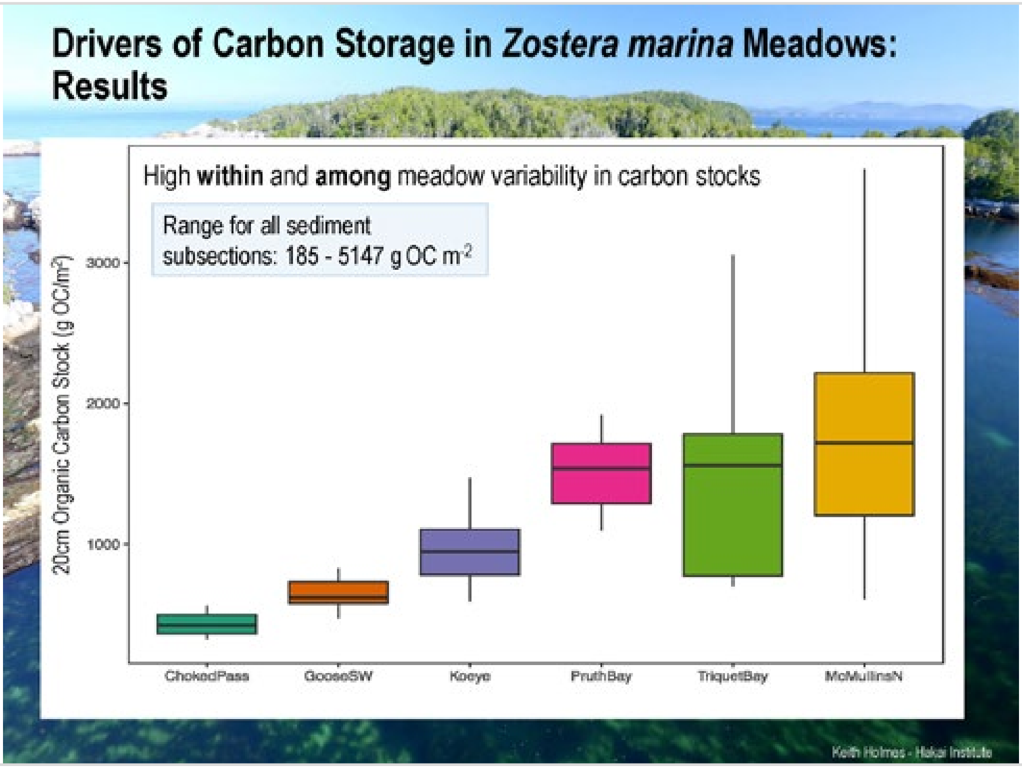

Variability in Carbon Storage In Temperate Eelgrass (Zostera marina) Meadows
Carolyn Prentice – Hakai Institute
WWF Webinar - Restoration and Monitoring
February 3, 2021
Keith Holmes - Hakai Institute

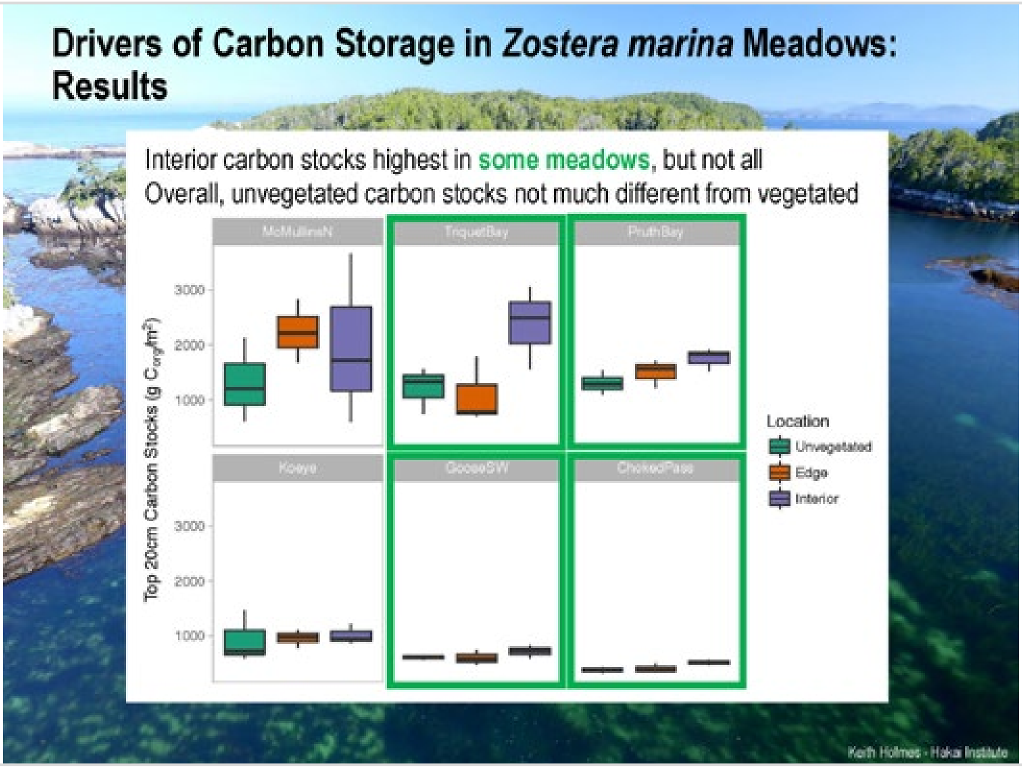

Drivers of Carbon Storage in Zostera marina Meadows
SFU
Hakai
Science on the Coastal Margin
LIMNOLOGY and OCEANOGRAPHY
ASLO
Reduced water motion enhances organic carbon stocks in temperate eelgrass meadows
Carolyn Prentice, Margot Hessing-Lewis, Rhea Sanders-Smith, Anne K. Salomon
Keith Holmes - Hakai Institute

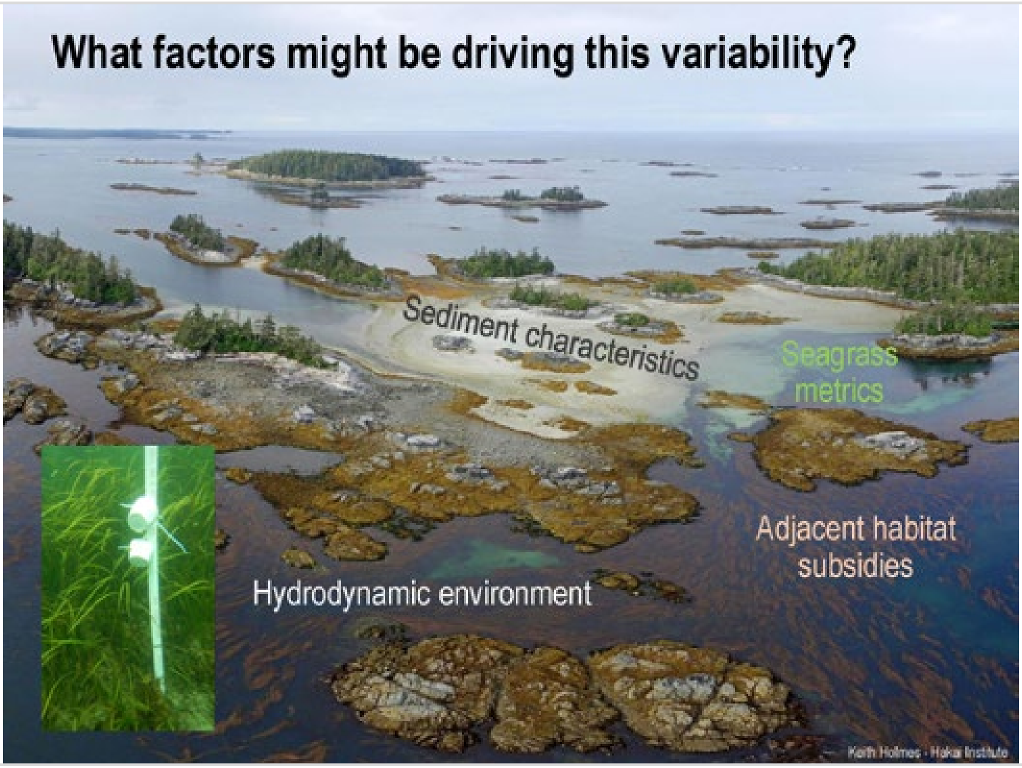

Drivers of Carbon Storage in *Zostera marina* Meadows:
Study Region
Heiltsuk Nation
BC
Wulkinuxv Nation
WA
Meadows in this region vary in their characteristics:
• Hydrodynamic regime (exposure/currents)
• Size and patchiness
• Density and canopy height
• Sediment characteristics
← Pacific Ocean
Keith Holmes - Hakai Institute

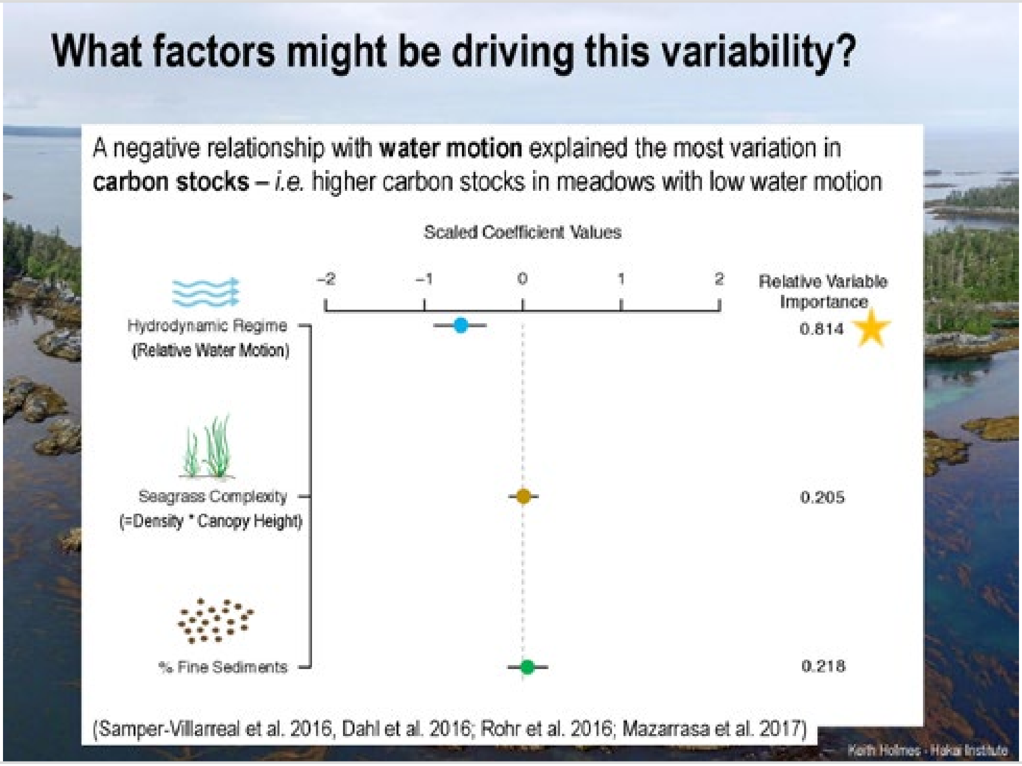

Drivers of Carbon Storage in *Zostera marina* Meadows:
Study Design & Hypotheses
Meadow Interior (n=3)
<
Meadow Edge (n=3)
<
Unvegetated Sediments (n=3)
x 6 meadows
(Ricart et al. 2015; Oreska et al. 2017)
Keith Holmes - Hakai Institute

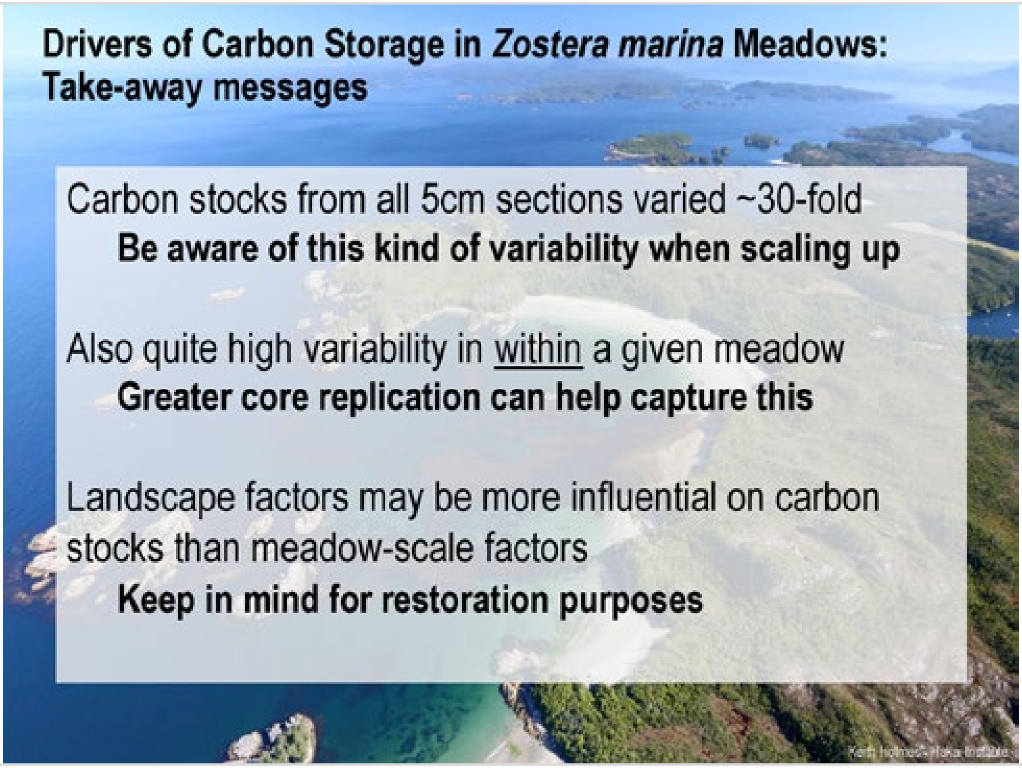

Sliced into 5cm sections and took subsamples
5 cm
Collected cores via SCUBA diving
Analyzed carbon content, dry bulk density, isotopes
Carbon Stocks (g OC/m²)
Keith Holmes - Hakai Institute


Drivers of Carbon Storage in Zostera marina Meadows: Results
High within and among meadow variability in carbon stocks
Range for all sediment subsections: 185 - 5147 g OC m-2
20cm Organic Carbon Stock (g OC/m²)
3000
2000
1000
ChokedPass
GooseSW
Koeye
PruthBay
TriquetBay
McMullinsN
Keith Holmes - Hakai Institute

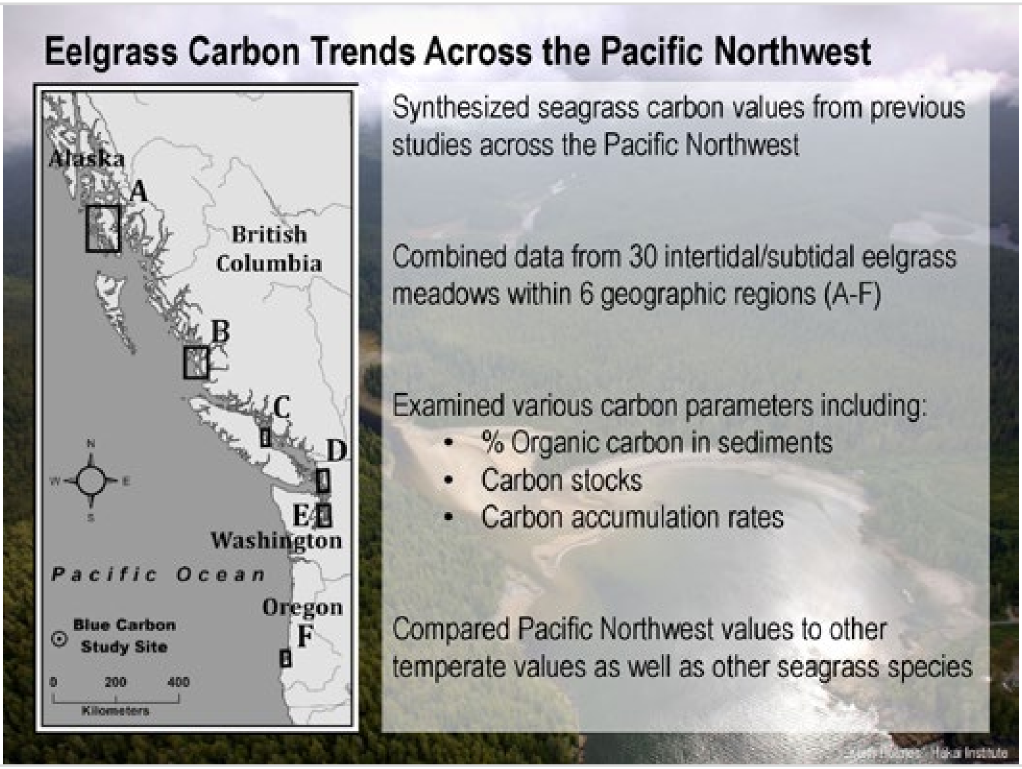

Drivers of Carbon Storage in Zostera marina Meadows: Results
Interior carbon stocks highest in some meadows, but not all
Overall, unvegetated carbon stocks not much different from vegetated
McMullinsN
TriquetBay
PruthBay
Koeye
GooseSW
ChokedPass
Top 20cm Carbon Stocks (g C_{org}/m^2)
3000
2000
1000
Location
Unvegetated
Edge
Interior
Keith Holmes - Hakai Institute

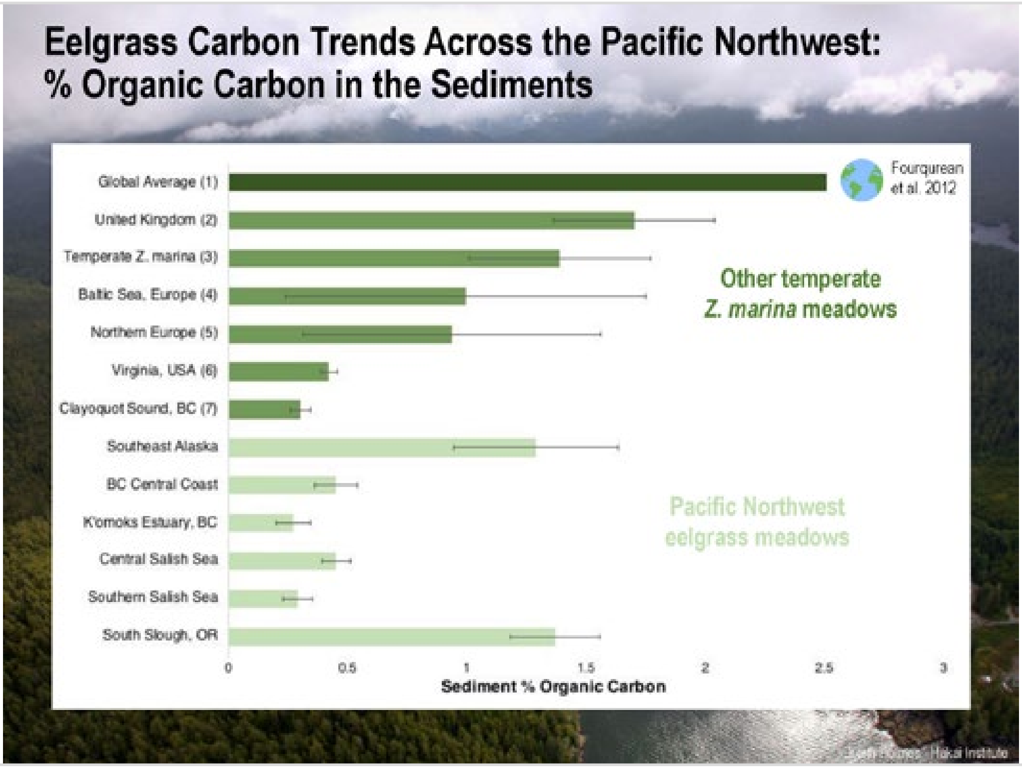

What factors might be driving this variability?
Sediment characteristics
Seagrass metrics
Adjacent habitat subsidies
Hydrodynamic environment
Keith Holmes - Hakai Institute

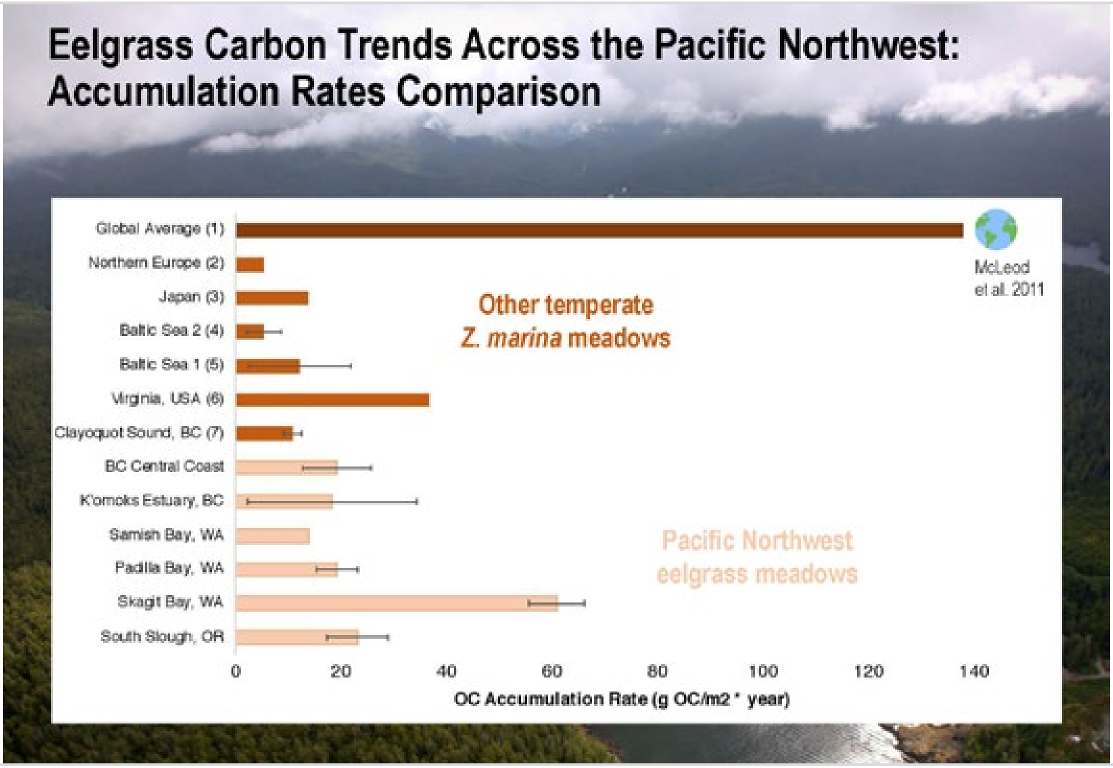

What factors might be driving this variability?
A negative relationship with water motion explained the most variation in carbon stocks – i.e. higher carbon stocks in meadows with low water motion
Scaled Coefficient Values
−2 −1 0 1 2
Relative Variable Importance
Hydrodynamic Regime (Relative Water Motion)
0.814
Seagrass Complexity (=Density * Canopy Height)
0.205
% Fine Sediments
0.218
(Samper-Villarreal et al. 2016, Dahl et al. 2016; Rohr et al. 2016; Mazarrasa et al. 2017)
Keith Holmes - Hakai Institute

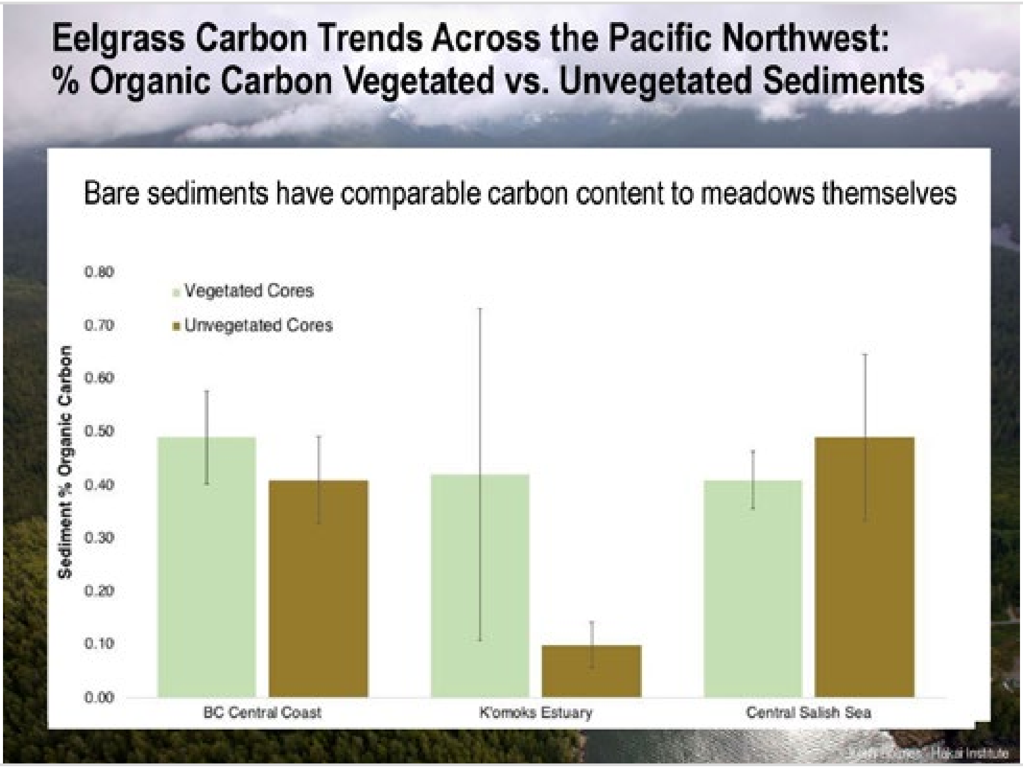

Drivers of Carbon Storage in Zostera marina Meadows: Take-away messages
Carbon stocks from all 5cm sections varied ~30-fold
Be aware of this kind of variability when scaling up
Also quite high variability in within a given meadow
Greater core replication can help capture this
Landscape factors may be more influential on carbon stocks than meadow-scale factors
Keep in mind for restoration purposes
Keith Holmes - Hakai Institute

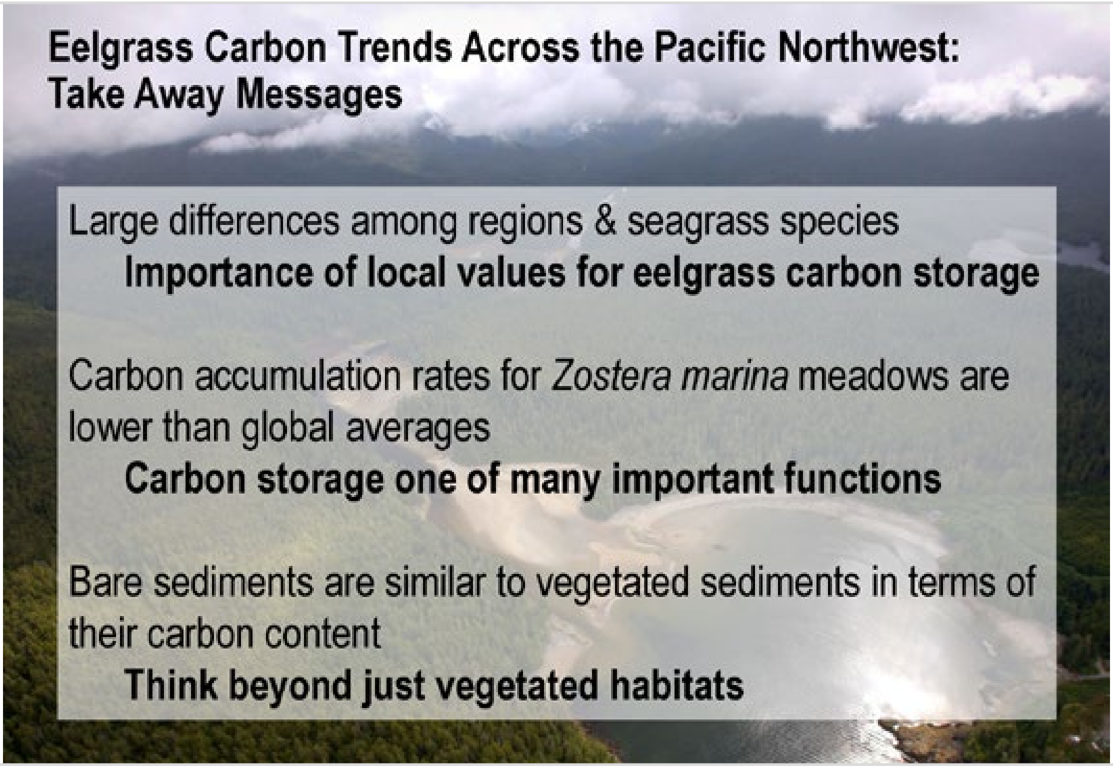

Eelgrass Carbon Trends Across the Pacific Northwest
Global Biogeochemical Cycles
RESEARCH ARTICLE
Special Section:
A Synthesis of Blue Carbon Stocks, Sources, and Accumulation Rates in Eelgrass (Zostera marina) Meadows in the Northeast Pacific
C. Prentice, K. L. Poppe, M. Lutz, E. Murray, T. A. Stephens, A. Spooner, M. Hessing-Lewis, R. Sanders-Smith, J. M. Rybczyk, J. Apple, F. T. Short, J. Gaeckle, A. Helms, C. Mattson, W. W. Raymond, and T. Klinger
Hakai
UNIVERSITY of WASHINGTON
SFU
Royal Roads
WESTERN
Hakai Institute


Eelgrass Carbon Trends Across the Pacific Northwest
Alaska
A
British Columbia
B
C
D
E
Washington
Pacific Ocean
Oregon
F
Blue Carbon Study Site
0 200 400
Kilometers
Synthesized seagrass carbon values from previous studies across the Pacific Northwest
Combined data from 30 intertidal/subtidal eelgrass meadows within 6 geographic regions (A-F)
Examined various carbon parameters including:
• % Organic carbon in sediments
• Carbon stocks
• Carbon accumulation rates
Compared Pacific Northwest values to other temperate values as well as other seagrass species
Hakai Institute


Eelgrass Carbon Trends Across the Pacific Northwest:
% Organic Carbon in the Sediments
Global Average (1)
United Kingdom (2)
Temperate Z. marina (3)
Baltic Sea, Europe (4)
Northern Europe (5)
Virginia, USA (6)
Clayoquot Sound, BC (7)
Southeast Alaska
BC Central Coast
K'omoks Estuary, BC
Central Salish Sea
Southern Salish Sea
South Slough, OR
0
0.5
1
1.5
2
2.5
3
Sediment % Organic Carbon
Fourqurean et al. 2012
Other temperate
Z. marina meadows
Pacific Northwest
eelgrass meadows


Eelgrass Carbon Trends Across the Pacific Northwest:
Accumulation Rates Comparison
Global Average (1)
Northern Europe (2)
Japan (3)
Baltic Sea 2 (4)
Baltic Sea 1 (5)
Virginia, USA (6)
Clayoquot Sound, BC (7)
BC Central Coast
K'omoks Estuary, BC
Samish Bay, WA
Padilla Bay, WA
Skagit Bay, WA
South Slough, OR
0
20
40
60
80
100
120
140
OC Accumulation Rate (g OC/m2 * year)
McLeod et al. 2011
Other temperate
Z. marina meadows
Pacific Northwest
eelgrass meadows


Eelgrass Carbon Trends Across the Pacific Northwest:
% Organic Carbon Vegetated vs. Unvegetated Sediments
Bare sediments have comparable carbon content to meadows themselves
Vegetated Cores
Unvegetated Cores
Sediment % Organic Carbon
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
BC Central Coast
K'omoks Estuary
Central Salish Sea


Eelgrass Carbon Trends Across the Pacific Northwest:
Take Away Messages
Large differences among regions & seagrass species
Importance of local values for eelgrass carbon storage
Carbon accumulation rates for Zostera marina meadows are lower than global averages
Carbon storage one of many important functions
Bare sediments are similar to vegetated sediments in terms of their carbon content
Think beyond just vegetated habitats

Conclusions:

Not all seagrass meadows are the same - important to consider variability at multiple scales:

- **Local** - within meadows (e.g. edge vs. interior)
- **Regional** – (e.g. among meadows across the PNW)
- **Global** (different seagrass species)

Use caution when scaling up values to broader regions

- Inaccurate to use values from other regions/species
- Apply appropriate methods to scale up variability

Monitoring – sufficient sample size and spatial coverage

Restoration – consider physical environment as well as meadow conditions when thinking about restoration projects

Speed talks


20+ years of collaboration
>400 ha tidal wetland restored
Atlantic Canada's leading experts in coastal wetland restoration
Mission:
To help build climate resilient coastal communities and ecosystems by protecting, enhancing, and restoring natural processes through innovative research, collaboration, and implementation of nature-based adaptation and natural infrastructure solutions.
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TransCoastal Adaptations
Centre for Nature-Based Solutions
Contact:
Tony M. Bowron
Tony.bowron@cbwes.com
cbwes.com
Dr. Danika van Proosdij
dvanproo@smu.ca
transcoastaladaptations.com
Managed Realignment
Nature-based Adaptation
"Making Room for…" projects
Research & Discovery
Outreach & Education
Innovation & Application


Designing Solutions to the Hidden Impacts of Climate Change on Canada's Undersea Forests
Danielle Denley, Meredith Fraser, Alejandro Frid, Mike Reid, Anne Salomon
SFU SIMON FRASER UNIVERSITY
ENGAGING THE WORLD
CCIRA
CENTRAL COAST INDIGENOUS RESOURCE ALLIANCE
PICS
PACIFIC INSTITUTE FOR CLIMATE SOLUTIONS
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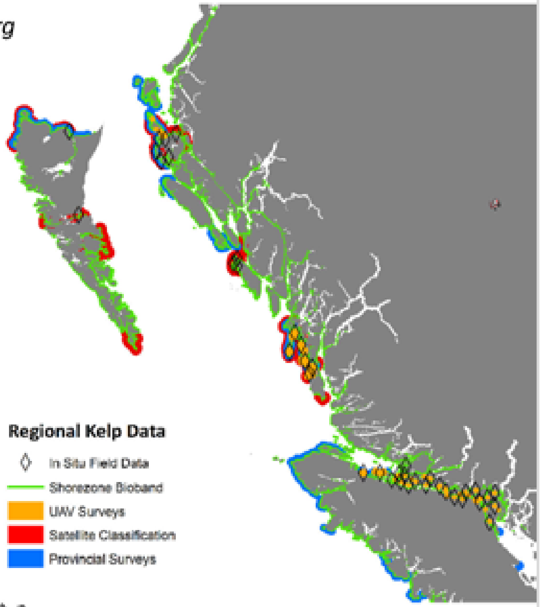
>5 – 15%
>15 – 25%
>25 – 50%
>50 – 75%
Danielle Denley (SFU)
Doug Newman
(Heiltsuk Guardian Watchman)
Photos: Markus Thompson & Mark Wunsch
Drawing: M. Fraser

Marine Plan Partnership

MaPP

www.mappocean.org

- Partnership between 17 First Nations and the Province of BC in the Northern Shelf Bioregion
- Implementing 4 sub-regional marine plans and a regional action framework
- Coordinated regional kelp monitoring (field-based, satellites, UAVs) to inform ecosystem-based management (EBM)
- *Aim:* Understand kelp spatial distribution, condition, change over time, key drivers to inform management (e.g., cumulative effects assessment, protected area management; habitat restoration)
- *Key challenge:* capacity



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