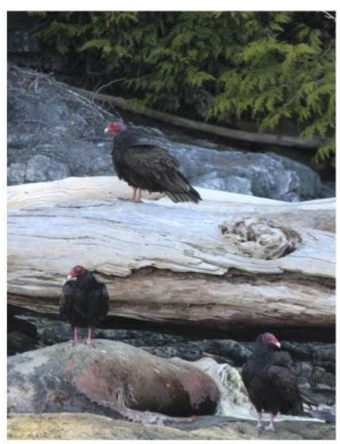

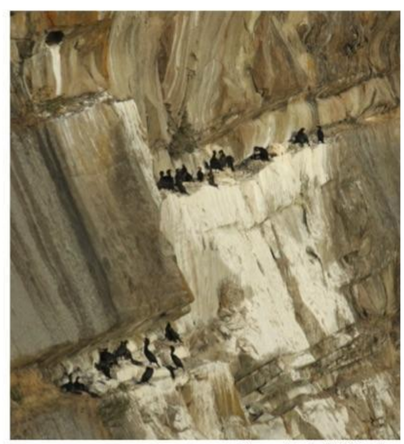

Photos by Emily Wharin

Incorporating a Marine-Terrestrial Interactions Component Into the Chrystal Creek Watershed Restoration Project: A Research Report

By Emma Borg and Emily Wharin

Table of Contents

1.0 Abstract

In this report, we describe marine-terrestrial interactions and discuss which of the lesser-understood marine-to-terrestrial vectors are relevant at Chrystal Cove and within the Chrystal Creek Watershed. We found that the most prominent vectors that transfer marine nutrients throughout the watershed are seabirds, specifically gulls and cormorants, river otters, and carrion cycling by turkey vultures. These animals bring nutrients such as nitrogen, carbon, phosphorus, and ammonia from marine ecosystems to terrestrial ecosystems. Nitrogen, phosphorus, and ammonia are limiting nutrients for many plants, so an increased availability of these nutrients will increase plant growth. We also lay out a framework that details how to conduct stable isotope analysis for nitrogen and carbon on soil samples and plant matter to determine if there is a significant amount of marine-derived nitrogen and carbon throughout the watershed.

2.0 Territory Acknowledgement

We would like to acknowledge that the site of this project is on the unceded Coast Salish territory of the Penelakut First Nation and ceded territory of the Tsawwassen First Nation. As we understand it, there are additional Indigenous ties to Galiano Island with the Lamalcha and Hwlitsum First Nations and other Hul'qumi'num speaking peoples. We would also like to acknowledge the SENĆOŦEN and W̱SÁNEĆ speaking peoples and anyone else who had or currently has a connection to this land (Acknowledging our shared territory, n.d.).

3.0 Introduction

We chose this project to address potential marine-terrestrial interactions in an existing restoration project focused on the Chrystal Creek Watershed. We are pursuing the topic of marine-terrestrial interactions because recent research has shown that land-sea linkages play an important role in nutrient transfer and the overall health of the ecosystem. Human activities, such as land use, disturb land-sea connectivity (Fang et al., 2018). These linkages are not widely considered in many terrestrial-based restoration projects in disturbed areas. This report summarizes the key interactions affecting marine-connected restoration sites. These marine-terrestrial interactions involve the bi-directional flow of materials and nutrients between these two ecosystems via biotic and abiotic vectors. In this report, we will be focusing on the transfer of marine-derived nutrients onto land via biotic vectors because it is not yet well defined or understood for this area. We recognize that the topic of marine-terrestrial interactions is a relatively new area of study (i.e., the last two decades) and thus is relatively novel and unexplored in restoration practices.

This project is in support of an already existing watershed restoration project. This report and accompanying infographic are intended to provide the Galiano Conservancy Association (GCA) with a starting point for understanding the marine-terrestrial interactions associated with the Chrystal Creek Watershed Restoration Project. Additionally, it will provide recommendations for actions that could be taken to gather a more site-specific understanding of these interactions and how these interactions impact the availability of limiting nutrients in the Chrystal Creek Watershed.

4.0 Site Description

4.1 Location

The Chrystal Creek Watershed is the restoration site of interest for this project. It is located on Galiano Island, B.C. The site is situated approximately halfway up Galiano Island on the southwest coast. It is centrally located at the Millard Learning Centre (legally District Lot 57) owned by the GCA (Figure 1).

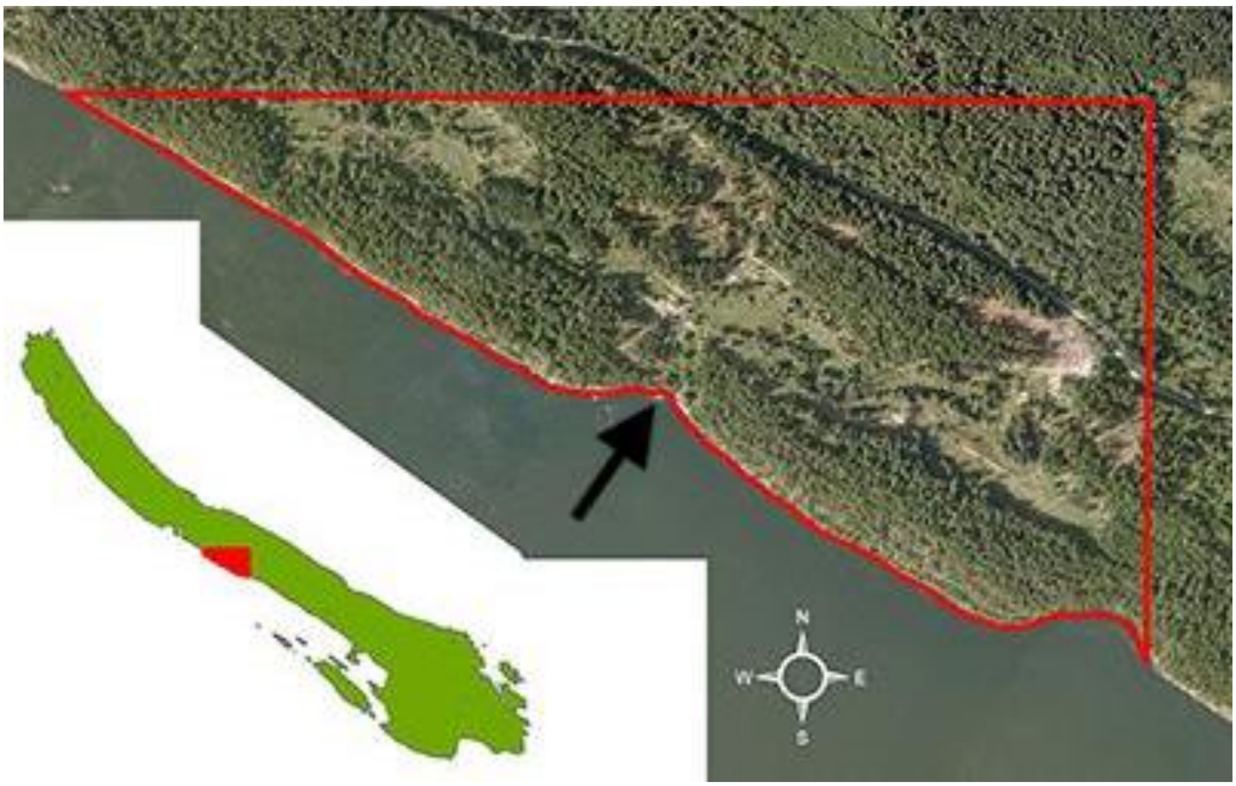

Figure 1. Map indicating the location of this project's site of interest on Galiano Island, BC. The black arrow indicated the general location of Chrystal Cove, which is the outflow of the associated Chrystal Creek Watershed, within the GCA's Millard Learning Centre property (District Lot 57). Figure adapted from the GCA Website (https://galianoconservancy.ca).

4.2 The Galiano Conservancy

The GCA is a non-profit society and registered charity that was founded in 1989. Their purpose is "to preserve, protect and enhance the quality of the human and natural environment," which they do through activities and initiatives including conservation, restoration, stewardship, and education (GCA Mission, n.d.). Land acquisition through direct purchase and cooperative partnerships has been the primary method that the GCA has used to manage and conserve land and habitat on Galiano Island. The GCA purchased the District Lot 57 property in 2012 (Figure 1). The property is now the base of operations, which is known as the Millard Learning Centre (MLC). The MLC is the heart of their many research and educational programs (GCA Mission, n.d.).

Our goal is to provide the GCA with a synthesis of information from the recent literature that will help guide their current Chrystal Creek Watershed Restoration Project, as well as future restoration endeavors. By providing a synthesis of the potential marine-terrestrial interactions present at the site, the GCA will be able to support and encourage these linkages to persist and/or form. These interactions are an important component in a restoration project like the Chrystal Creek Watershed project. Incorporating a marine element into their existing terrestrial-based project is especially relevant to the GCA, whose mission is terrestrial *and* marine conservation (GCA Mission, n.d.).

4.3 History of the site

The primary site for this report is Chrystal Cove, which is the outflow of the Chrystal Creek Watershed, which is wholly contained within the boundaries of MLC property. Thus, the Cove is the most active point of interaction between the marine and terrestrial landscapes on the MLC property. There have been many human interactions and disturbances over its history, which have resulted in the need for restoration.

The Chrystal Creek Watershed is 28 hectares in size and is centrally located on the MLC property (Figure 1). This watershed does not occupy the entire property, but the entire watershed is contained within the MLC property. The Chrystal Creek Watershed drains an area that contains a gently sloped valley bounded by steep sandstone ridges that flow through a break in the western ridge, dropping more than 20m down, to where it empties into the ocean through Chrystal Cove. The water drains through Chrystal Cove and flows into Trincomali Channel, which is the channel between Saltspring Island and Galiano Island, on the southwest side of Galiano Island (Figure 2; EcoAction 2020-2022 Proposal).

Figure 2. Map of the Galiano Conservancy's Millard Learning Centre property with the Chrystal Creek watershed outlined in black, and restoration area mapping within. Figure adapted from a map provided by Adam Huggins at the GCA.

Chrystal Cove is of particular interest because there is a large-scale, multi-phase restoration project underway for the Chrystal Creek Watershed. Exploring the marine-terrestrial interactions of Chrystal Cove's land-sea interface will have implications for this restoration project. This restoration project was proposed for the watershed because the previous century of human use and degradation of the land has altered many historic conditions (EcoAction 2020-2022 Proposal). The anthropogenic impacts on the land have primarily included logging, agriculture, and human settlement, which extended down into Chrystal Cove (Campbell, 2015; EcoAction 2020-2022 Proposal; Renwick-Shields and Weller, n.d.). These areas of human disturbance can be seen in Figure 3. The history of human impact is evident in Chrystal Cove based on the abundance of non-native invasive species that were able to invade due to the disturbed landscape (Campbell, 2015). Extensive terrestrial restoration work done near Chrystal Cove has included surveying vegetation communities, monitoring species composition, removing invasive plants, protecting saplings from herbivory, and planting native plant species (Campbell, 2015). Since this cove has an unusual hybrid native/introduced species composition, any biodiversity data collected here would not be reflective of the pre-degraded ecosystem. Thus, it may be necessary to look elsewhere on or nearby the MLC for reference sites that are more representative (e.g., the cove that borders the Trincomali Nature Sanctuary, which has not been heavily used by humans).

It is also important to acknowledge that this land is on the traditional territories of the Hul'qumi'num speaking peoples (Penelakut, Chemainus, Cowichan Tribes, Halalt, Lake Cowichan, and Lyackson), the Hwlitsum Nation, and Tsawwassen First Nation (Renwick-Shields and Weller, n.d.). Although traditional use of the land by First Nations on this site is not presently known, there was likely some interaction with this low-bank cove and stream access to the west side of Galiano Island (Renwick-Shields and Weller, n.d.).

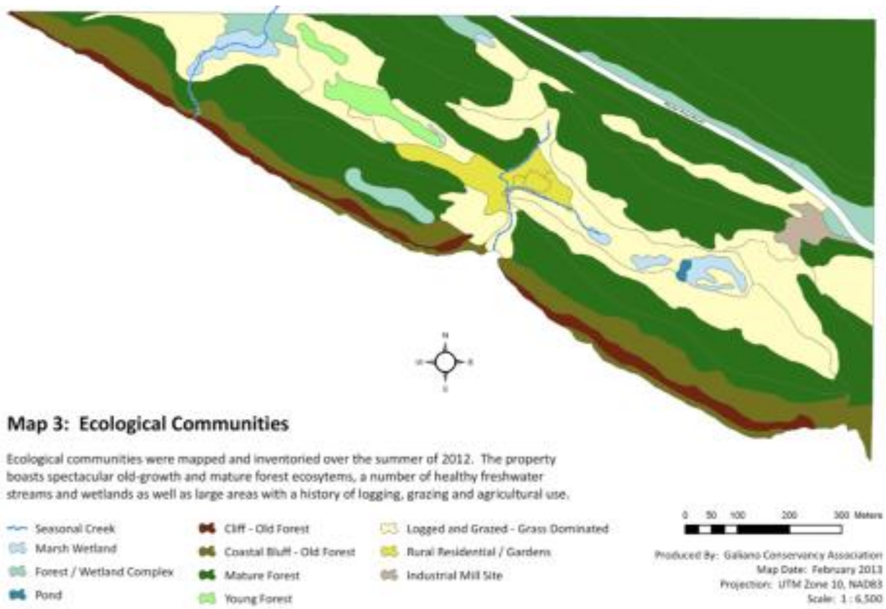

Figure 3. This is a figure depicting the ecological communities on the GCA's Millard Learning Centre property. This map also displays the areas of anthropogenic influence on the land which is useful in understanding the history of the Chrystal Creek watershed. Retrieved from the Galiano Centre Management Plan (Galiano Learning Centre Management Committee, 2013).

As a result of this site's disturbance, many features of the natural watershed have been lost, including historic hydrology, soil, plant composition, and forest character (EcoAction 2020-2022 Proposal). To successfully restore this watershed to an intact, ecologically functional ecosystem, we argue that marine-terrestrial interactions are a relevant consideration in the restorative process because they can positively affect ecosystem health. It would be beneficial to be able to answer the following questions: are marine-derived nutrients being transferred onto land by local fauna, is this having a positive impact on watershed recovery and biodiversity enrichment at this site, and how can these interactions be supported?

In terms of the terrestrial characteristics of this site, the Chrystal Creek Watershed is part of the Coastal Douglas-fir biogeoclimatic zone. The Watershed comprises a mix of cliff old forest, coastal bluff old forest, and inland mature forest (figure 3). These distinct ecological communities are dominated by different tree species such as Garry oak (*Quercus garryana*), Douglas-fir (*Pseudotsuga menziesii*), and western redcedar (*Thuja plicata*) that support distinct ecosystem types. Efforts of the GCA to determine the historical ecological character of this watershed found that it was likely predominated by large western redcedar trees associated in patches as mixed skunk cabbage - cedar swamp ecosystems (EcoAction 2020-2022 Proposal).

The marine characteristics of this site are much less defined. Although we plan on focusing on Chrystal Cove primarily, it is important to consider the larger marine landscape. There is a continuous flow of water and marine life along the coastline, and thus interactions along the shore are not confined to Crystal Cove. The Cove opens into the Trincomali Channel, which experiences a daily flush of water through it. Water from Haro Strait surges through Swanson Channel into Trincomali Channel then flows out into the Georgia Strait through both Porlier Pass and Active Pass. Porlier Pass and Active Pass are located at either end of the Trincomali Channel (Thomson, 1981). These two passes experience strong tides and currents as the water flushes out into the Georgia Strait, which is a much larger body of water with comparatively less confined, intense patterns of water flow (Thomson, 1981).

Additionally, Galiano Island sees a range of fauna, including many land and sea birds, marine mammals, semi-aquatic mammals, and marine invertebrates. There are two Important Bird Areas on either end of Galiano Island (https://www.ibacanada.ca/), as well as a protected cormorant nesting cliff just south of the MLC along the shore in the Trincomali Nature Sanctuary ('Trincomali Nature Sanctuary', 2019). There is also a Rockfish Conservation Area (RCA) extending offshore along this section of the Galiano Island shoreline in an attempt to stop the fishing of these long-lived and in some cases threatened group of fishes (Category Archives; Species at Risk, n.d.). The GCA plays a large role in the rockfish conservation initiative associated with RCAs. Additionally, they have several cetacean conservation initiatives and associated habitat considerations, including eelgrass meadows and kelp beds (Category Archives; Species at Risk, n.d.). The biological diversity associated with this coastline contributes to facilitating marine-terrestrial interactions.

5.0 Goals and Objectives

Goal 1: Develop a comprehensive understanding of marine-terrestrial interactions in support of active restoration projects.

Objective 1: To provide the GCA with a document that synthesizes the key points from the literature that will allow them to easily consider these factors when they take on restoration projects.

Objective 2: Link our findings from the literature to the Chrystal Creek watershed restoration project. Provide GCA with recommendations about how to consider the marine-terrestrial interactions in their restoration plan for the Chrystal Creek Watershed to make it a more robust plan that considers all aspects that are affecting the watershed.

Goal 2: Create an educational resource that supports a deeper understanding of marine-terrestrial ecological interactions.

Objective 1: Create a report that provides documentation relevant to future education materials and potential future research pursuits.

Objective 2. Create an information graphic summarizing our key findings in a way that will be accessible to the public. This infographic can be distributed digitally or displayed as an interpretive sign near Chrystal Cove.

Goal 3: Provide a framework for stable isotope analysis to support research on marine-terrestrial interactions

Objective: Provide a framework on how to conduct stable isotope analysis on nitrogen and carbon to assess the marine-terrestrial interactions.

6.0 Summary of the Marine-Terrestrial Interactions

6.1 Brief overview

Until recently, not much was known about the interactions between marine and terrestrial ecosystems. Land-sea linkages refer to the interaction of physical, chemical, and biological processes between marine and terrestrial ecosystems (Fang *et al*., 2018). As more research is done in this area, important linkages are emerging. According to emerging literature, several different vectors facilitate the transfer of nutrients between marine and terrestrial ecosystems.

Salmon transfer into the riparian zone via bears has been shown to significantly increase the amount of nitrogen in the soil (Hocking and Reimchen, 2002; 2006). Every year when the salmon spawn, they transport marine-derived nutrients from the Northern Pacific Ocean into coastal ecosystems (Hocking and Reimchen, 2002). Salmon nutrients are transferred into terrestrial habitats primarily by bear mediated carcass transfer and bear urine (Hocking and

Reimchen, 2002). The impact of salmon and bears at the land-sea interface has been the subject of many recent studies, but there are no regularly occurring bears present on Galiano.

Another vector of marine-derived nutrients onto land is First Nations communities (Trant *et al*., 2016). Shell middens found in historical coastal villages or campsites contain the remnants of marine harvested food sources that were brought onto land (Trant *et al*., 2016). The soil near shell middens is high in phosphorus and calcium, which are both limiting factors in coastal temperate rainforests (Trant *et al*., 2016). There was First Nations use at Montague Harbor, which is on the Southwestern part of Galiano Island (Grier, 2014). There were extensive shell middens at Montague Harbor (Grier, 2014). Montague Harbor was a long-term habitation site for First Nations as well (Grier, 2014). There is no evidence of extensive First Nations use or shell middens at Chrystal Cove.

Since Chrystal Cove does not have any resident bears or spawning salmon or First Nations use, we will focus on other vectors of marine-derived nutrient transfer. Seabirds, river otters (*Lontra canadensis*), and turkey vultures (*Cathartes aura*) are the prominent vectors of marine-terrestrial interactions. All of these are abundant in Chrystal Cove, so they will have the greatest impact on the terrestrial ecosystem.

6.2 Effect of Seabirds on Nutrient Transfer

Seabirds play an important role in redistributing nutrients between marine and terrestrial environments over large geographical areas (Hentati-Sundberg *et al.*, 2020). There have been high levels of $\delta^{15}N$ found in areas surrounding seabird colonies (Hentati-Sundberg *et al.*, 2020). In a study by Bokhorst, Convey, and Aerts, they found that penguins in the Antarctic transferred significant amounts of nitrogen from the sea to land, causing the nitrogen in the vegetation to be enriched well beyond the reaches of the penguin colonies. (2019). The same study found that the presence of the penguins and the nutrients they transport created biodiversity hotspots (Bokhorst, Convey, and Aerts, 2019).

Seabirds are an important vector in the transfer of nutrients, such as ammonia and nitrogen, from marine ecosystems to terrestrial ecosystems (Ellis, Farina, and Witman, 2006). Seabirds bring large amounts of marine-derived nutrients to the land, which increases nutrient availability to terrestrial species (Ellis, Farina, and Witman, 2006). During the breeding season, seabirds leave food scraps, eggshells, feathers, and the bodies of dead chicks on land (Ellis, Farina, and Witman, 2006). These add significant nutrients to the terrestrial ecosystem (Ellis, Farina, and Witman, 2006; Rowe *et al.*, 2017; Zwolicki *et al*., 2016). Seabirds also produce guano concentrated around roosting and nesting areas that are rich in nutrients, such as nitrogen and phosphorus, which are limiting nutrients in terrestrial ecosystems (Ellis, Farina, and Witman, 2006). These nutrients enrich the soil and can increase the amount of nitrogen and phosphorus in terrestrial ecosystems by 100-400 times (Ellis, Farina, and Witman, 2006; Rowe *et al.*, 2017). The presence of seabirds typically has a positive effect on plant growth (Ellis, Farina, and Witman, 2006). A study by Ellis, Farina, and Witman in 2006 found that all plant species surrounding the gull and cormorant colonies were enriched with $\delta^{15}N$. The same study also found that concentrations of ammonia, nitrate, and phosphate in soils increased as the nesting density increased (Ellis, Farina, and Witman, 2006).

Nitrogen and phosphorus can be easily lost if the ecosystem has steep slopes, but seabirds help to maintain good levels of nutrients (Rowe *et al.*, 2017). This is relevant to Chrystal Cove and the rest of the Chrystal Creek Watershed because there are steep inclines from the Cove up into the rest of the watershed. We assume the steepness of the terrain will not limit the availability of nutrients brought from the marine ecosystem by seabirds.

Many types of seabirds interact with the MLC property. Most notably, the cliffs of the adjacent Trincomali Nature Sanctuary support the nesting of several sea birds including double-crested cormorants (*Phalacrocorax auritus*), pelagic cormorants (*Phalacrocorax pelagicus*), glaucous-winged gulls (*Larus glaucescens*), and pigeon guillemots (*Cepphus columba*) ('Trincomali Nature Sanctuary', 2019). The main birds we expect to bring marine nutrients into the Chrystal Creek Watershed are gulls and cormorants because of their abundance.

Although the cormorant colonies are located on cliffs adjacent to Chrystal Cove, they can still have significant impacts on the watershed. In a study done on penguin colonies by Bokhorst, Convey, and Aerts, they found that the biodiversity hotspots caused by the nutrients from the penguin colony covered an area ranging from 0.4 to 6.6 km^2, which was up to 240 larger than the colony itself (2019). The cormorant colonies adjacent to the site are smaller than the penguin colony that was studied, so it is unlikely that nutrients will cover the same area; however, the nutrients from the guano stained cliffs of the cormorant colonies will benefit plants well beyond the colonies' borders.

6.3 Effect of River Otters on Nutrient Transfer

River otters are also important vectors for nutrient transfer from marine to terrestrial environments (Ben-David *et al.*, 1998; Roe *et al.*, 2010). River otters often occur and forage in large social groups (Ben-David *et al.*, 1998). These groups of river otters also share latrine sites where they deposit urine, feces, and excretions from their anal glands (Ben-David *et al.*, 1998). River otter latrine sites provide marine-derived nutrient fertilization and physical disturbance for surrounding areas (Roe *et al.*, 2010). A study by Ben-David *et al*. used stable isotope analysis to determine that plants near latrine sites had significantly higher concentrations of marine-derived nitrogen compared to pants that were not near latrine sites (1998). Latrine sites contain substantial quantities of limiting nutrients that were deposited by river otters (Roe *et al.*, 2010).

River otters are commonly seen swimming in Chrystal Cove and the Trincomali Channel. The river otters often venture into the forest of the Chrystal Creek Watershed. We know there is a strong presence of river otters in and around Chrystal Cove and the Chrystal Creek Watershed, so there should be increased nitrogen in the soils and plants found near sites where feces are frequently found. Anecdotal accounts suggest river otters move significantly (>1 km) away from the shore on Galiano Island.

6.4 Effect of Carrion Cycling on Nutrient Transfer

In addition to the nutrient transfer at the land-sea interface by seabirds and river otters, carrion cycling is an important vector of nutrient transfer between different ecosystems (Beasley, Olson, and Devault, 2012). There is still a lot of unknown surrounding carrion cycling between marine and terrestrial ecosystems, but it most likely has significant impacts on nutrient cycling and transfer between the ecosystems (Beasley, Olson, and Devault, 2012). There are many turkey vultures that frequent the MLC property and they can disperse nutrients from the carrion they consume.

Because the MLC property includes coastline that connects the terrestrial and marine ecosystems, the turkey vultures likely consume a wide variety of different types of carrion. Turkey vultures will feast on marine organisms (e.g., a dead seal) then drop their feces on land.

Because their feces are dropped on land, marine nutrients from their feces are available to terrestrial vegetation in the Chrystal Creek Watershed.

7.0 Stable isotope analysis: a direction for future research

To determine whether the interactions between the marine and terrestrial environment are significant, the GCA could perform a systematic study using stable isotope analysis of Nitrogen to find the value of $\delta^{15}N$. The ratio of the stable isotopes of nitrogen, which is the ratio of $^{15}N/^{14}N$ and is expressed as $\delta^{15}N$, changes depending on whether the origin of the nutrients is terrestrial or marine (Zwolicki *et al*., 2016). The proportion of ^{15}N is usually higher in marine organic matter, which means that stable isotope analysis can be used to determine the origin of the nitrogen in the Chrystal Creek Watershed (Zwolicki *et al*., 2016). Analysis of invertebrates, plants, or soil can be done to find $\delta^{15}N$, which is a measure of the two stable isotopes of nitrogen, ^{15}N, and ^{14}N (Hicks *et al*., 2005). Stable isotope analysis of carbon to find $\delta^{13}C$ (ratio of $^{13}C/^{12}C$) can also show if marine components are found in terrestrial ecosystems (Hicks *et al*., 2005; Zwolicki *et al*., 2016). High $\delta^{15}N$ and $\delta^{13}C$ found in terrestrial samples indicate that there is a presence of marine-derived nitrogen and carbon present in the terrestrial ecosystem (Hicks *et al*., 2005). The stable isotope analyses of nitrogen and carbon can help to assess the extent of the marine-terrestrial interactions present in the Chrystal Creek watershed.

7.1 Potential method for conducting stable isotope analysis

The first step in an approach to understanding the distribution of marine nutrients at the MLC involves sample design. There are several approaches, including purposive sampling in known sites (and controls) of marine nutrient deposition, and transects. Transects across the property would allow for systematic sampling, which may reveal more extensive marine nutrients or in unexpected locations. It may also determine whether there is a sufficiently strong distributed signal of marine nutrients. The transects could be run from the cove up to the top of the watershed. The transects should be spaced evenly and cover the entirety of the watershed. The spacing will depend on how many transects the GCA wants to do (e.g., spaced at 10, 25, 50, or 100 meters). Once the transects are established, quadrats can be used to mark your sample plot at fixed intercepts along the transects. We suggest using a quadrat that is $1m^2$. The quadrats should be evenly spaced along the length of each transect and occur on alternating sides of the transects. Figure 4 shows what these transects and quadrats might look like. A study by Zwolicki *et al*. suggests assessing vegetation percentage cover of the quadrat, taking three soil cores along a diagonal of the quadrat, and making sure there is at least one sample of a monocot, eudicot, moss, and lichen from each quadrat, if possible (2016). We suggest taking a representative sample for each species found in the quadrat. The plant samples and soil cores will be used in the stable isotope analyses.

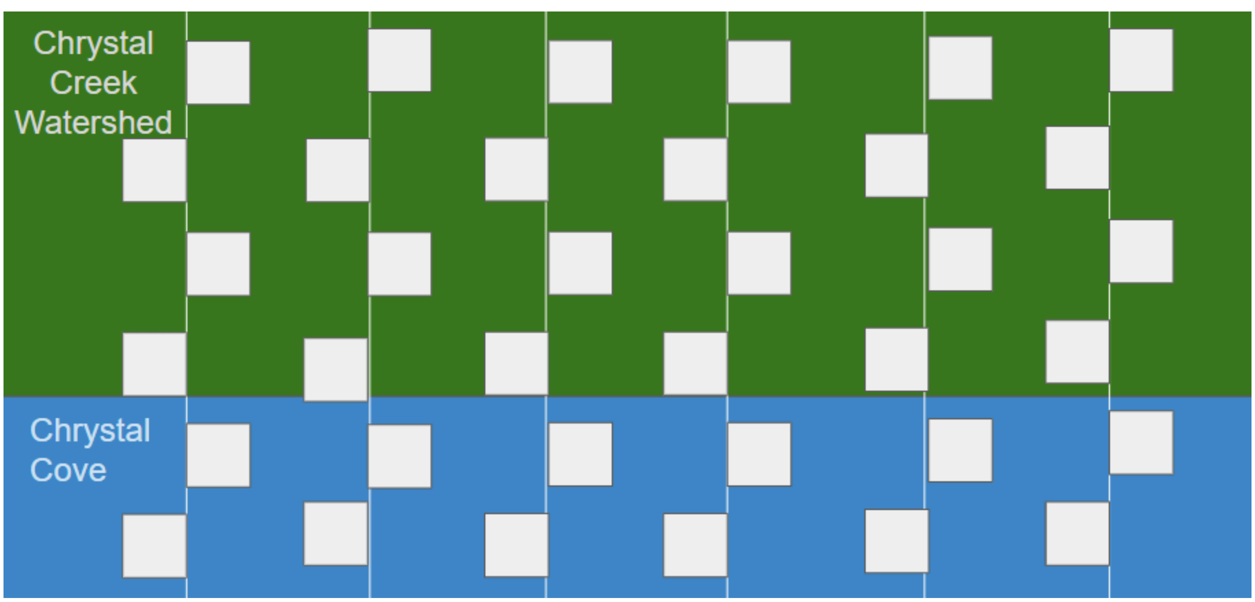

Figure 4. This diagram is an example of a set up for the transects and quadrats that can be used to collect plant and soil samples for stable isotope analysis.

Once the data have been collected from every transect, stable isotope analyses can proceed. The following method is adapted from Zwolicki *et al*., 2016. To analyze the $\delta^{15}N$ and $\delta^{13}C$ signatures of the soil, each sample has to be filtered through a 0.25mm mesh sieve to remove stones and large plant debris. The soil was ground with a vibrating mill to a grain size of less than 0.03 mm after it was sieved. To analyze plant tissues, clean the samples to make sure all feces, dirt, *etc.* is removed. After this, they should be dried at 40–60°C and ground using a vibrating mill. Before isotopic analysis can be conducted, inorganic carbon must be removed. This is done by adding 1 mL of HCl 1N per 100 mg of soil and 4 mL of cyclohexane per 50 mg of soil. After this, 1-2 mg of each sample is packed into a tin capsule. Finally, a continuous flow mass spectrometer coupled to an elemental analyzer is used to determine the stable isotope ratios of nitrogen and carbon. The results of these analyses can be used to determine the significance of marine-derived nutrients throughout the Chrystal Creek Watershed. Facilities for conducting these analyses are available at the University of Victoria and other research universities.

8.0 Conclusion

Our project provides the GCA with a synthesis of the relevant literature on marine-terrestrial interactions, which can be consulted while working on the Chrystal Creek Watershed restoration project and future restoration projects. The presence of wildlife such as cormorants, gulls, river otters, turkey vultures, and more will likely facilitate the movement of nutrients, such as nitrogen, carbon, phosphorus, and ammonia from the marine ecosystem of Chrystal Cove and the Trincomali Channel into the rest of the watershed. The nutrient exchange between the marine and terrestrial ecosystems could provide key insights into the importance of the land-sea linkages between the two ecosystems. The study of marine-terrestrial interactions is relatively new. There are not many restoration projects that have taken the nutrient transfer from marine to terrestrial ecosystems into account. If the GCA decides to conduct a stable isotope analysis, they will gain a better understanding of how strong the marine-terrestrial interactions are. A better understanding of this linkage could benefit restoration efforts and inspire the pairing of marine and terrestrial landscapes in conservation, restoration, and management of natural places.

9.0 References

Acknowledging our shared territory [Webpage]. (n.d.). Retrieved December 3, 2020, from https://galianoconservancy.ca/acknowledging-our-shared-territory/

Beasley, J. C., Olson, Z. H., & DeVault, T. L. (2012). Carrion cycling in food webs: comparisons among terrestrial and marine ecosystems. Oikos, 121(7), 1021-1026. doi:10.1111/j.1600-0706.2012.20353.x

Ben-David, M., Bowyer, R. T., Duffy, L. K., Roby, D. D., & Schell, D. M. (1998). Social behavior and ecosystem processes: River otter latrines and nutrient dynamics of terrestrial vegetation. Ecology (Durham), 79(7), 2567-2571. doi:10.1890/0012-9658(1998)079[2567:SBAEPR]2.0.CO;2

Bokhorst, S., Convey, P., & Aerts, R. (2019). Nitrogen inputs by marine vertebrates drive abundance and richness in Antarctic terrestrial ecosystems. Current Biology, 29(10), 1721-1727.e3. doi:10.1016/j.cub.2019.04.038

Campbell, A. (2015). The Chrystal Cove Restoration Project. Student project for ES 441 in coordination with the Galiano Conservancy Association. University of Victoria. Retrieved from Dr. Eric Higgs.

Category Archives: Species at Risk [Webpage]. (n.d.). Retrieved October 21, 2020, from https://galianoconservancy.ca/category/stewardshipspotlight/speciesatrisk/

EcoAction 2020-2022 Proposal. (n.d.). Galiano Conservancy Association.

ELLIS, J. C., FARIÑA, J. M., & WITMAN, J. O. N. D. (2006). Nutrient transfer from sea to land: the case of gulls and cormorants in the Gulf of Maine. *Journal of Animal Ecology*, *75*(2), 565–574. https://doi.org/https://doi.org/10.1111/j.1365-2656.2006.01077.x

Fang, X., Hou, X., Li, X., Hou, W., Nakaoka, M., & Yu, X. (2018). Ecological connectivity between land and sea: A review. Ecological Research, 33(1), 51-61. doi:10.1007/s11284-017-1549-x

Ferry Fares: BC Ferries [Web page]. (n.d.). Retrieved October 21, 2020, from https://www.bcferries.com/routes-fares/ferry-fares

Galiano Learning Centre Management Committee. (2013). Galiano Centre Management Plan. Prepared on behalf of the Galiano Conservancy Association.

GCA Mission [Web page] (n.d.). Retrieved October 21, 2020, from https://galianoconservancy.ca/about/our-mission/

Grier, C. (2014). Landscape Construction, Ownership and Social Change in the Southern Gulf Islands of British Columbia. *Canadian Journal of Archaeology / Journal Canadien D'Archéologie, 38*(1), 211-249. Retrieved December 10, 2020, from http://www.jstor.org/stable/43967083

Hentati-Sundberg, J., Raymond, C., Sköld, M., Svensson, O., Gustafsson, B., Bonaglia, S. (2020). Fueling of a marine-terrestrial ecosystem by a major seabird colony. Scientific Reports, 10(1), 1-10. doi:10.1038/s41598-020-72238-6

Hicks, B. J., Wipfli, M. S., Lang, D. W., & Lang, M. E. (2005). Marine-derived nitrogen and carbon in freshwater-riparian food webs of the Copper River Delta, southcentral Alaska. Oecologia, 144(4), 558-569. doi:10.1007/s00442-005-0035-2

Hocking, M. D., & Reimchen, T. E. (2002). Salmon-derived nitrogen in terrestrial invertebrates from coniferous forests of the pacific northwest. BMC Ecology, 2(1), 4-4. doi:10.1186/1472-6785-2-4

Hocking, M. D., & Reimchen, T. E. (2006). Consumption and distribution of salmon (oncorhynchus spp.) nutrients and energy by terrestrial flies. Canadian Journal of Fisheries and Aquatic Sciences, 63(9), 2076-2086. doi:10.1139/f06-110

Renwick-Shields, B. & Weller, J. (n.d.). Historical Survey of District Lot 57.

Roe, A. M., Meyer, C. B., Nibbelink, N. P., & Ben-David, M. (2010). Differential tree and shrub production in response to fertilization and disturbance by coastal river otters in Alaska. Ecology (Durham), 91(11), 3177-3188. doi:10.1890/09-1216.1

Rowe, J. A., Litton, C. M., Lepczyk, C. A., & Popp, B. N. (2017). Impacts of Endangered Seabirds on Nutrient Cycling in Montane Forest Ecosystems of Hawaiʻi. *Pacific Science, 71*(4), 495–509. https://doi.org/10.2984/71.4.7

Thomson, R. E. (1981) *Oceanography of the British Columbia coast*. Department of Fisheries and Oceans. Retrieved from https://waves-vagues.dfo-mpo.gc.ca/Library/487.pdf

Trant, A. J., Nijland, W., Hoffman, K. M., Mathews, D. L., McLaren, D., Nelson, T. A., & Starzomski, B. M. (2016). Intertidal resource use over millennia enhances forest productivity. Nature Communications, 7(1), 12491. doi:10.1038/ncomms12491

Trincomali Nature Sanctuary [Web page]. (2019) Retrieved from http://www.islandstrustconservancy.ca/protected-places/places-protected-in-the-islands/all/galiano-island/trincomali-nature-sanctuary/

Zwolicki, A., Zmudczyńska-Skarbek, K., Richard, P., & Stempniewicz, L. (2016). Importance of marine-derived nutrients supplied by planktivorous seabirds to high arctic tundra plant communities. *PLoS ONE*, *11*(5), e0154950. https://doi.org/10.1371/journal.pone.0154950