Climate Change Considerations for the Millard Learning Centre on Galiano Island

Brenna Pavan and Charlotte Estey

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Eric Higgs

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Table of Contents

1. Introduction

The following report summarizes the regional climate change projections that are pertinent to the Millard Learning Centre for the Galiano Conservancy Association on Galiano Island. These climate change projections are likely to affect the Centre through increased drought conditions, forest fires and pest outbreaks, thereby implicating the Centre's coastal Douglas-fir ecosystem as well as the Conservancy's rockfish conservation program and agricultural projects (*i.e.*, the native forage forest and the food forest garden). Considering these projections and implications, we make recommendations for the Conservancy's conservation planning so that the Conservancy can adapt to and mitigate climate change. Our recommendations include strategies for drought management and for monitoring the effects of climate change. We also consider adaptive management to inform the Conservancy's future projects.

2. Regional Climate Change Projections

Climate change will generally bring warmer temperatures and more annual precipitation to the region. In the past, climate change in southern coastal British Columbia (BC) has been less severe than in more northern parts of the province (BC Ministry of the Environment, 2016). For instance, summer temperatures in most of northern BC have warmed 1.4°C to 1.6°C per century, yet summer temperatures in southern and central BC have warmed only 0.6°C to 0.8°C per century (BC Ministry of the Environment, 2016). While climate change may be less severe in southern coastal BC, the effects of climate change on the coastal Douglas-fir (CDF) ecosystem are still important for the Galiano Conservancy Association to consider in its conservation planning, so as to adapt to and mitigate climate change.

When considering climate change in the area, it is important to keep in mind two climatic cycles: El Niño/ La Niña Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) (Lemmen, Warren, James, & Mercer Clarke, 2016). These cycles have a strong influence on BC's climate, causing relatively strong fluctuations of several degrees that last from months to years, making it more difficult to discern a climate change signal (Lemmen *et al.*, 2016).

Figure 1 and Figure 2 below illustrate the projected climate change trajectories for the Victoria region into 2050 and 2080, respectively. The trajectories shown are for a Representative Concentration Pathway (RCP) of 8.5. This is the most extreme of four RCPs, which describe various climate change scenarios that depend on whether human activity can reduce its greenhouse gas emissions and lessen its impact on climate change. We have decided to use the worst-case scenario RCP of 8.5 for our climate change projections, as this scenario is unfortunately becoming the most likely (Pojar, 2010).

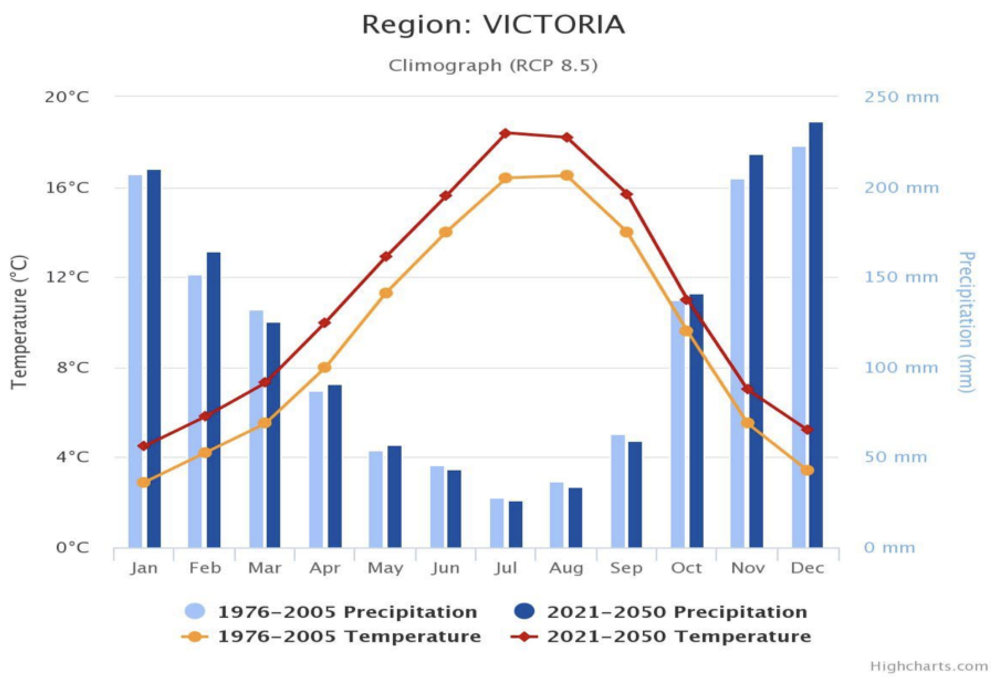

Figure 1. Climate Change Projections for the Victoria Region from a baseline period of 1976-2005 to the future period of 2021-2050 (Climate Atlas of Canada, 2018).

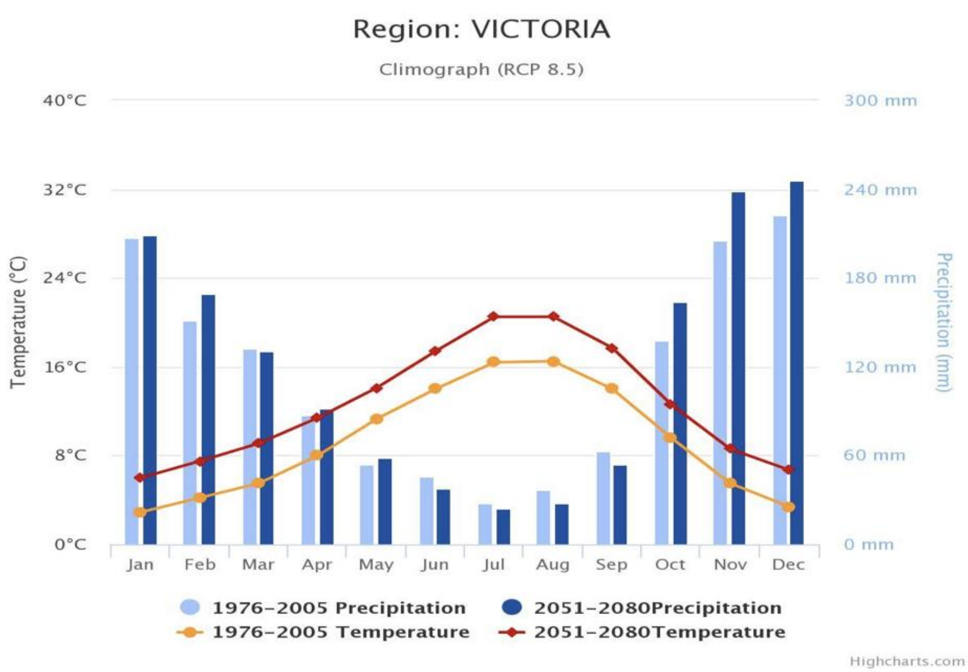

Figure 2. Climate Change Projections for the Victoria Region from a baseline period of 1976-2005 to the future period of 2051-2080 (Climate Atlas of Canada, 2018).

2.1 Precipitation

For projected precipitation and temperature trends in this section, we have chosen to provide the trend data for the Vancouver Island region as this is the most relevant data we can find for the Southern Gulf Islands. Unfortunately, the Pacific Climate Impacts Consortium (PCIC) does not provide trend data specific to the Southern Gulf Islands.

From the 1961-1990 baseline historical period, the projected changes in precipitation for the 2050s (2040-2069) for the Vancouver Island Region is a 14% decrease over the summer, and a 6% increase over the winter. The projected changes for the 2080s (2070-2099) show a 13% decrease in summer precipitation and a 12% increase in winter precipitation. The overall annual precipitation will increase by 6% and 8% over the 2050s and 2080s, respectively, although this increase will not be evenly distributed across the seasons (PCIC, 2013).

2.2 Temperature

Also from the 1961-1990 baseline historical period, the projected changes in temperature for the 2050s (2040-2069) for the Vancouver Island Region show an overall mean temperature increase of 1.5°C, and for the 2080s (2070-2099), an overall mean temperature increase of 2.5°C (Pacific Climate Impacts Consortium, 2013). While the 2080s may seem far into the future, it is useful to consider these climate change projections when thinking about the effects on trees, which have long life cycles and are therefore slow to regenerate.

2.3 Ocean Acidification

Temperature and precipitation (as well as streamflow) will have implications for ocean acidity over the long term in coastal BC. The north Pacific has already experienced a decline in pH, a trend that is quite extreme relative to typical variations in surface water pH during glacial-interglacial cycles over the past 800,000 years (Hönisch *et al.*, 2009). Thus, BC is already particularly vulnerable to ocean acidification relative to other coastal environments in Canada (Lemmen *et al.*, 2016). Given even a small shift towards more acidic water, calcium carbonate would start to dissolve and molluscs and other marine organism that rely on shells would suffer (Feely *et al.*, 2004). Unfortunately, understanding the long-term risk of increased ocean acidity to marine life is not currently possible for the coastal region (Ianson, 2013). This is because the processes that contribute to ocean acidity can vary between regions and can be hard to predict in expansive areas like the Strait of Georgia, while the highly variable marine circulation is responsible for other data limitations (Nemcek *et al.,* 2008).

This increase in ocean acidification may implicate the rockfish conservation program, as rockfish are highly susceptible to decreasing ocean pH and rising ocean temperature. A drop in pH can disorient rockfish, and alter their behaviour (T. Mommsen, personal communication, August 23, 2018).

2.4 Impacts on Coastal Douglas-fir Ecosystem

More extreme weather may affect the CDF ecosystem in a number of ways, by increasing drought conditions, worsening forest fires, and increasing the threat of pests and disease (Pojar, 2010). These factors all influence tree health, which should be of high conservation concern as trees are integral to carbon sequestration and storage which can help mitigate climate change (Pojar, 2010). And, because portions of the Millard Learning Centre's CDF ecosystem are home to old-growth forest, conservation becomes even more important. Old-growth forests serve as a global carbon dioxide sink, as they can continue to accumulate carbon for centuries (Luyssaert *et al.,* 2008). If these forests are disturbed, much of this carbon, even soil carbon, will be released back into the atmosphere (Luyssaert *et al.*, 2008).

Another important consideration for climate change planning for the CDF ecosystem is that trees have a long generation time, which may reduce their short-term ability to adapt to climate change. Species adapt to environmental changes through natural selection at a rate negatively related to their generation time (reproductive age), which will mean that tree populations may experience short-term demographic reductions (Pojar, 2010). So, although trees have a large capacity for adaptation in the long-term, in the short-term we may see genetically impoverished forests (Pojar, 2010).

2.4.1 Drought

Hotter, drier summers will affect drought conditions through increased rates of evaporation and plant transpiration (Pojar, 2010). Water retention and droughts can can cause ‘dieback’ (Ste-Marie, 2014). Flooding, which might become a concern in the winter months, can also lead to dieback (Rotherham, 2016). Dieback of Western redcedar (*Thuja plicata*) has recently been reported along the south coast of BC, presumably because of increasing drought stress (Pojar, 2010). While the Western redcedar is predicted to suffer widespread decline in South coastal BC, it might significantly expand its range in the Kootenays, the central interior, and on the north coast, as the climate in these regions becomes more suitable for the CDF ecosystem (Pojar, 2010). These regions will also become more suitable for the Douglas-fir (*Pseudotsuga menziesii*) and possibly also the Western hemlock (*Tsuga heterophylla*) within the next 80 years (Pojar, 2010).

2.4.2 Fire Frequency and Smoke Levels

Climate change will also have implications for wildfires and smoke levels. Reduced precipitation and warmer temperatures in the summer months will likely mean that fires will become more frequent and with larger areas burned, while increasing in severity and length of fire season (Pojar, 2010). Climate change has already led to an increase in the areas burned by forest fires in Canada over the last few decades, which has potential implications for terrestrial emissions of carbon dioxide and for forest ecosystems (Gillett *et al.*, 2004). This past summer was the second year in a row that a state of emergency was declared over the wildfires in BC, with 2018 being the ‘worst fire season on record’ (Lindsay, 2018). Our group experienced the increased length and severity of this year’s forest fire season during our time at the Millard Learning Centre. The smoke levels were considered a safety hazard which reduced our ability to do fieldwork.

This increase in fire risk is related to the “synchronous relationship” between climate and fuel moisture conditions, as a warmer drier climate will lead to drier forest fuels that will increase the chance of successful fire ignition and propagation (Nitschke & Innes, 2008). Warmer temperatures will also extend the length of fire season and increase the likelihood of fires occurring over a greater proportion of the year (Nitschke & Innes, 2008).

2.4.3 Pests

A further concern of climate change is the increasing threat of insects and diseases to forest health. Insects - such as various bark beetles and foliage insects - are very adaptable and would be able to respond to a changing environment faster than their long-lived hosts, such as trees (Pojar, 2010). Warmer temperatures may lead to range expansions, contractions and shifts, and an increase in the number and variety of forest pests, which poses challenges to forests that may be following a variety of successional pathways (Pojar, 2010).

The outbreak of the mountain pine beetle (*Dendroctonus ponderosae*) in western Canada represents an example of how climate change can contribute to pest outbreaks. Increased summer temperatures and decreased summer precipitation in recent decades facilitated the expansion of the outbreak northward and into higher elevation forest (Kurz *et al.*, 2008). Of course, outbreaks of the beetle are problematic as they result in widespread tree mortality which reduces forest carbon uptake and increases future emissions from the decay of dead trees (Kurz *et al.*, 2008).

3. Drought Management Strategies

Increased summer drought conditions will demand greater focus on water management in the area. This can be accomplished either through adapting the ecology of the area to a lack of water, or by increasing water retention in the soil so that there is more water available in the ground during the drier summer season. For the agricultural projects (such as the native forage forest and the food forest garden), we recommend a continued focus on integrated rainwater management systems, such as through a combination of irrigation and rainfed agriculture. In drier or drought prone areas, a combination of irrigation and rainfed agriculture has been found to produce the best crop results (Rockström *et al*., 2002).

3.1 Rain Gardens

With drier summer months, water capture and storage in the soil during wetter winter months will become increasingly important. To facilitate this, rain gardens can be used to increase water capture, while reducing runoff (Dietz & Clausen, 2005) which allows for more water to enter and remain in the soil. By giving the water an area to sit in without overflowing, more water is likely to infiltrate the soil which helps to replenish groundwater levels (CRD, 2013). With the projected increasing precipitation levels in the winter, this would allow the soil enough time to absorb the water without getting too quickly saturated and causing the water to flow straight into the nearest stream or pond. While this approach would not directly provide any water catchment that could be used to irrigate or redistribute across the property during drought conditions, it would provide the system with a buffer against drought due to a greater level of stored water being available to the plants.

Rain gardens can be easily tailored to various site conditions, such as available space, soil permeability, slope, and native species (CRD, 2013). While they are typically used for collecting water in urban settings from solid surfaces such as concrete, they can be applied in a more rural setting. Existing buildings, such as the Millard Learning Centre classroom building, or the design of future structures, such as the planned program center, could both incorporate rain gardens into the design of the surrounding area. They could also be incorporated along the main roads and public highway on District Lot 57, where the interaction between the rain gardens and the existing forest/wetland complexes would be an interesting experiment in incorporating rain gardens into already wet environments. As a further experimental undertaking, they could be incorporated in areas with compacted or degraded soil where the ability to capture and store water is found to be low, to aid infiltration in these areas.

Typically individual rain gardens are small and if they do cover a large area, it is as a patchwork of multiple small rain gardens over a larger area. However, Fisherman's Wharf in Victoria has a large rain garden that could be used as a reference if a larger project were undertaken (City of Victoria, n.d.). Small but numerous rain gardens would suit the purposes for District Lot 57, since they would be dealing directly with rainfall rather than industrial amounts of rainwater from storm drains of entire urban neighbourhoods. In addition to rain gardens for water collection, it may also be a helpful possibility to harvest rainwater from the classroom to provide water from the forage forest.

3.2 Greywater Irrigation

To combat drier summers and more drought conditions, greywater can be reused for irrigation of either the agricultural projects, or used to be distributed into the groundwater and out to the ecosystem as a whole. It will only be possible to collect a finite amount of rainwater during the wetter winter months, and that water will become more important to the area as drought conditions worsen over time, making it important to reuse any water that is available. Greywater originating from the current Millard learning center in the kitchen and bathrooms could play a key role in watering the native forage forest especially, since that is the closest project to the center that requires large water inputs. This method of drought management would be based on decreasing the total water needs of the site.

A filtration system will be required in order to use greywater in the area, as unfiltered greywater should not be put into either an ecosystem or an agricultural system (Yates & Gerba, 1998). Wood chip biofilters should be installed in order to remove larger particles in the water that could slow infiltration into the soil (Woodchip Biofilters, n.d.). These biofilters will also give water an area to collect in initially and slow the flow of water through the system. Biofilters would consist of a box filled with wood chips, and a drain to catch particles and allow water to flow out. Maintenance of this system would consist mainly of replacing the wood chips every 3-4 months. After being initially filtered, the water could be sent into a constructed wetland area near the learning center. A reed bed system would then be used to filter the grey water, while keeping it below ground level and minimizing contact humans or other animals could have with it (Constructed Wetlands, n.d.). An outflow pipe or hose then would send the filtered water to either the forage forest area to be used immediately for irrigation, or to some other catchment area where it could be collected and stored. Alternatively, a recycled vertical flow constructed wetland, which is a system specifically designed for small scale greywater treatment, could be implemented (Gross *et al.*, 2007). Instead of using an area to create a wetland using plants and water input, this method uses two containers stacked up, with the top containing organic layers, and the bottom being a catchment area. This method does require a sedimentation tank and a reservoir to store water in, depending on what the filtered greywater would be used for.

A branched drain system (Branched Drain System, n.d.) could be implemented, if the main purpose of the greywater was to irrigate the forage forest. It would require a series of drains to transport the water directly from the greywater sources or tanks out to the forage forest area. The water would then be emptied into mulch basins, larger versions of wood chip biofilters that are buried in the soil. The water would then be filtered and leak out of these basins into the surrounding area. This method does not provide as much filtration as the previous methods and requires more time and money to implement, however it does transport the water directly to the areas where it is needed.

3.3 Drought Resistant Plants

By focusing on planting drought resistant species in either agricultural or restoration projects, the ecosystem as a whole would require less water and be less impacted by the increasingly dry summers. Water capture in this case would be less of a concern, as the plants would be better adapted for the future conditions. This method would then be working with the new and changing climate, rather than trying to maintain a previous system. Further research would need to be done to determine which native plant species have water requirements that compliment projected precipitation levels and water availability, and those would then be planted in the forage forest. The same species could then be used more heavily in general ecological restoration projects as well. The same process would be done for the food forest, however the plants would not necessarily have to be native. Though in that case, precautions would be necessary to ensure that no drought resistant non-native species that were planted had the potential to become invasive.

4. Monitoring Strategies

Regional climatic conditions and expected trend data are limited for Galiano Island. Some microclimatic data are currently being collected to be analyzed for the Island, which will provide much more specific information about trends and what to expect for the future. However, when it comes to projections and predicting how trends will continue into the future, the more data that can be taken into consideration the better. There are some factors that could be monitored by the Conservancy on its own lands, to be better equipped to use adaptive management strategies. Monitoring will require significant time and resource investments. Thus, while the following recommendations may not be feasible with the Conservancy's current resources, they should be kept in mind should the resources become available.

4.1 Microclimate Data Collection

Measurements of the microclimates around District Lot 57 could help to inform future projects as to where the best location on the lot could be for them, based on the climate requirements of individual projects. Locations around District Lot 57 would need to be identified as either suspected unique microclimate zones, or areas of special interest for development or other projects, and measurements of various climatic factors would be taken at various points in the day and various times of year. There is a project underway by graduate student Andrew

Simon in Environmental Studies to place a series of microclimate monitoring stations at the Millard Learning Centre. This array of monitoring stations would provide mostly automatic logging of data.

4.2 Ocean Acidification Tracking

Due to the difficulty in predicting the details of how ocean pH will change in B.C., other than a general understanding that the ocean is becoming more acidic, we recommend that the changes in ocean pH in the current Marine Protection Zones should be actively monitored by the Conservancy. By collecting this regional data, the trends can be observed over time, and the current rockfish conservation project could be better informed about what to expect from, and how to respond to, climate change. Tracking these local changes gives data that cannot be projected with current methods, and will help to inform both the projects of the Conservancy itself and other marine conservation projects in the surrounding area. Even small changes in ocean pH can have large and far reaching impacts on marine life, so the general data that can be acquired from climate projections will not provide enough information to advise conservation efforts. Local information and tracking of trends can be used to determine if the current protected areas are still habitable to species that are the focus of conservation efforts, such as rockfish. If these areas cannot support rockfish, or support the systems or species that rockfish rely on, then a decision can be made to either try and reclaim that area, or attempt to move the protected zone to a new area. These decisions cannot be identified or made without the local information provided by these tracking efforts.

4.3 Forest Pest Monitoring

The potential implications of a pest outbreak at the Millard Learning Centre's CDF ecosystem highlights the importance of implementing a forest pest management project. The National Forest Pest Strategy (NFPS) in Canada promotes a proactive, risk-based approach to forest pest management (Canadian Council of Forest Ministers, 2012). The success of this approach depends in part on early detection through monitoring as well as identification of native and invasive alien species (Canadian Council of Forest Ministers, 2012). Currently, 64% of the managed forest in Canada is monitored by the provinces and territories (with the exception of Nunavut) through both aerial and ground surveys. Surveys are typically conducted annually or as pest populations dictate., and emphasis is placed on monitoring major forest pests on managed forests (Canadian Council of Forest Ministers, 2012).

If the Conservancy is not already monitoring the CDF ecosystem for pests, we recommend that the Conservancy implement a pest monitoring initiative in the near future. For instance, ground surveys can provide information about insect populations by monitoring various life stages (Canadian Council of Forest Ministers, 2012). Surveys can also be conducted to determine presence or absence of certain insects and to assess and predict population levels (Canadian Council of Forest Ministers, 2012). Of course, it will be especially important to identify high-priority pests before they become established (Canadian Council of Forest Ministers, 2012).

4.4 Community Input

Personal observations are another important source of data for how conditions have changed in the past. An interview process could be implemented to both gather this data and involve the community more closely in the process of creating a comprehensive climate change adaptation plan. Questions for trend data should be focused more on those residents that have lived on Galiano Island for 10 years or longer, or those with family ties to the island and oral histories that trace back in history, and so have a longer frame of reference to observe significant changes. These questions would be based on any changes residents have observed over the years in seasonal temperatures, total precipitation and frequency of precipitation, soil quality, and any other notable aspects they can think of that they would like to mention. Follow up questions would include any concerns they may have about, or their general view of, the changes they have observed, if any. The data gathered from these interviews would be qualitative rather than quantitative, as in the other suggested monitoring strategies, but would still inform general trends that have been seen over time and give a better picture of what historical baselines of “normal” conditions would look like. Some of the interviews would likely produce climatic data from further back in time than either the conservancy or any other research projects on the island have.

Further questioning could include any member in the community, regardless of how long they have resided on the island, and focus on community input for what residents think should be done to either mitigate or adapt to climate change. This could include opinions on existing or planned climate change projects, or suggestions for future efforts. This will encourage the community to be more directly involved, and may encourage some residents to use smaller scale projects on their own land, such as rain gardens. Since community support is so important, especially to small scale conservation projects, an interview process would encourage direct cooperation with the community to determine what there is existing support for, as well as projects that may be more controversial in the area.

5. Informing Projects

Adaptive management requires many difficult and sometimes controversial considerations to be considered. The following are two key issues that we recommend should be further studied so as to inform future Conservancy projects. Both reference conditions and the consideration of where species are best suited to live are important when planning restoration efforts and with conditions changing at the current pace, these will become even more important in efforts to successfully restore ecosystems.

5.1 New Reference Conditions

Most restoration projects are guided by some sort of historical reference system that provides a template to work from. However, the current reference system used by the Conservancy is based on climatic conditions that are rapidly changing, making it no longer representative of what can exist in an area. A new reference system can be identified using the projected conditions of the site, and that should become the new template for restoration projects. This system would likely be in an area that either now has the conditions that are predicted for the future in B.C., or has in the very recent past had those conditions. For example, there have been some comparisons between B.C. and California in terms of comparable climates. This could be a good starting place for future investigation into whether California's historic ecosystems could serve as useful reference ecosystems for ecosystems in B.C.

5.2 Assisted Migration

A changing climate may affect the suitability of certain species to the region. Some species may not be able to migrate northward quickly enough to follow movement of their ideal habitat and will need assistance (Pojar, 2010). To overcome this, assisted migration has been proposed as a method for saving species that are threatened with extinction or extirpation in a particular area because of climate change (Ste-Marie, 2014). Assisted migration "refers to human intervention to deliberately move species to new, more favorable, locations to help them to survive and flourish in a changing climate" (Ste-Marie, 2014, p. 3).

Two 'incremental forms' of assisted migration are starting to be implemented in Canada as a means of achieving many of the goals of sustainable forest management: assisted population migration and assisted range expansion (Ste-Marie, 2014). In assisted population migration, the aim is to increase genetic diversity by helping the tree species to cope with threats related to climate change and to take advantage of opportunities for increased growth due to warmer temperature. In assisted range expansion, seeds are planted in areas farther north and at higher altitudes than their existing range, where the climate is deemed suitable for growth (Ste-Marie, 2014). These forms of assisted migration are considered 'lower risk' when compared to assisted long-distance migration, a third type of assisted migration in which species are moved far outside their current range, beyond where they would naturally spread. In contrast, assisted population migration and assisted range expansion, involve moving the tree species a short ecological, geographic, or climatic distance within or just beyond its current range (Ste-Marie, 2014). An assisted migration study, led by Jessica Hellman, is currently underway to understand how to help Garry oak savannah ecosystems move northward on Vancouver Island. The project is controversial yet offers valuable insight into assisted migration efforts.

The Galiano Conservancy Association has the potential for using assisted migration mostly because it can experiment to an extent with ecological restoration. Aside from the Western redcedar, assisted tree migration may not be useful in conservation planning, as the region is not projected to become more suitable for trees other than those already within the CDF ecosystem. This is evident in Figure 3 below, which predicts the region to still be suitable for the CDF ecosystem by 2085 (Pojar, 2010).

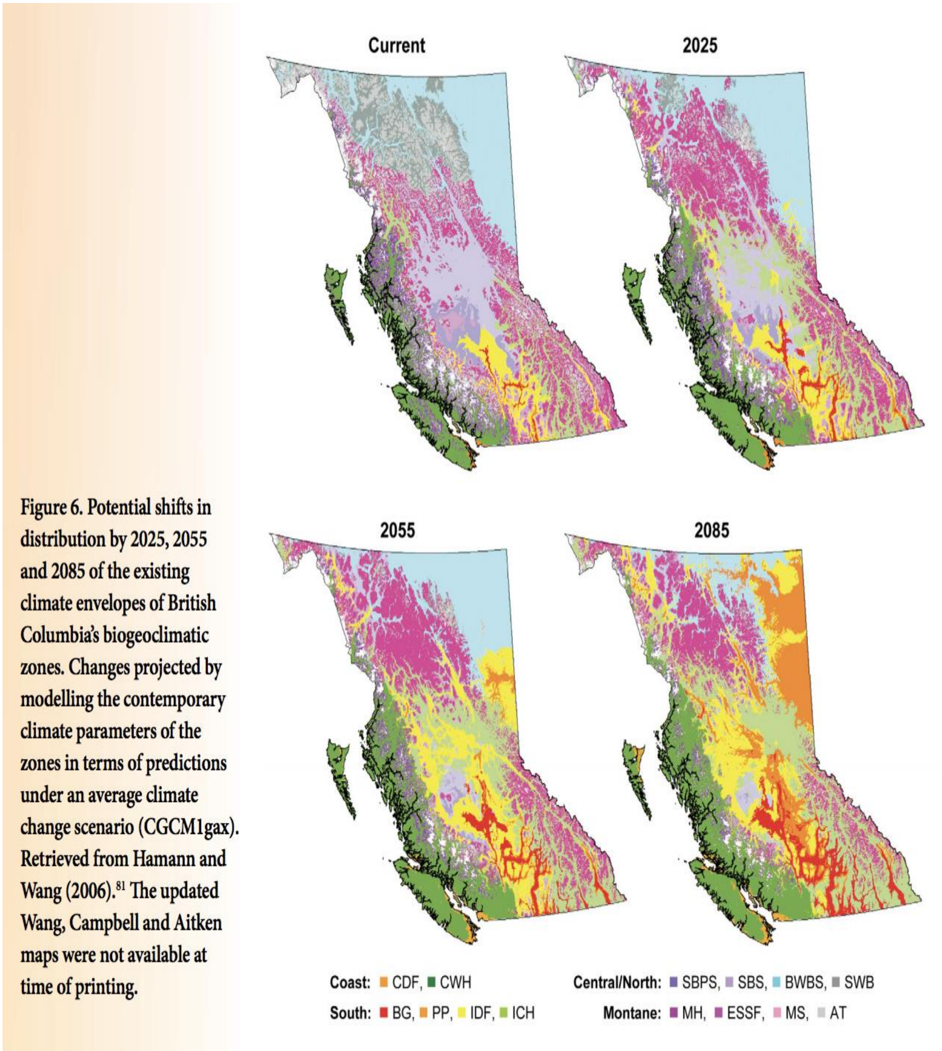

Figure 3. Potential shifts in distribution by 2025, 2055, and 2085 of the existing climate envelopes of British Columbia's biogeoclimatic zones (Pojar, 2010; Hamann & Wang, 2006).

6. Conclusions

Climate change will likely lead to increased drought, fire frequency, and pest outbreaks in the region, having implications for the Millard Learning Centre site by affecting the CDF ecosystem, the rockfish conservation program, the native forage forest and the food forest garden. After considering these implications, we made recommendations for the Conservancy to incorporate strategies for drought management and to monitor the effects of climate change. We then made recommendations to inform future projects, such as identifying new reference systems and considering assisted tree migration to help the Western redcedar migrate northwards.

Our report is limited in that it could not consider every influence of climate change on the region. For instance, we did not consider how increased winter precipitation may increase seasonal flooding, nor did we consider the effects of rising sea levels to the site. Yet, we do not believe rising sea levels to be of concern to the site considering its elevation. We also did not consider how climate change may affect the Conservancy's land acquisition decisions, yet we understand that there is already a study in place looking into this.

Despite the unfortunate nature of climate change and its anticipated effects for the region, we sincerely hope that the Conservancy is able to take adaptive and mitigative measures in its conservation planning, so that the Conservancy can persist for generations to come and continue to inspire and educate young minds.

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