COASTAL BLUFFS FOR GREEN ROOFS:

A Habitat Template Approach

Kara Anderson, Tamara Bonnemaison, and Mark Stevenson
April 2014

Abstract

Borrowing from the ecological theory of habitat templates, the analogous habitat characteristics of urban rooftops in Vancouver and natural coastal bluff ecosystems provide potential design solutions for green roofs. Both habitats display similar conditions, like limited substrate, poor drainage, disturbance, and summer drought. Species of plants that thrive in coastal bluff environments are likely to succeed in use on living roofs. Coastal bluff grasses are already in use in green roof palettes, but other aspects of the ecosystem remain unutilized in green roof design. Mosses, as an important part of the ecological community, show promise for application on green roofs as a runoff mitigation tool. Another important aspect of the bluff that can be applied is the micro topography. Substrate on the coastal bluff is varied, extremely shallow in most parts with depressions and fissures of deeper soil that support different plant species. The application of a designed micro topography to a green roof could allow for diverse plantings with seasonal interest, while minimizing the weight of the substrate. Directions for further research include testing evapotranspiration of mosses, and implementing coastal bluff green roofs for study.

Introduction

Green roofs comprise an important part of integrated LID systems for managing stormwater runoff in urban areas. As they are adopted into common practice, it is evident that one type of green roof does not fit all situations. As is found by Roehr and Kong, comparable green roofs in Vancouver, Kelowna and Shanghai have vastly different runoff reduction capabilities (2010). This research illustrates the need to examine local climatic conditions when designing and implementing green roofs.

Different temperature and rainfall patterns influence the effectiveness of green roofs and the health of the plants used. Landscape architects and designers are increasingly using native species in their green roof palettes in the belief that the plants are implicitly beneficial to the local environment, and suited to the conditions (Butler et al, 2012). There is ambiguity in the definition of what a native plant is in green roof research, as found by Butler et al, who also have called into question the assumption that these plants are suited for use in green roofs (2012).

The conditions on rooftops can differ significantly from the surrounding local climate on the ground. Poor drainage, high winds, and little shade create a distinct microclimate on green roofs. It is necessary to consider this microclimate when choosing plants and designing green roofs. This paper examines the suitability of coastal bluff ecosystems as a complete habitat template for green roofs in Vancouver. By considering microclimate, substrate, and plants holistically there is potential to develop a paradigm of effective green roof design in Vancouver.

This research into using coastal bluff ecosystems as a habitat template for green roofs in Vancouver acts as an examination of potential for further research. By identifying the challenges to green roofs in Vancouver, looking at the habitat template approach, and studying the characteristics and plants of the coastal bluff ecosystem, this paper aims to determine potential for successful application.

Vancouver Green Roofs

The goals of green roofs in Vancouver are the same as the goals of green roofs across the world. Runoff reduction, improved water quality, increased energy efficiency of the buildings they are applied to, provision of habitat for urban wildlife, increased aesthetic value of urban areas, and so on (Peck and Kuhn). However, conditions in Vancouver create challenges to the success of green roofs. Graph 1 (in appendix A) shows the average monthly temperature and precipitation in Vancouver, adapted from Canadian Climate Normals data. Winters in Vancouver are mild and very wet, receiving most of the annual precipitation. Summer is considerably dryer with warmer temperatures.

The disparity between precipitation in the winter and summer months means that plants are inundated with water for part of the year, and then deprived of it for the rest of the year. If plants are chosen to thrive in the wet winter conditions, they require irrigation in the summer. Conversely, if plants are chosen to tolerate the drought conditions of the summer, their runoff reduction capacity is lower in the winter. This trade off between irrigation and runoff reduction means that green roof success in Vancouver is compromised. The potential of using the coastal bluff ecosystem as a precedent for green roof design lies in the possibility of creating a roof that does not need irrigation in the summer, and remains highly effective in the winter.

A Habitat Template Approach

The habitat template approach borrows from ecological research, employing ideas of community ecology and ecosystem functions. Jeremy Lundholm of Saint Mary's University writes about the potential of incorporating specific landscape features as well as plants into green roof design (2006). A habitat template is described as "a quantitative description of the physical and chemical parameters that define a particular habitat and separate is from others" (Lundholm, 2006). These conditions prove favorable for some species, which make up the unique community of organisms that inhabit a particular habitat template.

This approach acts as an explanation why species of plants and animals are not evenly dispersed throughout the world. While urban areas have often been excluded from mainstream ecological theories, believed to be too disturbed to represent natural processes, the urban habitat presents a specific template. Lundholm remarks that "areas dominated by the built environment inflict novel selection pressures and harsh conditions on any species that attempts to colonize," but they do have functional equivalents in other natural habitats (2006).

Plant species that spontaneously colonize urban areas often originate from geographically marginal rock outcrop habitats, as is proposed the urban cliff hypothesis (Larson et al, 2004). The conditions present in these ecosystems are analogous to the conditions in urban environments and on rooftops. Green roof species have already been drawn from such habitat templates like European limestone pavements because they can tolerate the harsh conditions (Dunnett and Kingsbury, 2008). The kind of conditions that have been created in urban habitats include shallow/no soil cover and hard surfaces, poor drainage, high wind on rooftops and high levels of disturbance. Analogous habitats in nature include the limestone pavements, dry meadows, and vertical cliffs (Lundholm, 2006).

These habitats have already been used as sources of green roof plants, such as sedum species from vertical cliff habitats. Having an abundance of hard surfaces, poor drainage and summer drought, the species that thrive naturally in these conditions are likely to do well on green roofs as well. The coastal bluff habitat has many of the same conditions and has not yet been explored rigorously for potential as a precedent for green roof design.

Selected Case Studies

Several green roofs have been implemented in British Columbia that have used coastal bluff ecosystems as a precedent. Sharp and Diamond Landscape Architects, based out of Vancouver, have completed two such projects.

The Burnside Gorge Community Centre in Victoria, BC was completed in 2008. The project architect was Garyali Architect Inc., with Sharp and Diamond Landscape Architects. The building is LEED Gold certified, and won the 2009 Extensive Institutional Green Roof Award of Excellence. The green roof is incorporated into an integrated stormwater runoff management system which also incudes an open grid paving system in the parking lot. The Centre is located on a challenging ravine slope above Cecilia Creek. The surrounding area consists of parkland, which includes the popular Galloping Goose trail that runs through Victoria. The green roof is fully accessible, effectively extending the parkland into the community centre.

The design of the Community Centre green roof seeks to replicate the local Garry Oak ecosystem, as well as the coastal bluff ecosystem. The plants taken from these ecosystems are drought resistant, and it is reported that once they are established on the roof they will require no irrigation (City of Victoria, 2007).

Also on Vancouver Island, the Cowichan Campus of Vancouver Island University in Duncan BC was constructed with a green roof. LEED Gold certified, the building was completed in partnership with both Garyali Architect Inc. and Sharp and Diamond Landscape Architects again. Opened in 2011, the facility has integrated stormwater management features that include living roofs, wet meadows, permeable paving, and blue roofs. The living roof incorporates plants found in the coastal bluff ecosystem, mainly specific grass species.

Both of these projects show the potential of using the coastal bluff ecosystem as a precedent for green roof designs that do not require irrigation. The Burnside Gorge Community Centre and the VIU Cowichan Campus are located in areas with comparable climate to Vancouver (see appendix A for climate data), so could likely be replicated in Vancouver with success. With more research into a habitat template approach using the bluff ecosystem, more aspects could potentially be mimicked to increase success. The specific substrate conditions and complete plant communities of the coastal bluffs may have important lessons for green roof design.

Coastal Bluff Ecosystems as Precedents

LOCATION AND CHARACTERISTICS

Coastal bluff ecosystems are predominantly found in southern British Columbia on the Sunshine Coast, Vancouver Island and on the adjacent Gulf Islands. These coastal zones are characterized by extensive areas of exposed bedrock close to the shoreline or offshore on numerous rocky islets (see figure 1). Coastal bluffs are less common further north as shorelines are more protected from the elements, and deep deposits from former glaciers and rivers have buried the bedrock surface (Mcphee 2000).

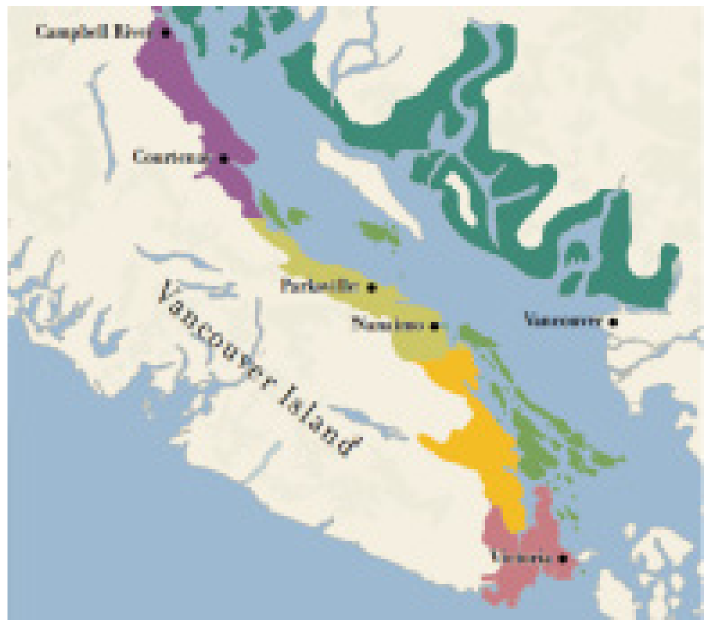


FIGURE 1.
Distribution of Coastal Bluff Ecosystems. Adapted From McPhee, M. W. 2000.

Though similar to terrestrial herbaceous ecosystems found in-land, coastal bluffs are distinctive because of their exposure to extremely high winds, ocean spray, storms and intense summer heat. They are typically dry, open sites with slopes ranging from level ground to 30% and frequently reaching vertical and overhanging positions. Distinct plant communities are formed by species adapted to these harsh environmental conditions, with vegetation cover usually between 20% to 95% of a site, interspersed with exposed bedrock (Mcphee 2000).

SUBSTRATES

Due to the harsh environment and steep slopes of coastal bluff ecosystems, accumulation of organic matter into distinct horizons may take years or never occur at all. The shallow substrate that does accrue exists in outwash deposits left in bedrock crevices and depressions sheltered from prevailing winds. These conditions give rise to dry, nutrient poor sand and sandy-loam soils that are often very saline. In short, soils are generally extremely poor in supplying moisture and nutrients to plant roots (Ministry of Environment 2013).

The exception to this excessive dryness is depressions in the bedrock that fill with water in the winter and spring rain and dry up during the summer. Plants and soils in these vernal pools are subject to either saturation or severe drought conditions throughout the year, with little moderation (Ministry of Environment 2013).

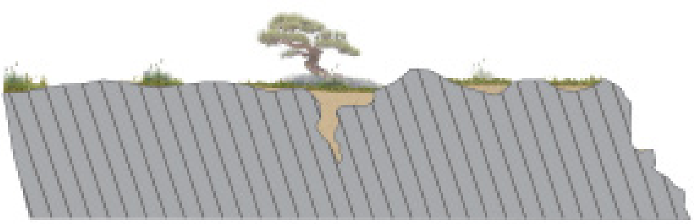


FIGURE 2.
Section of coastal bluff showing soil accumulation.

Plants of the Coastal Bluff

The plants found on the coastal bluff ecosystems of British Columbia's west coast have adapted to harsh conditions including shallow, nutrient-poor soils, heavy wind, salt spray, drought, and seasonal flooding. Matt Fairbarns describes the types of plants found in the coastal bluffs of British Columbia's Garry oak ecosystems as being predominantly composed of mosses, and also including shallow-rooted herbs, plants that grow in deeper soil pockets, and invasive species. Table 1 shows the plants that Fairbarns associates with coastal bluff ecosystems.

Green roofs, like coastal bluffs, are also very challenging environments for plants, often presenting very shallow soils, high wind conditions, extreme temperature fluctuations and drought (Dunnett and Kingsbury 2008). Although the conditions present on coastal bluffs are not exactly the same, it is worth studying some of the survival strategies that plants employ to survive on the bluff habitat, as many of these strategies are also likely effective in a green roof setting.

MOSS

Dicranum scoparium
Racomitrium canescens
Polytrichum juniperinum

PLANTS FOUND IN DEEP SOIL POCKETS

Elymus glaucus
Camassia liechtlinii
Bromus carinatus
Quercus garryana

SHALLOW-ROOTED HERBS

Sellaginella wallacei
Sedum spathulifolium
Claytonia perfoliata
Montia parvifolia
Cerastium arvense
Lotus micranthus

TABLE 1.
Native plants associated with the coastal bluffs of British Columbia. Adapted from Fairbarns 2013.

Drought Tolerance

A number of the plants commonly found in coastal bluff ecosystems demonstrate drought tolerance. Sedum spathulifolium (spoon-leaved stonecrop) is one such species. Like other sedums, S. spathulifolium has the ability to keep its stomata closed during the daytime and during periods of drought, and increases its evapotranspiration rates overnight (Al-Busaidi et al, 2013). Sedums have long been used by green roof designers for their ability to survive periods of drought and grow on shallow soils, and the coastal bluff habitat template approach suggests a continued interest in sedum species.

Temporality

Other plants have found the ultimate method of avoiding difficult growing seasons. Annual plants are commonly found on the coastal bluffs; species such as Claytonia perfoliata (miner's lettuce) and Cerastium arvense (field chickweed) are short-lived and primed to take advantage of good growing conditions. Annuals have generally been disregarded for green roofs, with the exception of intensive green roofs that employ highly-tended annual flower beds (Snodgrass and Snodgrass, 2006). The use of annual species on extensive or less-manicured roofs poses various challenges, particularly that it is difficult, if not impossible, to predict the response of annual species from year to year. Designers must rely on the plant's own ability to grow, set seed, and disperse, and each of these stages depend on complex living systems for their success. Nevertheless, annual self-seeding plants are well-poised to take advantage of rainfall when it happens, and need no resources the rest of the year. These species deserve more attention for green roofs where stormwater management rather than aesthetic predictability is the goal.

Drought Avoidance

Many of the plants found in B.C.'s coastal bluffs demonstrate drought-avoidance. These plants take advantage of periods of rainfall and warmer weather to do most or all of their growing, and enter a period of dormancy during the difficult conditions presented by the drought of summer or cold of winter. Spring bulbs are plentiful and beautiful on healthy coastal bluff ecosystems. Camassia quamash is one such species. This perennial emerges during the spring, gathers energy through photosynthesis, flowers, sets seed, and stores its energy in its bulb during the rest of the year.

Drought-avoiding species are useful to green roof designers for multiple reasons. Perennial flowering bulbs can be planted where one wants them, allowing for well-planned designs. These types of species are beautiful and are commonly used in landscape design, and so can be used to improve the public's attitude towards green roofs. Finally, since flowering bulb species are dormant during periods of drought, they require no irrigation, yet are available to assist with interception and evapotranspiration of rainfall during the rainy spring months. Camassia quamash has been used successfully used on West Coast green roofs with success. For example, the C. quamash on research green roof at Oregon State University had a 100%survival rate, even without irrigation (Lambrinos and Jordan 2010).

A Focus on Moss

In regards to drought-avoidance strategies, among the most effective in the plant world is that employed by mosses. Fairbarns (2013) points out that B.C.'s coastal bluffs are dominated by three species of moss: Racomitrium canescens (rock moss), Dicranum scoparium (broom moss), and Polytrichum juniperinum (juniper haircap moss). These mosses are able to grow on the thinnest of soils and even directly on bare rock, colonizing areas inaccessible to vascular plant species (ibid). Mosses trap nutrients from the air, are important to soil formation processes, and create favorable microclimates for the growth of other plant species (Chiaffreda and Denayer 2004). Perhaps the biggest lesson that green roof designers can learn from the coastal bluff is to embrace the world of mosses.

Many moss species commonly grow on roofs. On British Columbia's 'wet coast', Racomitrium canescens is found on nearly any type of roof, and must be constantly removed from roofs not designed to accommodate plants (Anderson, Lambrinos and Schroll 2010). Despite R. canescens and other moss species' prevalence on roofs, mosses have been largely ignore in green roof literature and implementation. Edmund and Lucie Snodgrass's definitive book, Green Roof Plants, a Resource and Planting Guide (2006), does not make a single mention of moss. Another major source of green roof planting information, Dunnett and Kingsbury's Planting Green Roofs and Living Walls (2008), reserves only two paragraphs for the entire subject of mosses, lichens, and ferns.

It is unclear why green roof practitioners and researchers have largely ignored mosses despite the fact that they clearly thrive on roofs. The most likely explanation revolves around aesthetic prejudices surrounding mosses, coupled with the fact that when mosses are dormant they appear dead and thus unattractive. Despite an overall disregard, there are a handful of researchers who have become interested in mosses for green roofs. Christine Thuring makes a case for the use of native species in B.C. green roofs, pointing out that "many coastal area rooftops have been colonized by mosses, which eventually create conditions for a succession of other volunteer plants" (2007, 6). Anderson, Lambrinos and Schroll studied the potential for moss roofs to retain stormwater and cool buildings in Portland, Oregon and found that moss roofs retained 60.3% of the total rainfall, while roofs planted with herb species retained only 37.1% of the rainfall (2010). Figure 3 provides more information about the results of this study. Mosses possess many characteristics that could be of great benefit for use on green roofs as a stormwater mitigation tool; these characteristics are summarized in below:

- *Moss can be dry for extended periods and re-hydrate within minutes of rainfall, thus not requiring summer irrigation.*
- *Moss grows from November to February when most of the West Coast's precipitation occurs.*
- *Moss lacks stomata and so cannot retain water, allowing for greater amounts of evaporation than other plant types*
- *Moss holds large amounts of water – up to 5 mm of water per square mm of moss surface.(Anderson, Lambrinos and Schroll 2010).*

Micro-Topography

Plants found growing on coastal bluffs are not evenly distributed. Convex rocky outcrops are often completely bare or display only a thin layer of lichens or moss, while concave areas and deep fissures support a wider range and different assemblage of species. Many coastal bluff plants depend on water-receiving areas and fissures for their survival, and under the right circumstances large perennial grasses such as Elymus glaucus (blue wildrye) and even stunted Quercus garryana (Garry oak) trees manage to survive the harsh conditions of the coastal bluff (Fairbarns 2013).

Green roofs are typically constructed with an even layer of soil and distribution of plants. Dr. Stephan Brenneisen pioneered a method of the varying substrate depth on green roofs in order to achieve higher plant and insect diversity, but this depth is achieved through hilling soil on top of an evenly-graded roof (Cantor 2008). The extra exposure to drying winds and water-shedding profile of the hills results in a topography that provides for diversity, but does not allow for the growth of larger or more water-hungry plants. The coastal bluff habitat template approach suggests the possibility of varying the topography of the roof itself, thus creating deeper soil pockets that also collect larger amounts of runoff and are less-exposed to the elements than their surroundings. These pockets

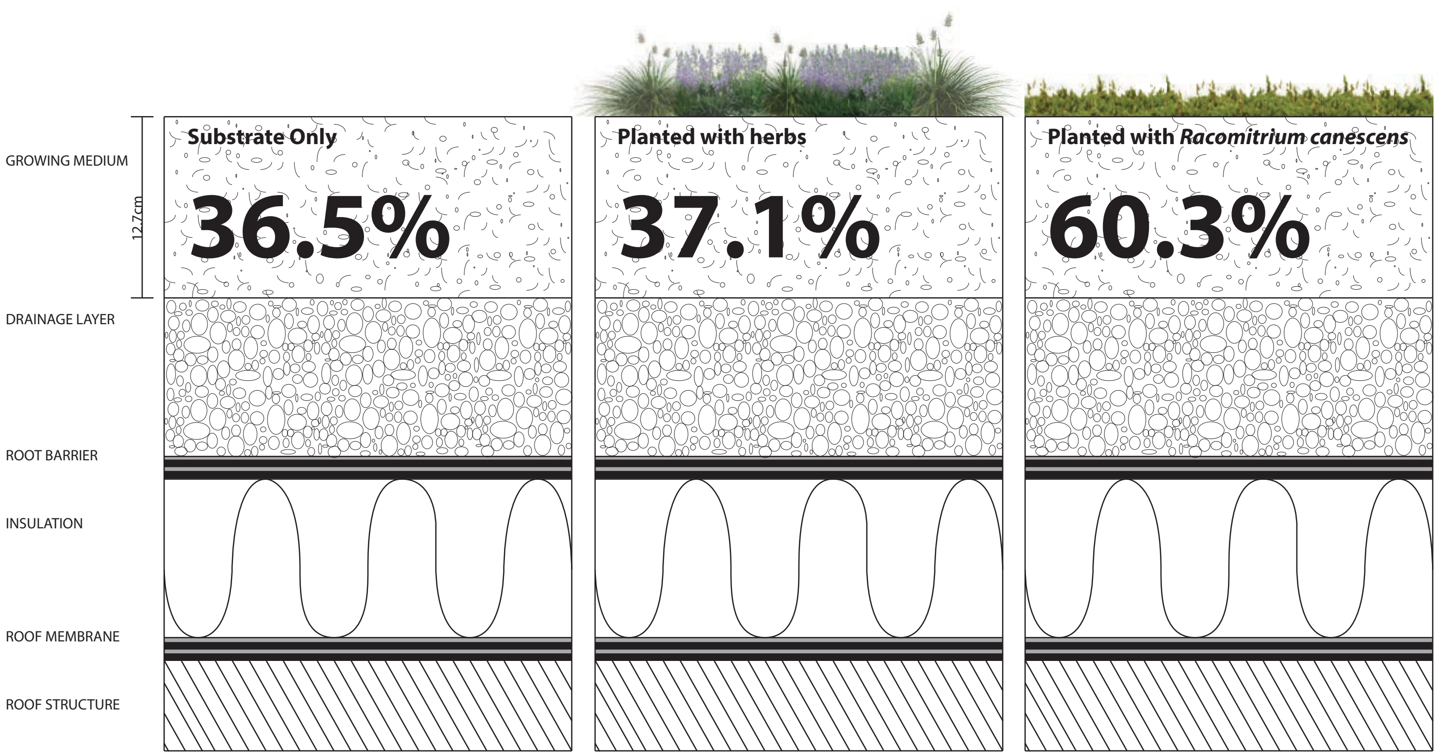


FIGURE 3.
Green roof potential to retain rainwater. Adapted from Anderson, Lambrinos and Schroll 2007.

of more desirable micro-topography would host the largest and greenest plants found on the roof – plants that could increase the stormwater performance of a green roof while providing for patches of lushness within a dormant summer planting.

The technical requirements of a varied base layer are beyond the scope of this research paper, but a few possibilities emerge from the study of typical green roof configurations. One approach could be to create a system of connected planters of varied depth, with the shallower planters draining into the deepest planters. This approach is similar to planter methods currently employed on intensive green roofs, with larger planters used for specimen trees and building loads designed accordingly. Another possibility could be to vary the height of drainage cells, so that from the surface of the roof the soil would appear to be even, while in reality there would be areas that would collect more water and contain deeper soil than others. Finally, the roof of the building itself could be varied, with the waterproofing membrane, insulation, and drainage layer following the topography of the roof. Lambrinos and Jordan point out that this method is often inadvertently designed into roofs:

> "As with a traditional flat roof, water on a green roof may pool in certain low spots, often around drains or at the bottom of slopes; these areas are micro-environments for plants that prefer more water" (Lambrinos and Jordan 2010, 23).

A more conscious effort to create areas where water pools and soil can accumulate could result in more attractive, diverse, and functional green roofs.

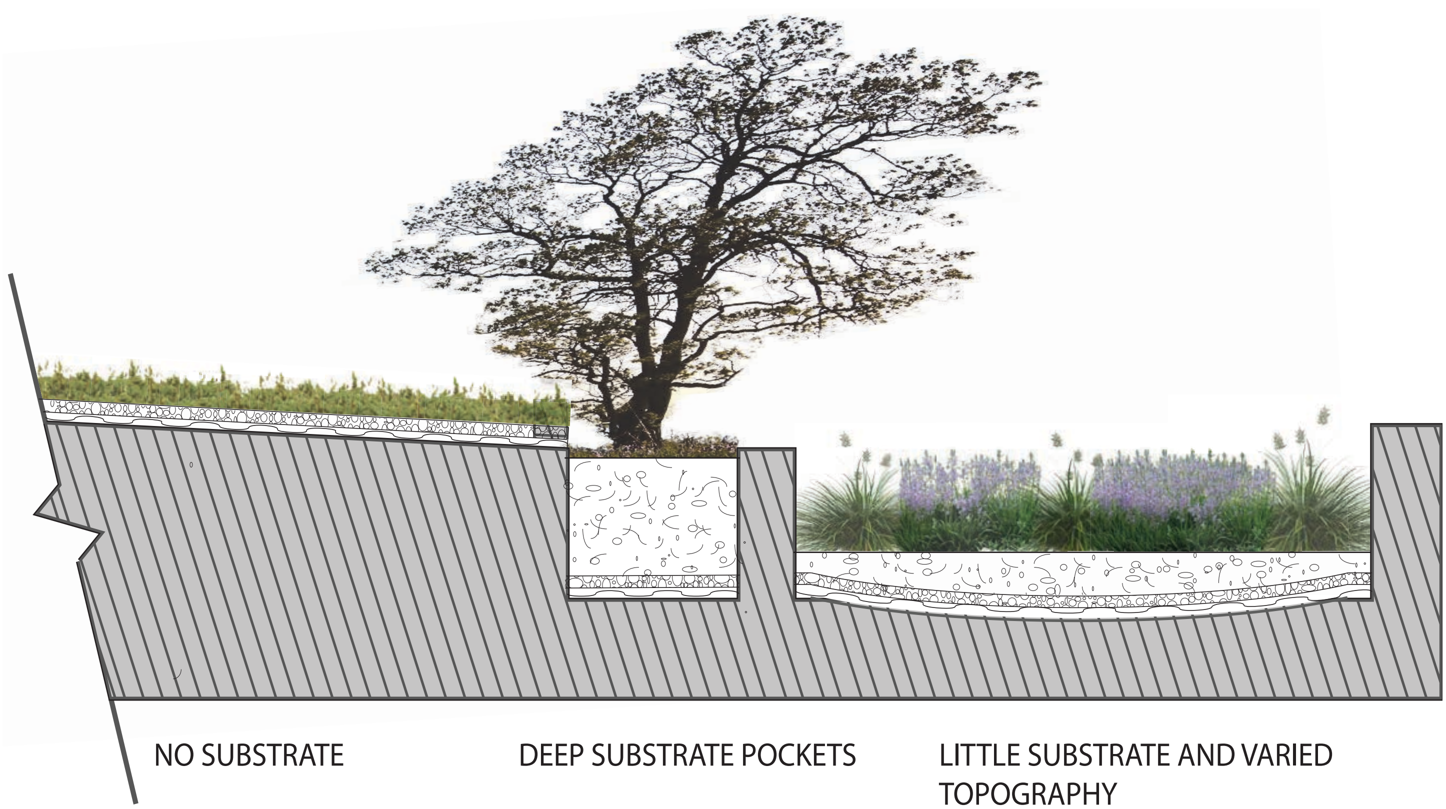


FIGURE 4.
Example of a green roof designed using lessons learned from the coastal bluffs.

Putting it all Together

Coastal bluffs can teach us a number of things about how to design a green roof: the survival strategies and habitat templates of individual plant species should be carefully considered; varied topographies allow for the survival of different plants; and mosses are an integral component of the ecosystem.

There are many ways to employ these principles in a green roof design, and the example provided in Figure 4 is one of them. On this roof, costs are kept low by using moss without substrate on the least visible areas of the roof. Large planters with high load requirements add visual interest on the most visible portions of the roof, and these planters are irrigated through runoff received from the moss roof. In areas where visual interest and cost must be equally balanced, a fairly shallow substrate with a gently varied topography is employed, allowing for groupings of plants that require moister, deeper soils and that will provide a show of bloom in spring. The plants in the shallow substrate are selected because they are either drought tolerant, drought avoidant, or are temporal (annual).

Aesthetics for Green Roofs

In the west we see moss as a nuisance, associated with derelict buildings and needing to be removed. In other cultures, such as in Japan, moss gardens have existed for centuries and are deeply appreciated. This reveals the subjectivity associated with perceptions of aesthetic beauty in the landscape. It is worth examining more closely how this notion pertains to green roofs. Richard K Sutton takes on this task in his paper Aesthetics for Green Roofs and Green Walls (2014). Sutton adopts M. Adlers (1981) reduction of beauty into two categories, enjoyable beauty and admirable beauty. The author then adds a third, wider and more useful category termed “ecological beauty.”

ENJOYABLE BEAUTY

Sutton sums up enjoyable beauty with a quote from St Thomas Aquinas, “that which being perceived, pleases” (qtd in Sutton 2014, 3). Such an idea of beauty is strongly subjective and essentially closed to dialogue or persuasion. Enjoyable beauty focuses on immediate gratification and fails to deal with a wider, older, and more complex context for the experience (Sutton 2014, 3).

ADMIRABLE BEAUTY

Admirable beauty is often based solely on formal and visual elements and design principles (Sutton 2014, 4). This “art model” attempts to be objective and requires disinterested interpretation. Sutton states “this approach can become superficial and focus narrowly on pleasure derived from shallow surfaces (2014, 4).” The affect of admirable beauty often ignores the surrounding context in favor of a designed object (Sutton 2014).

ECOLOGICAL BEAUTY

Ecological beauty, however, “arises from the subject (individual user), object (landscape) and their higher order connection (Individual-landscape-context)” (Gobster 1999). In this methodology, subject, object and context become integrated. “Beauty and its perception emerge from these underlying properties and interactions” (Sutton 2014, 4). Sutton suggests that an ecological approach to beauty extends beyond mere surface properties and “embraces unseen forms and processes, deeply and holistically engaging our personal experience (2014, 4).” This experience synchronously draws upon our understanding and teaches us about our general environment. Eventually, “experience bonds us to a specific place”(Sutton 2014, 4).

ECOLOGICAL AESTHETICS APPLIED TO GREEN ROOFS

Ecological beauty is especially important to green roofs. If the public bases their perceptions of green roofs solely on admirable and enjoyable beauty, then appreciation will be limited to a few elaborate intensive green roofs while extensive roofs remain unnoticed and undesirable. Since intensive roofs are often not feasible economically or structurally, a general shift toward appreciation of ecological beauty is necessary in order to achieve acceptance of all green roof types.

Sutton asserts that “active interpretation and knowledge" is required for ecological beauty (2014). In general, the public must be encouraged to cultivate sensibilities and acquire knowledge of their specific environment. But this can be facilitated by making green roofs more conspicuous, accessible and abundant. As Thayer puts it, "visibility and imageability of the sustainable landscape is critical to its experiential impact and the rate at which it will be adopted and emulated in common use" (1989, 108).

Using Coastal Bluff ecosystems as a habitat template has the potential to create roofs that are light, relatively inexpensive, and functional. This would allow for easier and more frequent implementation of green roofs in conspicuous locations and in general. Mimicking bluffs within a city could also serve to teach the public more about these unique local ecosystems.

As dialogue becomes more open about green roofs, education can also take place regarding storm water issues and the mitigation functions of green roofs in Vancouver. This is an unseen process which when revealed would serve to further enhance the ecological beauty of green roofs. As Thayer (1989) claims, "People who are able to comprehend how and why a sustainable landscape functions will respond differently to that landscape than those who are uninformed... environmental knowing heightens landscape experience."

Significance of Research

This research is important because stormwater mitigation in Vancouver is a critical issue. The combined stormwater/ sewage system means as much storm water as possible must be mitigated on site in order to avoid overflowing the antiquated system. Green roofs can help significantly in this task, but are arguably not a sustainable solution in the region. The local climate necessitates irrigation in the summer months making roofs expensive to maintain and wasteful of valuable potable water. On-site cisterns, pumps and filtration systems add to the weight of green roofs, consequently adding to the costs. The potential of coastal bluff ecosystems to act as a template for green roofs lies in the possibility of designing a living roof in Vancouver that does not require irrigation in the summer, minimizes the weight of substrate, and mitigates a high amount of runoff. Aesthetic benefits are secondary, but still an important aspect of green roofs.

Conclusion

In summary, using the Coastal Bluff ecosystem as a habitat template could result in a low maintenance, lightweight, living roof that does not require irrigation. This roof would be dramatically cheaper to install and maintain than a similar sized intensive roof and most extensive roofs, and valuable potable water would be conserved. It could be implemented easily and frequently, and efforts made at education and conspicuous placement of these living roofs could increase their acceptance and appreciation of ecological beauty. Also, mosses may perform better for cooling functions and storm water mitigation than other green roofs, (although cooling may not be desirable in winter). Overall, the potential benefits of using Coastal Bluff ecosystems as a habitat template for green roofs in Vancouver makes the topic worthy of extensive future study.

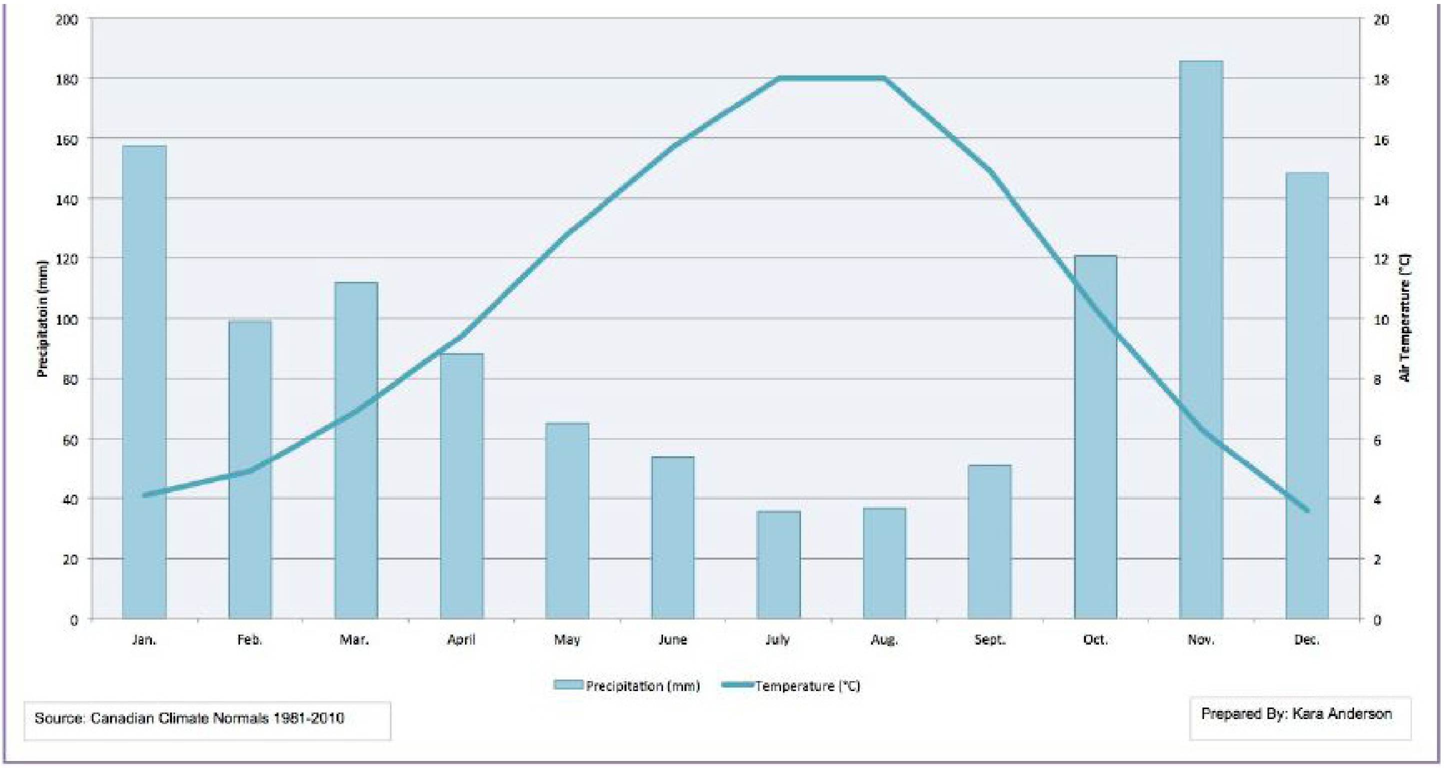
Areas for Further Research

Some areas for further research resulting from this study include:

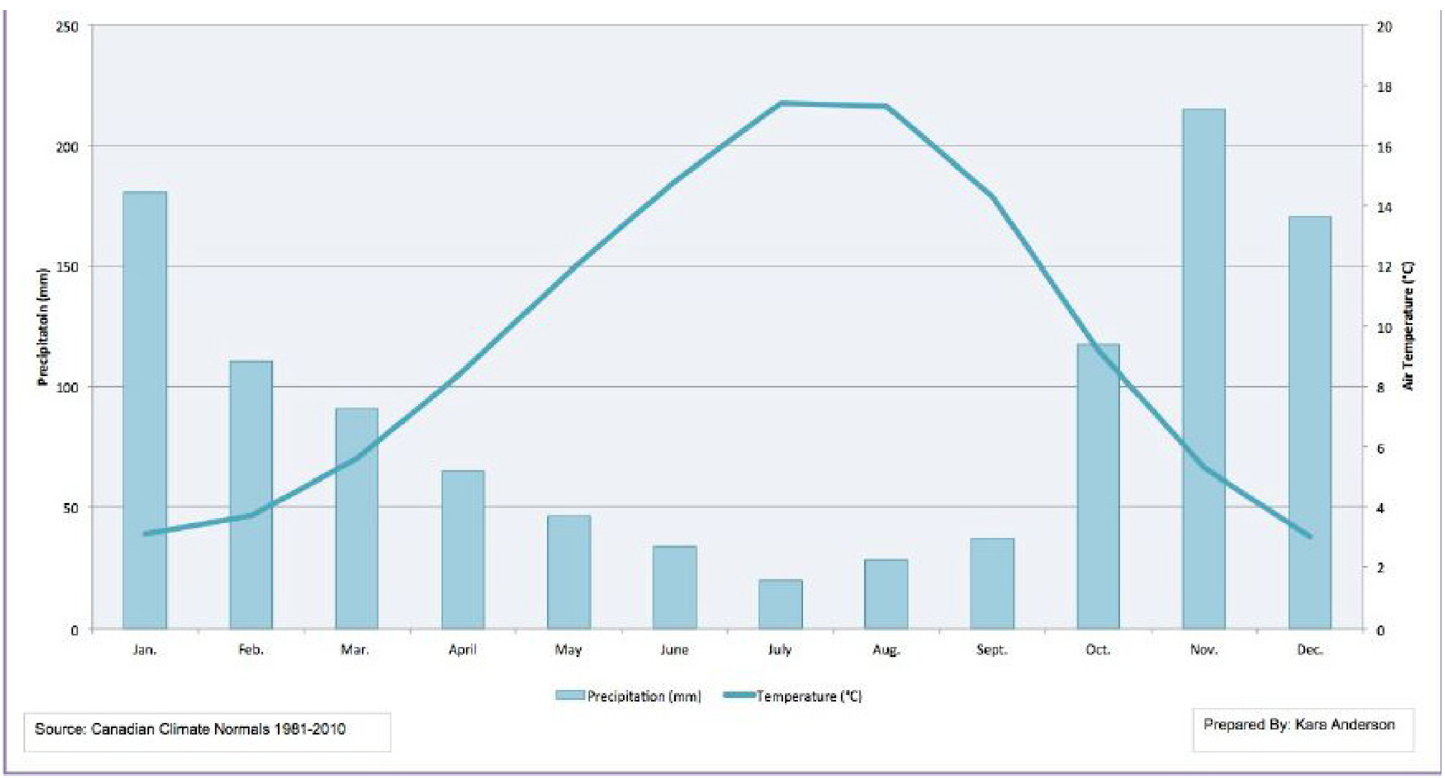
- The implementation of roofs so that experiments with different mosses, plant combinations and varied substrate depth could be enacted.
- Obtaining evapotranspiration data of mosses so that runoff and cooling functions may be calculated.
- Weight data must also be collected so that structural requirements can be calculated.

Rigorous study must be conducted further, as suggested above, before concrete conclusions can be made about the benefits of a coastal bluff template for green roofs in Vancouver. The potential of developing a green roof type that is lightweight and drought-resistant warrants this future study, potentially as an important development in green roof design.

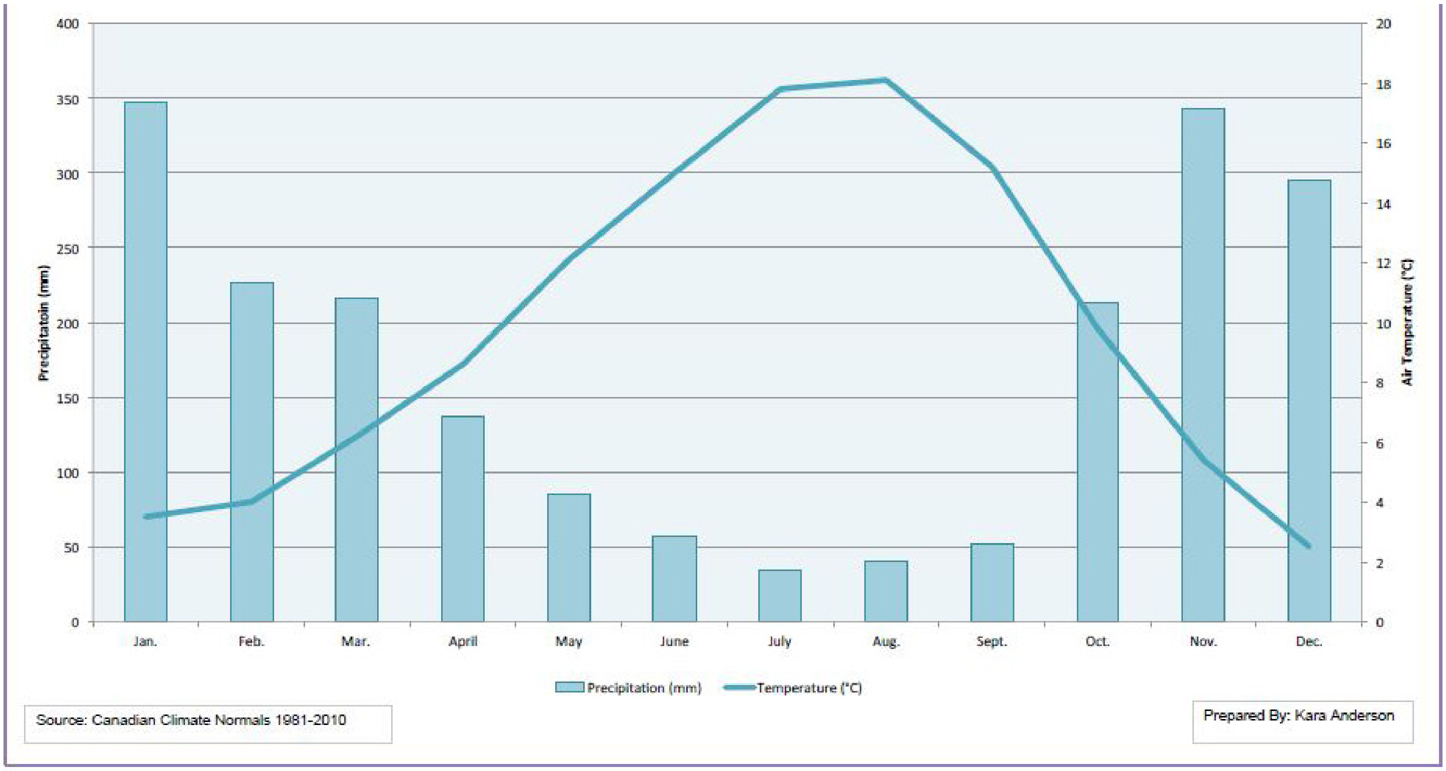
Appendix A.



GRAPH 1.
Mean monthly air temperatures and precipiation values for Vancouver (Vancouver Int'l Airport) 1981-2010.



GRAPH 2.
Mean monthly air temperatures and precipitation values for Victoria (Highland) 1981-2010.



GRAPH 3.
Mean monthly air temperatures and precipitation values for Lake Cowichan, 1981-2010.

Works cited

Adler, M. 1981. *Six Great Ideas*. New York: Macmillan

Al-Busaidi, A., T. Yamamoto, S. Tanak, and S. Moritani. 2013. Evapotranspiration of succulent plant. In *Evapotranspiration: An Overview,* ed. Alexandris Stavos, 241-257 InTech.

Anderson, Malcolm, John Lambrinos, and Erin Schroll. 2010. The potential value of mosses for stormwater management in urban environments. *Urban Ecosystems* 13: 319-332.

Butler, Colleen, Erin Butler and Colin M. Orians. 2012. Native plant enthusiasm reaches new heights: perceptions, evidence, and the future of green roofs. *Urban Forestry and Urban Greening* 11(1): 1-10.

Cantor, Steven. 2008. *Green Roofs in Sustainable Design*. W.W. Norton and Company Inc. New York, NY.

Chiaffredo, Michel and Franck-Olivier Denayer. 2004. Mosses: A Necessary Step for Perennial Plant Dynamics. In *Proceedings of the Second Annual International Green Roofs Conference: Greening Rooftops for Sustainable Communities*, Portland, May 2004.

Dunnett, Nigel and Noel Kingsbury. 2008. *Planting Green Roofs and Living Walls*. Timber Press. Portland, OR.

Fairbarns, Matt. 2013. Garry oak ecosystems. In Klinkenberg, Brian. (Ed.) 2013. *Biodiversity of British Columbia.* Lab for Advanced Spatia Analysis, Department of Geography, University of British Columbia, Vancouver.

Garyali Architect Inc. 2008. Projects. http://www.garyaliarchitect.com/Community.html. [13 March 2014].

Gobster, P. 1999. An ecological aesthetic for forest landscape management. *Landscape Journal* 18(1): 54–64.

Lambrinos, John and Marilyn Jordan. 2010. Extensive Green Roofs: Horticultural Considerations for Stormwater Management. *Pacific Horticulture* 71 (April): 22-26.

Larson, Douglas, Uta Matthes, Peter Kelly, Jeremy Lundholm and John Gerrath. 2004. *The Urban Cliff Revolution*. Toronto: Fitzhenry and Whiteside.

Lundholm, Jeremy. 2006. Green Roofs and Facades: A Habitat Approach. *Urban Habitats* 4(1): 87-101.

McPhee, M. W. 2000. *Sensitive ecosystems inventory, east Vancouver Island and Gulf Islands, 1993-1997.* Delta, B.C.: Pacific and Yukon Region, Canadian Wildlife Service, Environmental Conservation Branch. Ministry of Environment. 2013. East Vancouver Island & Gulf Islands. http://www.env.gov.bc.ca/sei/van_gulf technical/sec3.html [March 14, 2014]

Ngan, Goya. 2004. Green Roof Policies: Tools for Encouraging Sustainable Design. http://www.coolrooftoolkit.org/wpcontent/uploads/2012/04/Green- Roof-Policy-report-Goya-Ngan.pdf [12 April, 2014].