ABSTRACT

Title of Document: DESIGNING FOR BIODIVERSITY TO INFLUENCE HABITAT ON A GREEN ROOF IN THE DISTRICT OF COLUMBIA

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This paper will discuss design elements to enhance pollinator and avian diversity on a green roof in the District of Columbia. Biodiversity trends on green roofs in Canada, the United Kingdom, Switzerland, and the United States are discussed. Focusing on North America, reconciliation ecology is explored through the use of case studies. The design process for designing a green roof is divided into three parts: identifying program goals, site analysis, and design concept. Design guidelines are extrapolated from conservation literature for the creation of green roofs that support pollinator and avian habitat. These "bioroofs" will be draped over the United States Coast Guard Headquarters building which will serve as a template for creating a green roof to target the least tern, the killdeer, the butterfly and the bee, in the District of Columbia.

DESIGNING FOR BIODIVERSITY TO INFLUENCE HABITAT ON A GREEN ROOF IN THE DISTRICT OF COLUMBIA

By

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DEDICATION

To my parents who have allowed me to follow my dream and pursue something, about which, I am passionate.

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CHAPTER 1: INTRODUCTION

As cities expand, urban sprawl is leading to habitat loss (Baumann 2006; Cantor 2008; Schindler *et al.* 2011; Tallamy 2009). The District of Columbia is no exception. In his book, *Bringing Nature Home*, Tallamy argues "[i]mpervious surface increased more than 40 percent in the Chesapeake Bay watershed between 1990 and 2000" (Tallamy 2007, 32). More impervious surfaces mean fewer green spaces. Tallamy claims there is a one-to-one relationship between the amount of space we preserve and the number of species that can survive. That is, "each one percent reduction of natural area will cost one percent of steady state diversity" (Rosenzweig 2003, 194).

This concept has led to the creation of preserves, meant to create safe havens for wildlife. As civilization continues to grow, these preserves are becoming reservations, creating habitat islands. This is of concern because these disconnected "[t]iny habitat islands have high rates of extinction" (Tallamy 2009, 29).Traditional conservation may not be able to meet the future needs of conservation. A possible solution can be reached through the use of reconciliation ecology.

Reconciliation ecology is the future of conservation. This discipline provides the opportunities to knit future development with current development practices (Rosenzweig 2003; Lundholm and Richardson 2010). The expansion of civilization does not necessarily mean the destruction of habitat. This is not an either/or scenario. There is potential to increase biodiversity using what Kim calls, "building integrated habitat" (2004).

There is a need for designers to be involved with testing conservation ideas through design inquiry. What follows is a close look at the components that make up the tool kit for green roof designers. After exploring the components of a green roof, design strategies for enhancing biodiversity are discussed. After which, using the knowledge gained from case studies, the design process is outlined. Learning from the precedence set by other countries, this paper will try to bring reconciliation ecology to the the application of a design in the District of Columbia. Other countries have changed laws, to meet conservation needs. What would it take for green roofs to influence legislation in the District of Columbia?

1.1 Green Roof Benefits

It is important to discuss some of the numerous benefits offered by green roofs in the Washington, District of Columbia Metropolitan Area. Green roofs provide many primary and secondary benefits for both city inhabitants and the region as a whole. Specifically, green roofs have a positive impact on a building's (a) aesthetic, (b) stormwater management, (c) water filtration, (d) combating the urban heat island, (e) increased insulation, and (h) habitat restoration (Cantor 2008). All of these are discussed below.

1.1.1 Aesthetics

Within the city, there are many unused spaces which possess remarkable opportunities. These left over spaces are sometimes covered with black tar or reflective coating meant to project heat from the sun away from the building. These roofs are not designed for their appearance. Putting a value on aesthetics is not simple. However, one way to quantify the value of aesthetics is through property value.

Green space within urban environments is increasingly valued. Kayo Tajima (2003) confirms this in the paper, "New Estimates of the Demand for Urban Green Space: Implications for Valuing the Environmental Benefits of Boston's Big Dig Project," which found real estate values were influenced by proximity to green space (Tajima 2003). In addition to visual appeal, there are also many functional benefits of using vegetated roofs.

1.1.2 Stormwater management

In many cities, green roofs are advocated because of their ability to absorb, filter, and store water during storm events. This makes stormwater management a primary benefit of a vegetative roof (Getter 2006, 1276; Niu *et al.* 2010).

Green roofs are able to decrease peak flow discharge by slowing down the time it takes for water to reach the municipal storm sewer systems (Getter 2006, 1278; Hopkins and Goodwin 2011). By increasing the time of concentration, storm sewers are less likely to reach capacity. This is of great importance because when storm sewers reach capacity, "raw sewage pours into the Potomac and Anacostia Rivers and Rock Creek" Park (Earth Justice 2010). Preventing storm sewers from reaching capacity is not the only way green roofs are able to ameliorate stormwater problems.

1.1.3 Water Filtration

As with other vegetation, green roofs are able to collect suspended atmospheric soot and dust (Hopkins and Goodwin 2011). These particles are sometimes high in nitrogen and phosphorus – the same chemicals used in fertilizers. As particles fall to earth, they land on green roofs, where plants are able to metabolize these nutrients (Cantor 2008). If given the opportunity, green roofs are able to intercept and use these nutrients as “fertilizers” before they become problematic. These chemicals are most problematic during rain events.

During storm events, dust washes from impermeable surfaces where high volumes of pollutants are present. When this nutrient rich pollutant washes into the Potomac River, Anacostia River, and ultimately the Chesapeake Bay, it creates an unhealthy surplus of nutrients in the water. This nutrient overload can lead to algae blooms, which suck oxygen out of the water, and lead to aquatic death (Getter and Rowe 2006).

A plant’s ability to absorb atmospheric soot would be considered a peripheral benefit. That is, this benefit may not influence a building owner’s decision to use a green roof. It can be seen more as an added benefit. Another peripheral benefit of green roofs can be found in the ability of vegetation to cool the environment.

1.1.4 Combatting the urban heat island

It is common knowledge that cities are warmer than the surrounding suburbs (Getter and Rowe 2006). Buildings which are predominantly stone absorb solar radiation in the form of heat, and slowly release that energy during the nighttime (Cantor 2008; Hopkins and Goodwin 2011). This is one of many factors that contribute to the phenomenon known as the “urban heat island” (UHI). The UHI is the result of many components, two of which will be discussed below.

Densely populated areas are characteristically devoid of vegetation (Beatley 2011; Getter and Rowe 2006). Vegetation provides many benefits including shade, and vegetation has an ability to cool the environment (Srivastava 2011). By including plants of varying heights, it is possible to maximize the benefits of the shade they provide

(Lundholm *et al.* 2010). Plants use energy from the sun for evapotranspiration, this process results in lower leaf temperatures (Shrivastava 2011; Getter 2006, 1276). This lower temperature, in turn, lowers the temperature of the surrounding air, which cools the immediate environment (Srivastava 2011).

The second contributing factor to the UHI is the roof surface itself. Traditional roofs, generally using dark colored materials that absorb energy, reach temperatures of up to 175°F (Snodgrass 2006, 22), whereas green roofs stay much cooler during the day (Cantor 2008; 33). The lowered surface temperature of the green roof helps to combat the UHI (Anderson *et al.* 2010).

1.1.5 Increased Insulation

Green roofs provide a tangible thermal mitigating benefit, resulting in monetary savings (Niu *et al.* 2010; Lundholm *et al.* 2010; Clark *et al.* 2008). Studies performed by the BCIT Centre for Architectural Ecology in Vancouver, British Columbia, demonstrate green roof's positive thermal benefits (Connelly 2008). A study performed by Clark *et al.* (2008) confirms the work done in Canada.

In this study, energy savings were calculated by looking at 75 buildings on the University of Michigan's campus in Ann Arbor, Michigan. These buildings were analyzed using both energy modeling software and calculations using R-Value analysis. Cost of heating was calculated by the price of natural gas with the cost of cooling being determined by the cost of electricity. The result of the energy modeling—for a 2,000 square meter roof over one year—provided a $710 savings over a conventional roof. In the R-Value analysis, there was a $1,670 savings over a conventional roof (Clark *et al.* 2008).

1.1.6 Habitat Restoration

Creating habitat on a roof offers an opportunity not present among other locations. As wilderness is replaced with the built environment, there is an increase of roof area available. This space allows for green space in "areas that are otherwise unsuitable for natural restoration" (Currie and Bass 2010). The roof is a relatively undisturbed space, which may offer protection, by providing habitat for species of interest (Brenneisen 2006).

Switzerland (Brenneisen 2003), Canada (MacIvor 2011), and the United Kingdom (Gedge 2003) have already changed their laws to mandate the use of green roofs. These countries hope to weave conservation biology into the urban fabric using the principles of reconciliation ecology. By uniting the studies of conservation with ecology, there is potential for increased biodiversity within cities (Rosenzweig 2003). A quick history of reconciliation ecology in the United States is important to understand the potential for living roofs as habitat in North America.

The Backyard Wildlife HabitatTM (Rosenzweig 2003) Campaign was created by the U.S National Wildlife Federation. This program was meant to increase habitat within citizens' backyards throughout the United States. This program can be seen as an example of reconciliation ecology because of the way conservation is handled. Instead of preserving patches for conservation (Tallamy 2009), reconciliation ecology uses developed areas to integrate habitat with the built environment. The story of the eastern blue bird is a success story of reconciliation ecology.

The eastern bluebird (*Sialia sialis*) was suffering from a loss of habitat. The lack of available roosting locations was taking its toll. These birds were also being pushed out of their homes by introduced avian species. After observing the optimal size and shape of nestbox, “In 1979, the North American Bluebird Society was founded and began to encourage people to deploy appropriate nestboxes on their property” (Rosenzweig 2003, 203). The success of the eastern bluebird, illustrates that future development does not have to degrade habitat.

The success with the eastern bluebird illustrates a species ability to rebound with the help of application of reconciliation ecology. This example, demonstrates that conservation practices are able to work in built environments. While protecting natural areas is important, it is also possible to create havens for wildlife within densely populated areas. One way reconciliation ecology can be brought into the city is through the use of building integrated habitat.

1.2 Components of a Green Roof

There are many choices to consider when designing a vegetated roof. The four basic elements that make up a green roof include (a) the vegetation layer, (b) the substrate, (c) the drainage layer, and (d) the protection layer. Although these elements are all present on a green roof, the top two layers are most influential when designing for biodiversity and discussed further.

1.2.1 Vegetation Layer

When selecting plants to put on a green roof, it is important to look at green roof analogs. A green roof analogue would be an environment that is similar to the conditions present on a green roof, e.g., rock outcroppings, sand dunes, or desert environments (Lundholm and Richardson 2010). These environments are marked by temperature extremes, lack of water, and shallow substrates. These ecosystems can be used as 'habitat templates' (Lundholm 2006). A habitat template is one that consists of a specific variety of species, surviving in a particular environment. These analogs can be used to guide future design (Lundholm 2006).

Using a diverse planting pallet is one strategy to ensure the success of a green roof. From a biodiversity standpoint, it is important to use plants with tall, medium, and low forms. The use of different plant types increases the number of microclimates present on the roofscape. Some researchers suggest that *Sedum* species can increase the success of neighboring plants. One study performed by Butler (2011) concluded that certain *Sedum* species can act as 'nurse plants' by lowering soil temperatures and increasing the growing medium's water retention. The next few sections use ideas taken from the book entitled “Small Green Roofs: Low-tech Options for Greener Living,” by Nigel Dunnett *et al.* (2011).

1.2.2 Succulents and *Sedums*

There are many reasons *Sedums* are the most highly used species of succulent on green roofs (Dunnett *et al.* 2011). *Sedums* are low growing groundcovers which are able to spread quickly, survive low nutrient environments (Snodgrass 2003), and have the ability to survive in the harsh summer conditions present on a green roof (Butler and Orians 2011). These shallow rooted plants have a high success rate in the shallow substrate found on extensive roofs (Dunnett *et al.* 2011).

For the above reasons, *Sedum* species have proven successful on green roofs, which is why it is important to use *Sedums* as a foundation plant. Succulents can be relied upon for their hardiness and their ability to increase the success of surrounding plants (Butler and Orians 2011).

1.2.3 Flowering Herbaceous Species and Alpine Plants

These plants help to give a “visual, structural, and ecological diversity to a green roof” (Dunnett *et al.* 2011, 53). Herbaceous plants are softer than woody plants and traditionally die back to the ground (Dirr 1998). Herbaceous plants use stored energy found in their roots to regenerate the following year (Kourik and Anderson 1997). Alpine plants are well suited for green roofs because they have evolved in harsh environments at high altitudes above the tree line (Good and Millward 2007).

1.2.4 Grasses

Grasses are great accents to any organized planting. On green roofs grasses can help to provide shade during hot summer months (Oberndorfer *et al.* 2007) or provide their seeds as food for hungry avian species (Dunnett *et al.* 2011). When using grasses, it is important to keep them in check, because free seeding grasses can take over a roof thereby decreasing biodiversity (Dunnett 2011, 55).

1.2.5 Native Flowers

When targeting biodiversity it is important to use native plants as a nectar source. Invertebrates and other species have evolved over eons creating symbiotic relationships with specific species (Tallamy 2009). Many insects depend on the native plants with which they have evolved. An example of this relationship is between the Monarch butterfly and the milkweed (*Asclepias*) plant. Monarch butterflies will only lay their eggs on plants that are of the milkweed species. This plant provides food for their larva (Hansen Jesse and Obrycki 2000).

1.2.6 Bulbs

There is a great deal of potential for integrating bulbs into green roof designs. Ideal selections are those which come from arid and rocky regions of the world. Tulipa species have been used successfully on green roofs (Dunnett et al. 2011, 57) and they provide a fantastic punctuation and early pollen sources for any green roof. Dunnett *et al*. (2011) recommends the use of bulbs from the families of Tulipa, Muscari, and Narcissus. It was suggested that smaller varieties were able to perform more successfully on vegetated roofs. With the use of *Botanica, the Illustrated Encyclopedia of Over 10,000 Garden Plants and How to Cultivate Them*, the aforementioned families will be discussed.

1.2.6.1 Tulipa

Tulips are originally from central and western Asia. There are more than 100 species divided into 15 classes. This bulb should be planted in the fall, in a sunny location, six inches deep, in well-draining soil. The smaller varieties of Tulip include: *Tulipa kaufmanniana*, *T. saxatilis*, *T. urumiensis*, *T. tarda*, and *T. turkestanica*.

1.2.6.2 Muscari

Grape Hyacinth is originally from the Mediterranean region and west Asia. There are about 30 species. This frost hardy bulb should be planted in the fall and arranged in drifts within a rich, well-drained soil. This plant can handle the cold, but attention should be used in site location to prevent this bulb from overheating. Part shade is recommended. This is a smaller bulb not growing more than eight inches tall. Species of interest include the following: *Muscari botryoides*, *M. neglectum* syn. *M. racemosum*, and *M. armeniacum*.

1.2.6.3 Narcissus

Commonly known as the daffodil, this species is originally from the western Mediterranean. There are 50 species divided into 12 classes. This bulb should be planted in the fall, at a depth of 4-6 inches in well-drained soil. Daffodils prefer full sun in cool areas of the country. In warmer areas, Daffodils perform better in some shade. Notable species include the following: Narcissus 'Rugulosus,' N. 'Little Gem,' and N. bulbocodium.

1.2.7 Mosses

When looking for successful plants for a green roof, it makes sense to look at vegetation already present on many roofs in the region. In the Washington DC

Metropolitan Area there are roofs that are matted with moss. Although, this moss does not have a very strong root system, it is light in weight (Dunnett 2011, 59) and can soak up water like a sponge (Anderson *et al.* 2010).

According to the article, "Extensive Green Roofs and Mosses: Reflections from a Pilot Study in Terra Alta, West Virginia," (2009) the authors Studlar and Peck discuss the possibility of *Hedwigia.* This moss is very drought tolerant and has a desirable growth form (2009). This article discusses practical applications for mosses, its use in Japan, and its potential on green roofs.

In another article on the subject, "The Potential Value of Mosses for Stormwater Management in Urban Environments" (2010), Anderson *et al.* discuss the use of moss as a means to achieve greater stormwater retention. Although, there is a great deal of potential for mosses on green roofs, there is not enough data available to incorporate moss into this design.

1.2.8 Vegetables and Herbs

In New York City, some restaurants use their roofs for growing ingredients to serve their customers. Although this is an intriguing concept, this paper will not explore the concept of edible vegetation for people on green roofs. While this paper will not deal with green roofs that provide sustenance for humans, it will deal with green roofs that serve visual interest. When using a variety of plants, it makes sense to use different design criteria as a guide for the finished design.

1.3 Plant Establishment Methods

There are many options when selecting the way plants are installed on a green roof. Each of these methods provides different opportunities. The greatest success rate may come from using a variety of planting methods (Dunnett *et al.* 2011).

1.3.1 Pregrown Vegetation Mats

Pregrown vegetated mats are the fastest method to create results on a vegetated roof (Dunnett *et al.* 2011). Vegetated mats come in a variety of species and types. They can either be cut into portable crate sized sections or rolled onto the roof. For this to be successful, there must be appropriate substrate depth and water available during the establishment periods. After the mat is in place, other methods of installing the vegetation can be used.

1.3.2 Plant plugs

Using planting plugs is desirable, when a more finished look is necessary. Plugs are sold pregrown in trays, consisting of a compost growing medium (Dunnett *et al.* 2011). If using pregrown vegetation is out of the budget, cuttings can be used.

1.3.3 Cuttings

Cuttings are the least expensive way of propagating green roof plants. This method is used when cost is a major factor (Kohler 2006). *Sedum* species are easy to clone, making them ideal candidates for this method of establishment. In some cases, it is as simple as removing leaves and stems from surrounding *Sedum* plants and broadcasting them over the roof (Dunnett *et al.* 2011). Another strategy to increase the vegetation cover on a green roof is to use seeds.

1.3.4 Seeding

It is important to take into account the time of year when seeding a roof. For the highest yield, a roof should be seeded in the fall to late winter, or sometimes in the spring (Dunnett *et al.* 2011). Broadcasting a variety of seeds atop a roof is one way to achieve a higher yield. Different plants have different requirements and seeds will germinate where conditions are most favorable. It is important for the seeds to remain moist. Broadcasting the seeds onto a moist substrate will provide for the greatest germination potential. Another influence on the germination rate is the substrate.

1.5 Substrate

There have been studies in the United States and Great Britain discussing substrate composition. According to a study performed in the United States, it is important to incorporate the right amount of organic material into the substrate mixture. This is because organic matter retains water (Nagase and Dunnett 2011). With an increase in organic matter, there will be an increase in moisture retention. Moisture retention is important for plants during the establishment period. However, too much moisture can also create problems.

It is possible, through decomposition, for the percentage of organic matter in the soil to increase. The issue of too much organic matter also arises during the establishment period. As long as there is water available, plants will continue to grow. This is not a problem, until drought. With increased biomass, there is an increase in water demand. Too much growth may cause the plant to overextend its available resources leading to plant failure. Nagase and Dunnett (2011) believe, for best performance, the substrate should only contain 10 percent organic matter. While organic matter increases water retention, drainage is also an important factor in the design of a substrate.

The drainage properties of a green roof can be influenced by the use of different substrate compositions. Manipulating the topography and texture may have a positive effect on biodiversity (Gedge and Kadas 2005). Before going further, it is important to step back and define the term biodiversity.

1.6 Biodiversity

Defining biodiversity is not an easy task. *The Oxford Dictionary of English* (2010) defines biodiversity as, "the variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable" (2010). An even shorter definition found in *The New Oxford American Dictionary* (Kindle 2005) which defines biodiversity as, "the variety of life in the world or in a particular habitat or ecosystem" (Kindle 2005). Both of these definitions only discuss one component of biodiversity. A more comprehensive definition is given by Paul Wood in his book, "Biodiversity and Democracy: Rethinking Society and Nature" (2000), which describes biodiversity at three levels: genetic diversity, species diversity, and ecosystem diversity, or "variety, number, frequency" (38). In *Biodiversity, Conservation, and Sustainable Development: Principles and Practices with Asian Examples*, the author Clem Tisdell (1999) also divides biodiversity into three parts: intra-species diversity, diversity of species, and ecosystem diversity (Tisdell 1999, 8).

In the article, "Defining Biodiversity," Don C. DeLong (1996) reviewed 85 articles that defined biodiversity. Delong found that instead of defining biodiversity themselves, the authors merely quoted other authors' definitions. In "Defining

Biodiversity," the author looks at biodiversity as defined by derivation, by classification, by listing characteristics, by comparison, and by operation. Delong concludes, "Biodiversity is an attribute of a site or area that consists of the variety within and among biotic communities, whether influenced by humans or not" (DeLong 1996, 745). This author continues by saying the definition depends on the audience.

It is important to discuss how this paper will use the term biodiversity. This paper is not concerned with the microfaunal diversity found in the soil (Brown *et al.* 2000) or genetic diversity, and will focus on species richness and ecosystem diversity. Using this definition, leads to further questions. Are there advantages and disadvantages to biodiversity?

1.6.1 Advantages of Biodiversity

According to the website Conservation for Biological Diversity, the year 2010 was the International Year of Biodiversity. There is growing interest in trends such as "biodiversity banking" and "ecobanking." From an economic standpoint, there are many advantages to incorporating biodiversity into the design of a green roof. According to Dr. Brad Bass, director of the *Ecological Design Workshop*, biodiversity reduces energy consumption and runoff, controls flooding and erosion, cleans water, contributes to pollination, provides green space, and contributes to tourism (*Ecological Design Workshop*). The performance of a green roof is also affected by biodiversity.

In its most basic form, the success of a green roof depends on its plant diversity. This is because different plants have evolved under different conditions. As conditions change over time, only certain species will survive. Although, biodiversity is usually considered good, there are some instances where biodiversity is not beneficial.

1.6.2 Disadvantages of Biodiversity

For the purposes of this paper, biodiversity is the variety or quantity of both species and ecosystems. Although diversity is important, some species are problematic for green roofs. There are at least four types of organisms considered problematic on green roofs, including; some birds, predators, weeds, and plant pests.

Some birds have been known to remove plugs while scavenging for food (Dunnett *et al.* 2011). This disrupts the substrate and may kill some or all of the vegetation. However, if birds are roosting on a roof, both mammalian and avian predators are undesirable. Animal predators are not the only unwanted organisms on the roof.

Weeds are a universal problem for most managed landscapes. Given that a weed is any unwanted plant, it is important to identify, before removing plants considered weeds. Management should be aware of seed mixes used and when invasive plants go to seed (Rousseau and Connelly 2011). Biotic factors that influence the success of plant health are also important.

Plant pests, which feed on vegetation, including mites, grasshoppers, and aphids, can be a nuisance. Although, the pests may be harmful to plants in the short term, they are also a source of food for many birds. If birds were able to forage on green roofs, this space could influence elements beyond the building and may contribute to local ecosystems.

This paper will next explore green roofs, which result in an increase of biodiversity. If biodiversity can be increased on green roofs, is there a next step? Can green roofs function for conservation in the District of Columbia?

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CHAPTER 2: PRECEDENT

In the article, "The Role of Extensive Green Roofs in Sustainable Development," Getter and Rowe conclude, "[g]reen roofs are one potential method to counteract the destruction of natural habitats as we further our built environment" (1283). What follows, is a look at exemplary green roofs.

2.1 Domestic Case Studies

In North America, there are many progressive living roofs. The green roofs below use different methods to achieve similar ends.

2.1.1 California Academy of Science

Completed in 2007, this 197,000 square foot living roof is located in Golden Gate Park, San Francisco, California (fig. 2.1.1). The undulating surrounding landscape influenced the design of this LEED Platinum building (Cantor 2008). The California Academy of Science's roof was originally planted with dozens of native species. As time went on, native species continue to be added making this, according the "Green Architecture Factsheet," currently the largest swath of native plants in all of San Francisco (Stone 2012). There are many other components of this project that make it worth documenting.

Figure 2.1.1 – "California Academy of Sciences," illustrated by Aurthor.

The substrate is contained in three-inch coconut bio-trays, which will disintegrate over time, to create a continuously uniform substrate. This living roof used 50,000 coconut husk trays filled with 1.7 million plants (Cantor 2008). Its designed topography forms hills and undulating mounds resulting in a variety of microclimates. The physical form of this living roof is not the only thing that makes it unique.

The fact that this building is an academic facility allows it to be studied. There have been citizen scientist programs, who have used this roof to collect data. These citizen scientists have documented “39 arthropod families and 38 bird species” (Stone). Knowing this roof is a functioning ecosystem may add to its value.

2.1.2 Ducks Unlimited National Headquarters

Completed in 1992, this 28,400 square foot roof (Cantor 2008) is located in Winnipeg, Manitoba, Canada (fig. 2.1.2). This building is the home of the Ducks Unlimited National Headquarters and Oak Hammock Marsh Interpretive Centre. This building is almost entirely covered with a prairie made up of native vegetation. Where it is not covered with prairie grasses, it serves as an observation deck, open to the public.

Figure 2.1.2 – “Ducks Unlimited National Headquarters,” illustrated by Author.

This roof was planted with the help of seed mixes, modeled from existing low, mid, and high prairies in the area. After the first year of weed management, four species of flowering perennials were planted for aesthetic purposes (Cantor 2008, 181). For the full plant list, see Appendix C.

The growing medium is derived from native soils composed of a sandy clay loam mix (Cantor 2008). Although in some areas, for berms and mounds, soils were used with a higher percentage of clay. Standard grasses were planted with a substrate depth of six inches, where prairie grasses were planted in soils of sixteen to twenty-four inches (Cantor 2008).

2.1.3 Ford River Rouge Truck Assembly Plant

Completed in 2003, this 454,000 square feet (10.4 acres) green roof is located in Dearborn, Michigan (fig. 2.1.3)(Coffman 2005). In 2004, this truck assembly plant was recognized as the largest green roof in the world. According to the Green Roofs for Healthy Cities website, this project was part of a revitalization project aimed at attracting wildlife, creating the first onsite vegetation for more than 90 years. The roof's membrane life is predicted to double because of the predominantly sedum vegetative cover (2007). The roof is planted with (see Appendix B) thirteen sedum species (Getter 2006, 1279). The substrate is about 1 inch thick, and can absorb 3.6 million gallons of water (98 percent of annual rainfall). This substrate rests on a water retention fleece, atop a drainage layer, which is resting on the root barrier (Cantor 2008, 196).

Figure 2.1.3 – "Ford River Rouge Truck Assembly Plant," illustrated by Author.

Although, this living roof uses strictly sedum species, it does create needed habitat. The roof was recorded by Coffman (2005) to have 29 insect species, seven spider species, and two bird species during one twelve month period about one year after the roof was completed (Peck 2010; Getter 2006, 1279). To compliment this new green space, Ford has situated a bee apiary, where honey can be produced and collected. This roof is within sight of the Visitor Center's observation tower, intended to enhance the public image of the Ford Assembly Plant ("Ford Plant" 2007).

These examples highlight living roofs in North America. They demonstrate the potential for green roofs to serve as educational platforms. These roofs, were examples of different types of green roofs and residual wildlife. These examples will influence the substrate composition and topography of the Design Conclusion, e.g., taller grasses should be planted in deeper substrate. When making an argument, frequently, there is a need to understand the context surrounding the situation. The next section will discuss other countries using green roofs.

2.2 International Case Studies

Other countries are leading the way by changing legislation. Below are examples of how Canada, the United Kingdom, Switzerland, and parts of the United States are incorporating sustainable design into future development.

2.2.1 Canada

Toronto is the first North American city to adopt a bylaw requiring green roofs to be installed on new buildings with flat roofs (Beatley 2011; Currie 2010). According to the Toronto Green Roof Construction Standards website, this took effect on January 31, 2010. This law is part of an initiative to help increase biodiversity in Toronto. In North America, Toronto may be the city taking the lead in protecting biodiversity.

A study titled, "Using Green Roofs to enhance Biodiversity in the City of Toronto," (2011) was published in April, of 2010. The authors suggest that green roofs can contribute to biodiversity (a) by connecting existing habitat, (b) by supporting edge habitat, and (c) by supporting conservation.

Green roofs are able to contribute to biodiversity by "connecting existing habitats." One way habitats could connect within a city is through the creation of many smaller island habitats on green roofs. This model of conservation is called the "stepping stone" model (Kim 2004, 191; Hopkins and Goodwin 2011, 45). If designed correctly, living roofs can be used by wildlife during migration and for feeding or roosting. This goal could be achieved by strategically placing food producing green roofs along specific flyways. The District of Columbia is located along the southern portion of the North Atlantic Flyway. Some birds travel to Canada, during the hot summer months, only to return during the winter season. Conversely, some birds travel south during the winter months as far as South America (Devries and Forys 2004; Youth 1999). Other opportunities include the support of edge habitats.

Vegetated roofs can “support edge habitats” by blurring existing edges. Growing native plants on rooftops can blend the gradient between the natural landscape and built environment. The goal would be to provide similar food and habitat on the roof as found in the surrounding landscape. If vegetated roofs can be used for habitat creation, there is potential for the use of vegetated roofs to serve as habitat conservation.

Vegetated roofs are an opportunity to support “conservation.” In many parts of the world, there are habitats , which are similar to those that exist on green roofs. These “habitat templates” are similar to natural analogs found in rock outcroppings, cliffs, and barrens (Lundholm 2006; Coffman 2007). Although these habitats are being lost, green roofs offer opportunities to preserve these habitats. This can be done by recreating specific habitat on a roof.

Habitat analogs are more than just shared physical characteristics. These landscapes may serve as green roof design precedent. Toronto may be leading the way in North America, but can learn from the United Kingdom, where green roofs achieve conservations ends.

2.2.2 United Kingdom

In the article, “. . . From Rubble to Redstarts . . .’ the author, Dusty Gedge (2003), discusses the importance of green roofs in future development. In London, the black redstart is a bird that roosts in postindustrial vacant lots (Gedge 2006). It was thought, as redevelopment continued, the number of black redstarts would decline. This was the trend, until a regeneration project began in Deptford Creek in 1997.

Deptford Creek is located in Southeast London, which was valuable real estate, ideal for development. This site was also a brownfield with two nesting black redstarts. Although this bird was a protected species in the United Kingdom, at this point nothing could stop development. Designers began to formulate a solution.

The concept was to take the required habitat of the black redstart and elevate it to the roof. There was much apprehension, because this had never been done in the United Kingdom. As discussion continued, concerns remained about how to maximize the surface area of the roof. The solution was to vary the depth of the substrate, thereby increasing surface area (Gedge 2003).

Through the use of a brown roof, the designers were able to incorporate black redstart habitat into the design. Gedge (2003) claims that the Black Redstart Action Plan has played an important role in creating public awareness. This has led to an increase popularity of green roofs in London. The Black Redstart Action Plan was the creation of the London Biodiversity Partnership, which supported the conservation of the black redstart. This was achieved by recreating its habitat, on what is called a brown roof, and brings promise that future development does not mean a decline in biodiversity. This project was influenced by work done by Stephen Brenneisen, in Switzerland (Gedge 2003).

2.2.3 Switzerland

In Switzerland, black redstarts had been seen foraging on green roofs which led to an amendment to construction law in Basel, Switzerland (Brenneisen 2005). This amendment requires green roofs to be reviewed before construction. This review process is to ensure the designs achieve improved habitat goals (Coffman 2009, 76). These habitat goals influence the design in two ways: by varying substrate thickness and by requiring the use of the site's soil as a substrate amendments.

The former guideline was confirmed by observations made between two green roofs. It was shown that increased biodiversity was linked to an increase in substrate thickness. Conclusions were made by looking at two roofs, one with uniform substrate thickness, and the other with varied substrate thickness. For this experiment there was a greater change-over-time on the green roof that used varying substrate thickness (Brenneisen, 2003). That is, there was more biodiversity on green roofs that used changing substrate thickness than on green roofs with uniform substrate thickness.

The later recommendation was the result of a study showing the importance of using organic substrates on green roofs. After the redesign of a hospital in Switzerland, there was greater success after local soils were used as an amendment (Brenneisen, 2003).

2.2.4 The United States

In Seattle, the Green Factor requires developers of commercial buildings greater than 4,000 square feet to implement appropriate sustainable landscape measures (Beatley 2011). In San Francisco, the Planning Department has published the "Standards for Bird-Safe Buildings" (Olague *et al.* 2011). This document is similar to one published on the East Coast. In New York City, the Audubon Society in partnership with the American Bird Conservancy has published, "Bird-Friendly Building Design" (2011), which discusses ways to design for, and protect urban avian species. The above literature may have influenced the building rating system, Leadership in Energy and Environmental Design (LEED).

2.2.4.1 Leadership in Energy and Environmental Design

According to the "LEED Pilot Program Library," LEED now allows for the Pilot Credit 55: SS – Bird Collision Deterrence, to be "available for current project use" (2012). This is important for the Washington DC Area because they relate to the High Performance Act.

According to the "LEED Initiative in Governments and Schools" (2010), published by the U.S. Green Building Council, "On April 24, 2008, Governor O'Malley signed the High Performance Building Act into law, requiring all new public construction and major renovation projects of 7,500 sq ft or greater, and intended for occupation, to earn LEED Silver certification" (10). In order to achieve this end, green roofs play an important role.

Green roofs play a significant role in the LEED building rating system because of the many benefits green roofs provide. Green roofs are able to contribute to as many as 15 LEED Credits (Getter and Rowe 2006) under Sustainable Sites, Water Efficiency, and Energy and Atmosphere (Sale 2011). There are also five Credits potentially available under Innovations in Design (USGBC: LEED for New Construction).

The Innovation in Design portion of LEED enables credits to be given for sustainable practices that are not covered by other credits (USGBG: LEED for New Construction). Currently, LEED only deals with biodiversity in the Sustainable Sites (SS) Credit 5.2: Site Development—Maximize Open Space. This credit only deals with the building site, and not the roof. The fact that LEED puts a value on biodiversity increases the likelihood of earning Innovation in Design Credits for incorporating biodiversity into the green roof design.

The above examples demonstrate, the influence citizens can play in changing legislation. Research can be strong foundation for green roof advocates to pursue conservation ends. This is important because working with legislation will result in the greatest influence.

CHAPTER 3: DESIGN STRATEGIES

Regardless of the intent, vegetated roofs positively influence biodiversity. However, there are many ways a green roof design can maximize the potential for biodiversity. Below are some principles taken from the book entitled, "Small Green Roofs: Low-Tech Options for Greener Living," by Nigel Dunnett *et al*. (2011).

3.1 Vary the depth of the substrate

An increase in microclimates and ecosystem diversity is created by incorporating mounds, berms, and depressions into the layout of a roof (Gedge and Kadas 2005). Mounds also increase the surface area (Gedge 2003) of a roof which may allow for greater water retention. These mounds or drifts can be created from different materials or substrates.

3.2 Use Different Substrates

Using different textures of soil, including but not limited to soil, sand, gravel, and crushed stone, allows for increased diversity. Using different substrates to create different growing conditions is one potential benefit of varying the texture of a substrate. Green roof plants have evolved under different environmental conditions. By using different soil types, it would be possible to mimic the native habitat with which these species have evolved. Using different substrates with varying colors will also help chicks and eggs to blend into their surroundings more effectively.

Amending green roof substrates with soil found onsite might increase plant success. The green roof on the University of Basil Library supports this statement. The first roof was installed in the 1980's. After failing in the late 1990's, the roof was reseeded with a substrate of local clay, topsoil, and compost. This roof has been much more successful (Brenneisen 2003; "Greenroofs.com Projects - University Library Basel").

3.3 Provide a Diversity of Plants

From an economic standpoint, using a diverse plant pallet will help prevent plant failure. As average rainfall and changing temperatures provide for optimal conditions for certain species (Kohler 2006), some will be able to survive while others will perish. Increasing the number of species in a given design may increase plant success (Nagase and Dunnett 2010).

Plants provide benefits and influence elements beyond the building's property line. From an ecological standpoint, designers are able to use approaches also used by the conservation sciences (Benneisen 2006), to positively influence the quality of surrounding habitats. Plants are the first trophic level which influences species higher on the food chain (Tallamy 2009).

Douglas W. Tallamy (2009) states that plants "form the first trophic level: the energy that sustains all life" (20). Tallamy goes on to state, "the diversity of animals in a particular habitat is very closely linked to the diversity of the plants in that habitat" (20). This is because plants and animals have evolved together and depend on each other for food and protection. Insects and arthropods, which have more protein than beef, contribute to the diet of around 96 percent of all birds in North America (Tallamy 2009, 21, 24). While it is important to use different plants for the design, it is also important to vary implementation strategies. When using a variety of plants, the composition or style is also important.

3.3.1 Planting Styles

The design intent is the most influential factor in a green roof's design. There are many green roof styles, all influenced by the aims of the project (Cantor 2008).

3.3.1.1 Simple Mixture and Monoculture

When price is the driving factor, uniform *Sedum* green roofs are the lightest, simplest, and most inexpensive to install and maintain. An example of this type of green roof is found on the Ford Assembly Plant. This roof may only consist of *Sedum* species but this does not make it a monoculture. A truly monoculture roof would be one made up entirely of single species of grass or sod. Using a lawn as a vegetated roof is the most labor intensive form of green roof (Dunnett *et al.* 2011).

3.3.1.2 Patterns, Blocks, and Drifts

When the green roof can be seen from above, there is an aesthetic opportunity. When this is the case, using patterns, blocks, and drifts is a desirable approach. According to *Professional Planting Design: An Architectural and Horticultural Approach for Creating Mixed Bed Plantings*, Scott C. Scarfone states blocking is used during the conceptual phase of the design process (2007). During this phase, plants are represented as geometric shapes, which represent the plant's form. These geometric forms can then be organized into some rational pattern using repetition or some other theme.

Creating masses of a single type of plant can be described as a drift. Scarfone mentions using drifts to group plants into drifts according to form, texture, or color. Using drifts allows for the designer to organize the landscape in a similar way a painter organizes a canvas (Scarfore 2007) However, sometimes there are different ascetic requirements.

3.3.1.3 Complex Mixtures

When aesthetics and cost are both a factor, this design strategy can be used because it has fewer maintenance requirements (Dunnett *et al.* 2011, 62). Clustering nectar sources together may perform conservation benefits when designing for habitat (Ley 2012).

3.3.1.4 Meadows

When aesthetics and conservation are the goal, meadows provide a viable design option. Meadows are visually interesting because they are reminiscent of pastoral landscapes. These meadow landscapes provide many roosting locations and food sources for seed eating birds. A meadow can be established with the use of seed mixes complimented with accent plants (Dunnett *et al.* 2011), like that of the Ducks Unlimited Headquarters. This is also an example of using different plant establishment methods.

3.4 Use Different Plant Establishment Methods

It is important to use assorted establishment methods when there are a variety of goals. When there is a desired aesthetic, plugs are important to use for accent plants. Plugs help to give the roof a more finished appearance right from the start. If plugs are used, roofs may also be overseeded for greater vegetation cover. Using bulbs is a less expensive alternative while still providing initial interest and pollen sources for wildlife. The California Academy of Science continues to add native species to its roof, increasing the roof's habitat value. There are also examples of roofs that have been naturally colonized like the sand filtration plant in Moos, Zürich. This concrete building constructed in 1914, is home to over 175 different plant species, some of which are rare or endangered (Brenneisen 2005; Coffman 2009; Werthmann 2007).

3.5 Provide Other Structural Features

Providing elements such as rocks, mounds (Coffman 2009, 75), logs, and other debris, can influence plant success, create interest, and provide for nesting opportunities. In his book published by the National Wildlife Federation, David Mizejewski calls them "human-made cover" in the form of brush piles. These "wildlife brush shelters" (Munroe) create nodes of activity and create cooler temperatures. Allowing some plants to benefit from the shade these features provide (Dunnett *et al.* 2011). Water features may greatly increase the success of green roof habitat. In some cases it was the only reason a bird colony was successful (Jackson 1994). Incorporating certain elements like potted plants, or leaving small braches for nest cavity bees (Tonietto *et al*. 2011), may increase habitat value for insects.

3.6 Relate to the Surrounding Area

When designing a roofscape for increased biodiversity, it is important to incorporate external elements found within the site context. By understanding the climate, solar exposure, and surrounding ecosystems, designers are able to incorporate the needs of neighboring wildlife. By becoming familiar with the species that exist in the area, it is possible to provide for the needs of those species. Some insect species require host plants, while other species require food during life cycle changes. The next part of this document will discuss the design process.

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CHAPTER 4: DESIGNING FOR BIODIVERSITY

Traditionally, when a green roof is designed for the creation of habitat, it is called a "living roof." This was a term coined by Dusty Gedge, founder of livingroofs.com (Cantor 2008). While it is correct to describe the roofs created later in this chapter as living roofs, the term bioroof is more appropriate. In this case, "bio" is short for biodiversity. By putting the prefix bio before the word "roof," it makes it clear the intent of the roof is biodiversity, and may not strictly focus on stormwater management.

The design of a green roof, or bioroof, is similar to the design of any complex system (Cantor 2008). In chapter one of his book "Inquiry By Design," John Zeisel separates the design process into three parts: imaging, presenting, and testing.

After a strong foundation of research is in place, the first step in designing is what Zeisel calls imaging. Imaging or imagining is a way of going beyond the given components to realize their greater potential. Once a designer can see his or her design, it is time to put it down on paper in a step known as presenting.

Presenting can be done on trace paper with pen, pencil, marker, models, or photographs. The presenting process is a way of explaining the idea before it is evaluated. Sometimes the designer can evaluate while designing. This evaluation process is what Zeisel calls the testing stage.

The testing stage can be done alone, in groups, or as a formal presentation. The testing process gives an opportunity to revisit the design, with a critical eye, which provides the designer and client an opportunity to harmonize their hierarchy to achieve the desired ends (Zeisel 2006). Before this process can take place, a project site is needed.

Figure 4.1 – “U.S. Coast Guard Headquarters Building,” shown on the hillside site with ten-foot contour lines, illustrated by Author.

4.1 United States Coast Guard Headquarters Building

What follows is a conceptual design using four roofs to enhance biodiversity for conservation. The United States Coast Guard Headquarters Building (USCGH) (fig. 4.1) will serve as a template for the creation of four bioroofs, which will be designed for the least tern, the killdeer, the butterfly, and the bee.

The site for this project is the United States Coast Guard Headquarters (USCGH) building which is located in a part of the District of Columbia (fig. 4.2). The USCGH is located east of the Anacostia River in the District’s Anacostia neighborhood. This building, according to the U.S. Coast Guard Headquarters Project website, “represents one of the most ambitious green roofs ever attempted in the United States” (2010).

Andropogon Associates, Ltd, out of Philadelphia, Pennsylvania, was the designer for this project. The roof design mimics five ecoregions found in the area and consists entirely of native plants. This paper will discuss program goals, site analysis, and a design conclusion.

4.2 Identify Program Goals

During this first step, the designer is able to determine what the values are of the client, and what part of the design is most important to him or her. Finding the answers to who, what, when, where, and how the space will be used, is critical. The most significant objective, during this process, is to understand the goals of the project (Cantor 2008). This is because, if the intent is to create habitat, that will require different components, than to create an outdoor patio space.

This government project, must achieve at least a LEED Silver status. If the client is to achieve the highest credential, designing for biodiversity may play a significant role in achieving LEED Silver. This can be done through achieving one to five Innovation in Design credits ("USGBC: LEED for New Construction").

If the designers use creative means to achieve sustainable ends, designers may apply for Innovation in Design credits. These credits are in addition to the 15 credits mentioned before. These credits may mean the difference between achieving just Certified and achieving a Silver certification. To design for biodiversity an understanding of the site context is in order.

4.3 Site Analysis

Collecting site inventory is part of a site analysis. This includes understanding the building's surroundings, hardiness zones, shadow studies, and the characteristics of surrounding ecology. This project will focus on avian and pollinator species in the

District of Columbia

United States Coast Guard Headquarters

Figure 4.2 – "Site Context Map," showing the future site of USCGH building. By Author.

Anacostia and the surrounding area. Once the avian and pollinator species in the area have been identified, creating a list of the potential species is the next step. This list will help to target the species on which the final design will focus.

This list will consist of birds and pollinators located within the area of the project. Species will be crossed off if they do not live in the area, are a liability, or do not come from a habitats previously mentioned.

While selecting the final contenders, it is important to look at the habitat from which these species come. Selecting a species, which has evolved in a habitat similar to those present on a green roof, will allow it to be a habitat analog (Lundholm 2010). This will continue to narrow down the species list. The final contenders should be a species from a similar habitat analog, as those mentioned by Lundholm in his article, "Green Roofs and Facades: A Habitat Template Approach" (2006). Looking at analogs in Maryland and Virginia, one promising habitat type is the high shore.

Looking at coastal birds in the State of Maryland and the Commonwealth of Virginia, there are three preferred habitat types: Coastal Seabird Habitat, Coastal Wading Habitat, and Inland (Marshland) Waterbird Habitat (Johnston 2006). The location of this project is within the range of the Coastal Seabird Habitat in Maryland and Virginia, as well as the Inland Waterbird (Marshland) Habitat in Virginia. With the remaining species, it is important to see if the species have historically lived on roofs.

Through investigating "roof-nesting" bird species, three came to the fore—the least tern, the killdeer, and the black skimmer. Although, Maryland and Virginia are in the range of the black skimmer, this species does not come close enough to the project (O'Connell and Beck 2003) to be incorporated into the design. The former two birds are documented in the area (Baltimore Sun 1994; Youth 1999) and as a roof-nesting species (Akney and Hopkins 1985; Butcher *et al.* 2007; Coburn *et al.* 2001; Natural History 1994; Youth 1999). The next step was evaluating the final selected species.

4.3.1 Birds

Three birds in the Washington DC Area are of interest, the heron, the least tern (fig. 4.3), and the killdeer (fig. 4.4). For the heron, one requirement is close proximity—

within 10 miles—of wetland habitat (Funderburk 1991). There are many wetland sites near the United States Coast Guard Headquarters building including the Kenilworth Aquatic Gardens—five miles away, Roaches Run Waterfowl Sanctuary—two and a half miles away, and Dyke Marsh Wildlife Preserve—six miles away.

According to the book, *Habitat Requirements for Chesapeake Bay Living Resources* (1991), the little blue heron is in a "critical life stage" from April through the middle of October. The green-backed heron is also in this lifecycle faze from the middle of March to the middle of October. During this time, these birds are nesting and raising their young. Providing a food source for chicks during this time may be an important consideration. This Inland Waterbird is found in marshlands along the Anacostia River. Although this bird met all the other requirements, to the author's knowledge, there is no historic record of herons living on roofs. For this reason the heron will be eliminated. This is in contrast, to the volumes of data on roof-nesting least terns and the killdeer.

According to an article in the Florida Field Naturalist, it is common to see least terns (*S. a. antillarum*) nesting on flat gravel roofs in the Southeastern United States (DeVries and Forys 2004, 1). This claim is corroborated in the article, "Roof-top Selection by Least Terns in Pinellas County, Florida" (2006) which states, "[a]s many as 80 percent of Least Tern colonies in Florida are now found on roofs" (Fory and Borboen-Abrams 2006,

Figure 4.3 – "Least Tern," illustrated by Author.

502). This phenomenon is common. In Georgia for instance, 73 percent of breeding least tern pairs, nest on flat roofs (Youth 1999). Roof-nesting least terns have also been recorded in Alabama, Florida, Georgia, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, and Texas (Youth 1999). For the above reasons, the least tern will be included in this project.

Least tern chicks hatch between late June and early July (Erwin 1979, 112; Whittier 2006), whereas killdeer eggs hatch in June (Walebeck 1989). According to a *Maryland Birdlife* study, which looked at 37 roofs—from May 25 through August 4, 1987—finding six killdeer nests in the State of Maryland (1989), killdeer have a clutch size of four, and selects roofs with a lighter surface color. While there was not a percentage of success for these nests, this article did mention the need for chicks to leave the roof soon after hatching. This is because killdeer parents do not feed their young. Other articles discuss the needs of roof nesting birds.

Figure 4.4 – "Killdeer," illustrated by Author.

Using roofs for habitat may inadvertently lead to the creating of an ecological sink. In the article "Terns on Tar Beach," Jerome A. Jackson defines a sink as "a place attractive to wildlife, but one in which little, if any, successful reproduction can occur." To prevent this, the created habitat should provide some basic elements.

According to the article, "Green Roofs as a Habitat for Birds: A Review" (2010), a green roof needs four components to benefit birds: food, cover, water, and space. If these components are integrated into the design, it may increase the roof's potential for success as a habitat.

4.3.1.1 Food

Green roofs are able to provide food in the form of nectar, insects, spiders, and seeds (Fernandez-Canero and Gonzalez-Redondo 2010). In some cases, however, food present on the roof is not enough to feed newborn chicks. Tallamy argues that up to 96 percent of birds consume insects and a significant portion of this percentage is made up of young downy chicks. This may mean, that these chicks will benefit from attracting pollinators to their nesting area. As chicks forage for food on the roof, there are three potential hazards.

The first two hazards will result of a fall. Sometimes chicks fall from roofs, either by mistake, through drainage openings (Coburn *et al.* 2001), or on purpose during egress. When chicks are directed by a parent to jump from the roof (Walebeck 1989), if the landing is a hard surface, it may prove fatal (Ankney and Hopkins 1985). A soft landing is important for the safety of roof-nesting avian chicks.

Another hazard, also deals with a means of egress. Some roofs have parapets surrounding the entire roof. This is a problem because it does not allow young chicks to exit the roof. If chicks are not able to leave the roof, the young birds may not be able to get the nourishment they require, resulting in starvation.

4.3.1.2 Cover

Since roofs are extremely exposed environments, some form of cover is recommended. Cover is anything that can be used as protection from the sun, wind, precipitation, or can serve as a hiding place from predators (Mizejewski 2004).

Sometimes it can be as simple as using the right vegetation. Cover provides benefits for other species as well by offering a greater number of perches for insectivores, hiding locations for prey, or serving as a woody wildlife motel for insects (Mizejewski 2004, 65-74).

Cover provides many of the same functions on the roof as it would in a garden. Experiments were performed by Jerrod A. Butcher, using abiotic structures on roofs (Coburn *et al.* 2001; Butcher *et al.* 2007). Teepee structures were used to provide shade and serve as a safe haven for downy chicks. Although the teepee structures were innovative, they were not successful enough to be implemented on a large scale (Butcher *et al.* 2007). A simpler approach comes from Switzerland consisting of pipes, placed horizontally on the roof surface (Newton 2007, 157). These shading devices create hiding locations for young birds, where they can rest, out of reach from predators.

4.3.1.3 Water

Like all living organisms, birds and insects require water to survive. Viable sources of water on a green roof include irrigation, moisture retaining substrate (Fernandez-Coahero and Gonzolez-Redondo 2010), and HVAC condensate (Jackson 1994). Jackson (1994) discusses how condensate was used as a resource on the roof. Jackson describes how water would pool around the air-conditioners allowing for "Both chicks and adults [to] use this water for bathing and drinking" (Jackson 1994).

Water available in the surrounding area also played a role in the bird's choice of roof. Forys and Borboen-Abrams (2006) investigated over one hundred gravel roofs in Pinellas County, Florida and suggest that "the most important variable in predicting whether a rooftop has ever been occupied" (504) was its distance from a large body of water. The study indicated that buildings within one half mile of a body of water were more likely to have been be used by least terns.

4.3.1.4 Space

Each species will have varying degrees of specific requirements. Factors influencing these spatial requirements include population, available food, and available resources (Fernandez-Canero and Gonzalez-Redondo 2010). Discussed above were some of the criteria that will influence the design of two living roofs in this project. The other two roofs will target pollinators.

4.3.2 Pollinators

Studies have attributed an increase of insect populations to design factors (Brenneisen 2003; Coffman 2009; Kadas 2002) on green roofs. Both bees and butterflies will be discussed below.

4.3.2.1 Bees

Annually, domestic bees pollinate $10 billion worth of crops in the United States (Ley 2012). Bees are “the most important insect pollinator” (Borror 1970, 354) with more than 4,000 species native to the United States (Moisset and Buchmann 2012). The majority of these bees are solitary bees and nest, not in hives, but either in the ground or other natural cavity (Borror 1970, 354).

Studies have shown living roofs are able to provide appropriate habitat for bees (Colla *et al.* 2009). To target a specific species through design, it is important to use elements which are desirable to the targeted species. For example, Dusty Gedge recommends using a mixture of Sedum species, no fewer than ten, and each with varying bloom times (*Ecological Design Workshop*). Research has shown, with increased plant diversity, there is an increase of bee diversity (Tonietto *et al.* 2011). It is also important to locate blooming flowers close to one another (Tonietto *et al.* 2011) and to observe their flower structure (Ley 2012).

Flower structure is important because bees have different tongue sizes, and prefer different flower types. From "Selecting Plants for Pollinators: A Regional Guide for Farmers, Land Managers, and Gardeners in the Southeast Mixed Forest Province," the author Elizabeth L. Ley (2012), recommends using plants with shallow tubular flowers that provide landing platforms, like milkweed. The color of the flower is also important.

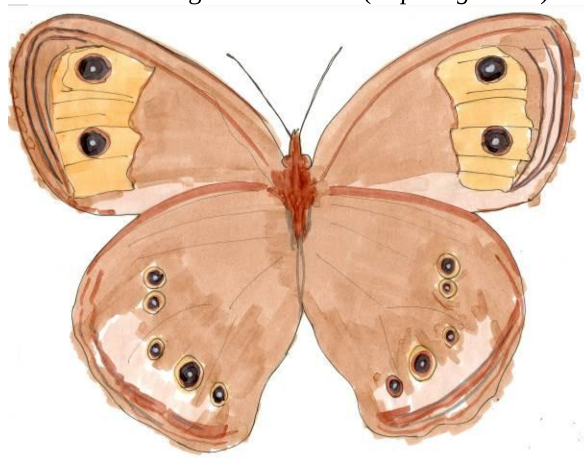
Bees can only see a specific wavelength of color, including bright white, yellow, and blue (Ley 2012). When designing a bioroof to target bee diversity, it is important to use harmonious plants that bloom in the above colors. Flowers should be in bloom between May through October, ideally throughout the year (Tonietto *et al*. 2011). Like butterflies, host plants are important for bees as well. After being evaluated, the following host plants will be incorporated into the design of the bioroof. Ground cherry is the host plant for *Colletes latitarsis*; *Cirsium* spp. and *Curcurbita* spp. (squash) which is the host plant for Peponapis (Tonietto *et al*. 2011).

The substrate is also worth considering when designing a bioroof to target bees. Using a substrate, which will allow bees to nest is possible (Colla *et al.* 2009). Including an area where the substrate can be used by ground nesting bees. Incorporating pollinators into the bioroof design will benefit both urban agriculture and aid in the creation of seeds. These seeds will help plants to reseed, and provide food for hungry wildlife (Colla *et al.* 2009). Although, bees may be the most important pollinator, bees are not the only pollinator this project will discuss.

4.3.2.2 Butterflies

This paper will focus on three butterfly species (fig. 4.5) which include the Eastern Tiger Swallowtail (*Papilio glaucus*) (host plants include wild cherry [*Prunus spp*.] and many others found in Appendix D), the Blue-eyed Grayling (*Cercyonis pegala*) (host plant is purple top grass [*Tridens flavus*]), and the Monarch (*Danaus plexippus*) (host plant is milkweed [*Asclepias*]). Green roofs demonstrate many characteristics of landscapes in early succession (Schrader and Böning 2006; Gedge and Kadas 2005). This is important because "[e]arly successional biotopes can accommodate high butterfly species richness in the urban environment" (Snep 2011, 247).

Eastern Tiger Swallowtail (*Papilio glaucus*).



Blue-eyed grayling (*Cercyonis pegala*).

Monarch butterfly (*Danaus plexippus*).

Figure 4.5 – "Butterflies," illustrated by Author.

Butterflies are in the order Lepidoptera and have four membranous wings and a coiled tube for a mouth (Borror 1970, 218). When designing for butterflies, it is important to use bright reds and purples because these are the colors they see best (Ley 2012). Adult Monarch butterflies have been seen in the area as they migrate north and south from April through June. These are the times when flowers should be in bloom to provide energy for the migrating insect (Journey North Interactive Map).

Butterflies enjoy surfaces that provide warm perches which heat up in the sun, like stones or gravel. The firm Cook and Fox Architects designed a successful butterfly green roof in New York City (*Ecological Design Workshop*). The design used a four-inch substrate, eight Sedum species, and a single wildflower (*Taliniuim calycinum*).

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CHAPTER 5: DESIGN CONCLUSIONS

Four roofs were selected to demonstrate how green roofs can be optimized for biodiversity . Two roofs will target two bird species, a third roof will target three butterfly species, and a final roof will target bees. The above species will be targeted through the use of specific design elements. The project's plant list includes native plants, which were deemed hardy enough to survive on a green roof. These plants were supplemented with species shown to be successful in the area (Appendix E) (Snodgrass 2006; Snodgrass 2012).

The plant list was arranged into a matrix organized by name, bloom season, bloom color, and height (Appendix E). Once this information was compiled, the plants were again labeled under their corresponding species, e.g., plants with a bloom color of white were categorized with bees and butterflies, because both of these species can see the color white (Ley 2012).

The first roof discussed is the roof selected for the least tern. Least terns must be located where their chicks have safe egress from the roof. The "Egress Diagram" shows this process (fig. 5.1). Having this as the most important factor in

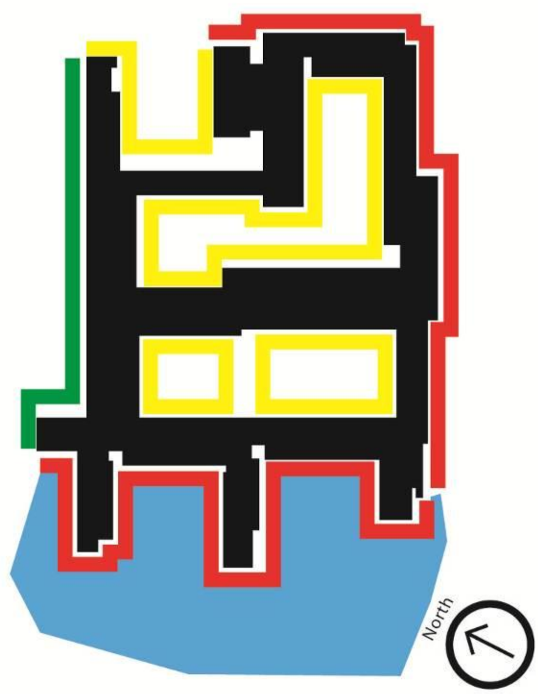

Figure 5.1 – "Egress Diagram," shows hard landings in red, enclosed spaces in yellow, and soft landings in green, illustrated by Author.

roof selection makes roofs located on the north exterior façade desirable. Another criterion is to provide a soft landing for chicks as they leave the roof. This further narrows down the selection, again making roofs on the northern façade most desirable. After selecting roof "P" (fig. 5.2) for the least tern, it is time to begin designing the surface of the roof. The roofscape design begins with the topography (fig. 5.1.5).

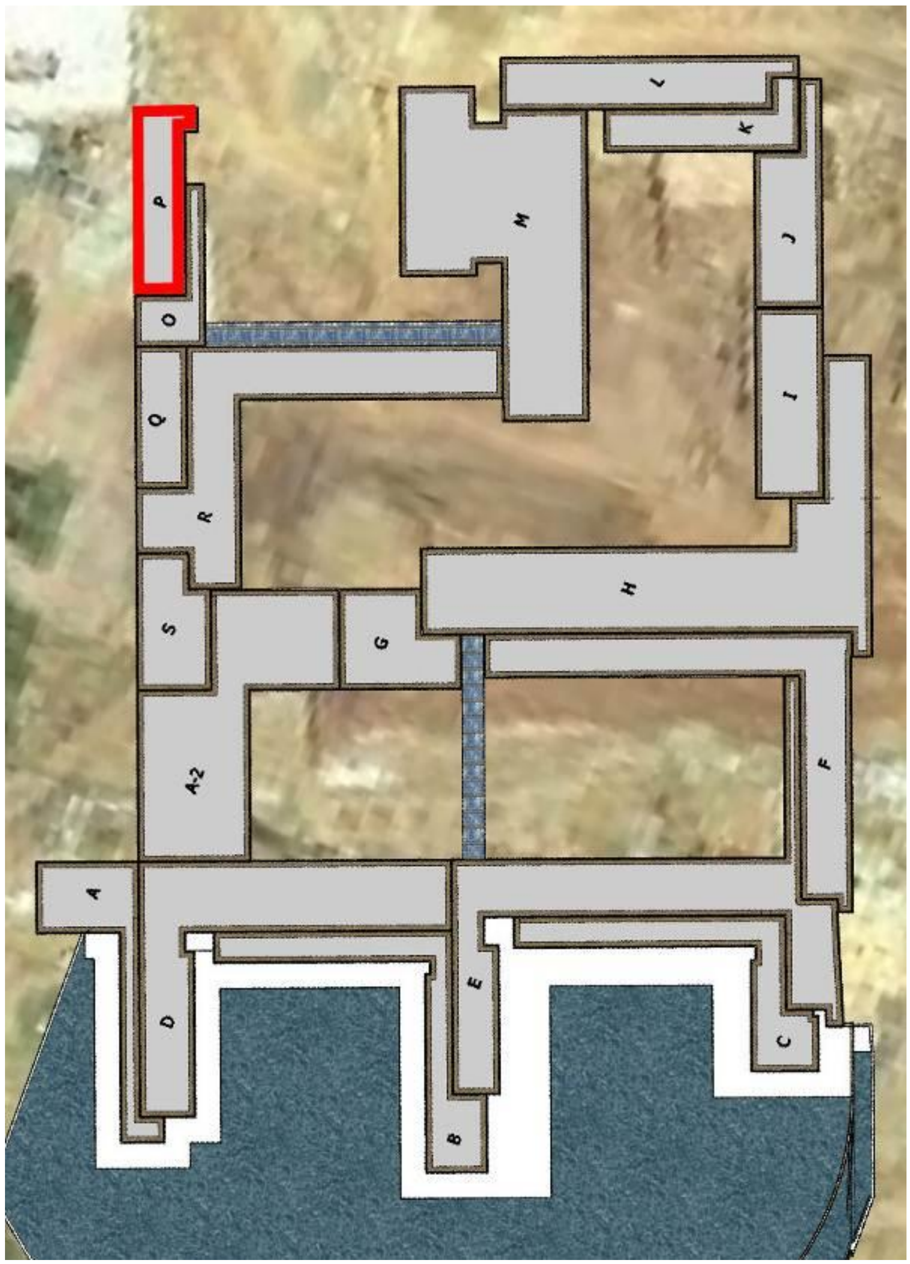

Figure 5.2 – "Roof Plan Layout," Roof P in upper left corner, illustrated by Author.

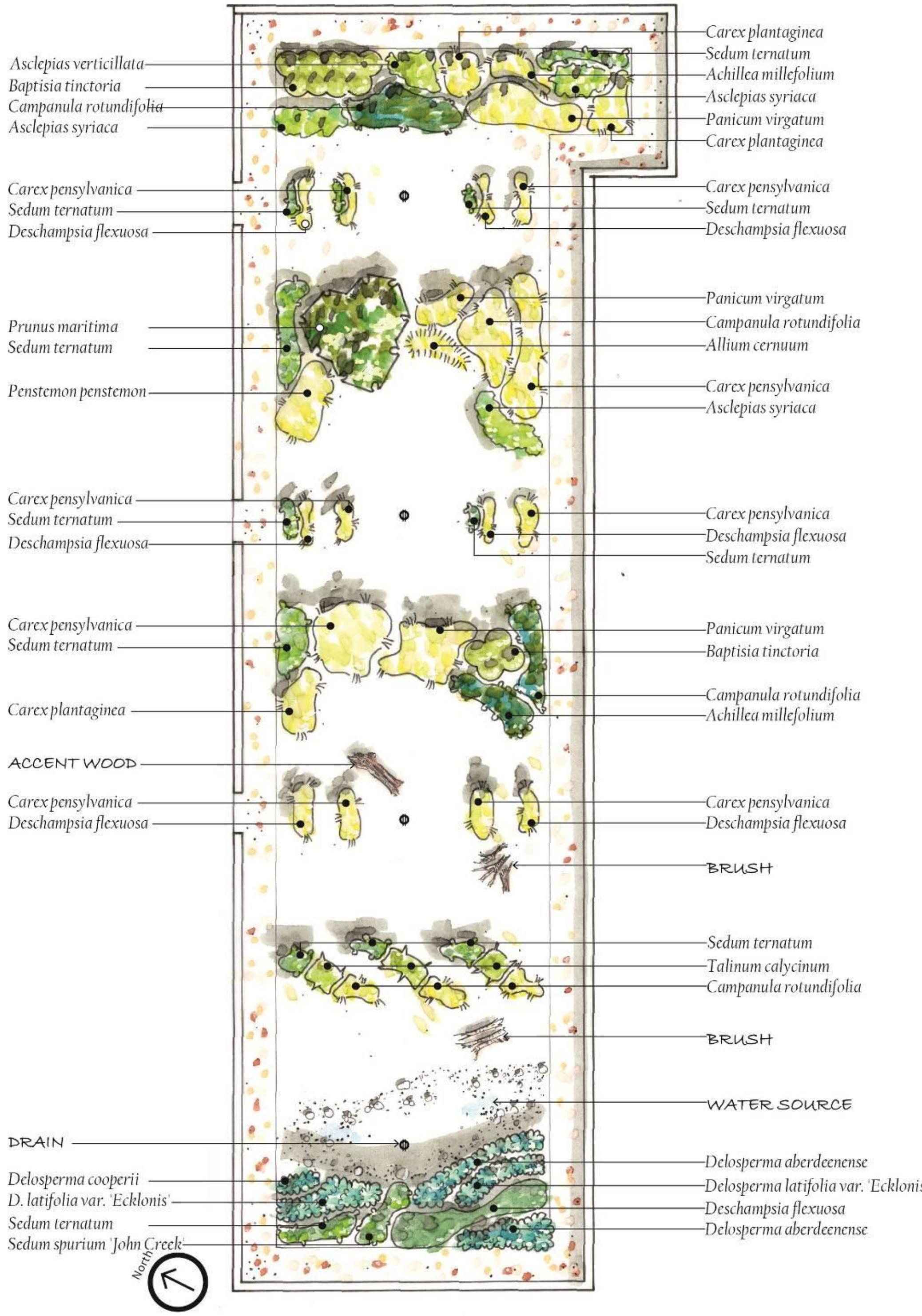

Figure 5.1.1 – "Least Tern Roof Plan," 6,000 square foot roof, designed with plants that bloom in June and July, illustrated by Author.

5.1 Roof One: Least Tern Roof

Figure 5.1.2 – "Least Tern Nest," illustrated by Author.

According to the article, "Least Tern Habitat Model," the least tern is a bird that prefers locations above the high tide line, along the shore of a water body. Mimicking these conditions on the roof may entice this species. The U.S. Fish and Wildlife Service declared that there were more nesting least terns on beaches with only twenty percent vegetative cover. Using this as a guide, and looking at the quantity of least terns nesting on flat roofs in Florida (DeVries and Fory 2004; Fisk 1975; Fory and Borboen-Abrams 2006) this seems to be a good recommendation.

The recommended color and texture of the substrate discussed in the article "Terns on Tar Beach," suggests using "pea-sized gravel" (1994) of varying color. This change in color helps eggs and chicks to blend into their surroundings. Like other shore birds, the eggs of the least tern have a speckled outer shell (fig. 4.1.2).

Figure 5.1.3 – "Least Tern Bird's Eye View," illustrated by Author.

After selecting the substrate, choosing the topography for the roof is the next step. This design is to mimic a high shore, with three dunes of varying size (fig. 5.1.3).

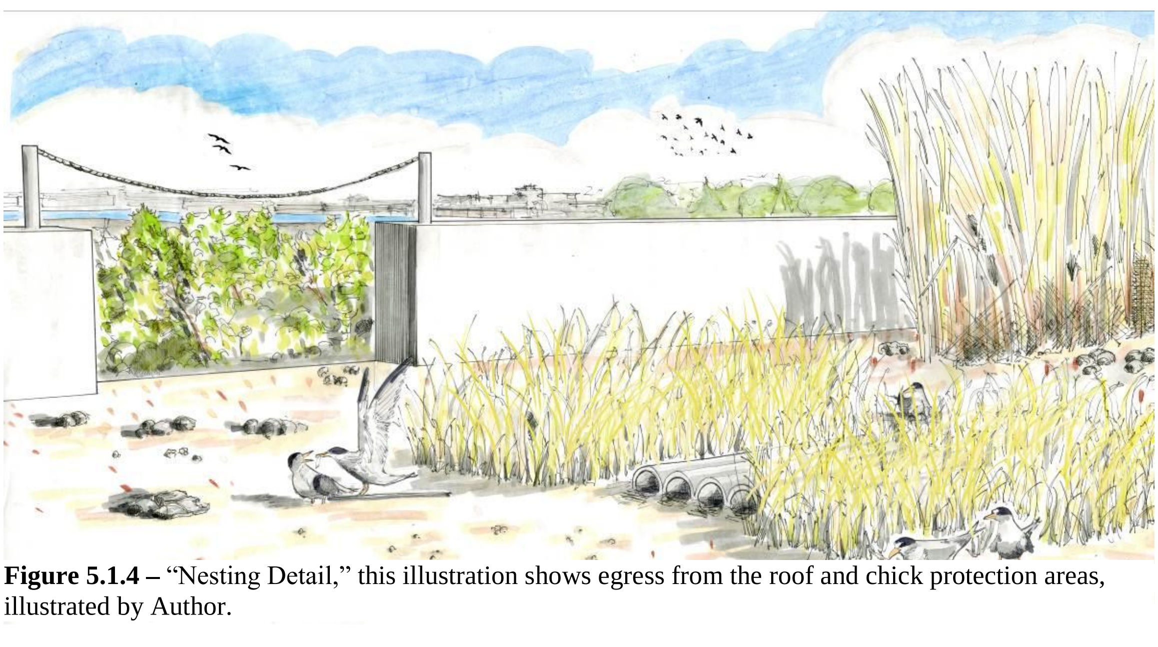

Figure 5.1.4 – "Nesting Detail," this illustration shows egress from the roof and chick protection areas, illustrated by Author.

The book, *Coastal Waterbird Colonies: Cape Elizabeth, Maine to Virginia*, (1979) discusses the life cycle of least terns on the Atlantic Coast. In the State of Maryland, least terns hatch in summer, peaking in June and July. Designing with this in mind, using a planting pallet that will bloom during this time, may provide a food source for young chicks, in the form of insects.

When the young chicks require food, there are three exit points found on the left of figure 5.1.5. When the parent least terns are out searching for food, there are locations where chicks are able to hide among the tall grasses or under the protective horizontal tubes (fig. 5.1.4). Just below the Least Tern Roof is the Butterfly Roof (fig. 5.2.1).

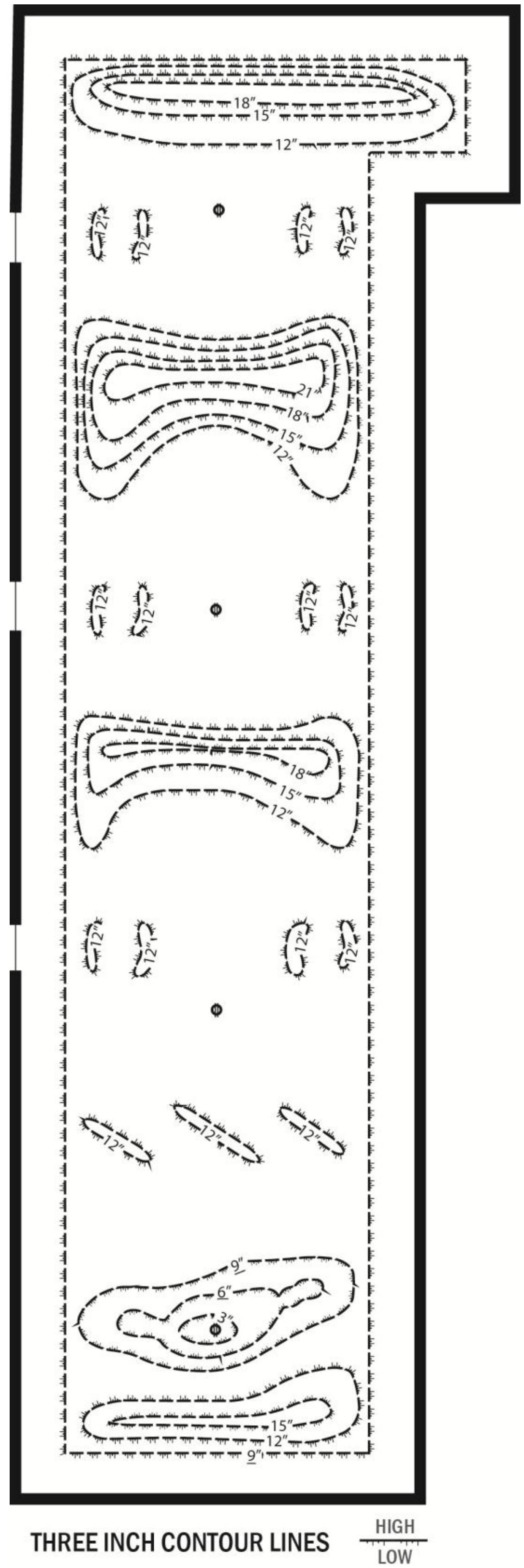

Figure 5.1.5 – “Least Tern Topography,” illustrated by Author.

5.2 Roof Two: The Butterfly Roof

The Butterfly Roof is one of the smaller roofs on the USCGH building. However, this roof allows for the greatest potential for wildlife encounters. The roof borders a glass curtain wall, which provides views from the office interior to the bioroof below.

This bioroof is organized into three seasons: spring, summer, and fall (fig.5.2.2). The spring portion of the roof is located on the eastern most part of the roofscape. Moving west along the roof, plants were selected which blend from a cool green and yellow spring color to a pink and white color during the summer. This roof was designed for three butterflies (fig. 4.6). Each of these butterflies require the host plants, discussed in section 4.3.2.2, to complete their life cycle. For this reason, after making sure these plants were not invasive, the host plants were integrated into the matrix (Appendix E). BlackRedstarts.org.uk website. Taking a closer look at the asymmetrical mounds (fig. 5.2.3) or drifts, the left slope of the drift is different from the right. The BlackRedstarts.org.uk website shows drifts that have one side at 17 degrees, and the other side at 30 degrees. Creating asymmetrical mounds will create different microclimates allowing for greater biodiversity. From the Butterfly Roof the Killdeer Roof—shown as roof "Q" in figure 5.2—can be seen below.

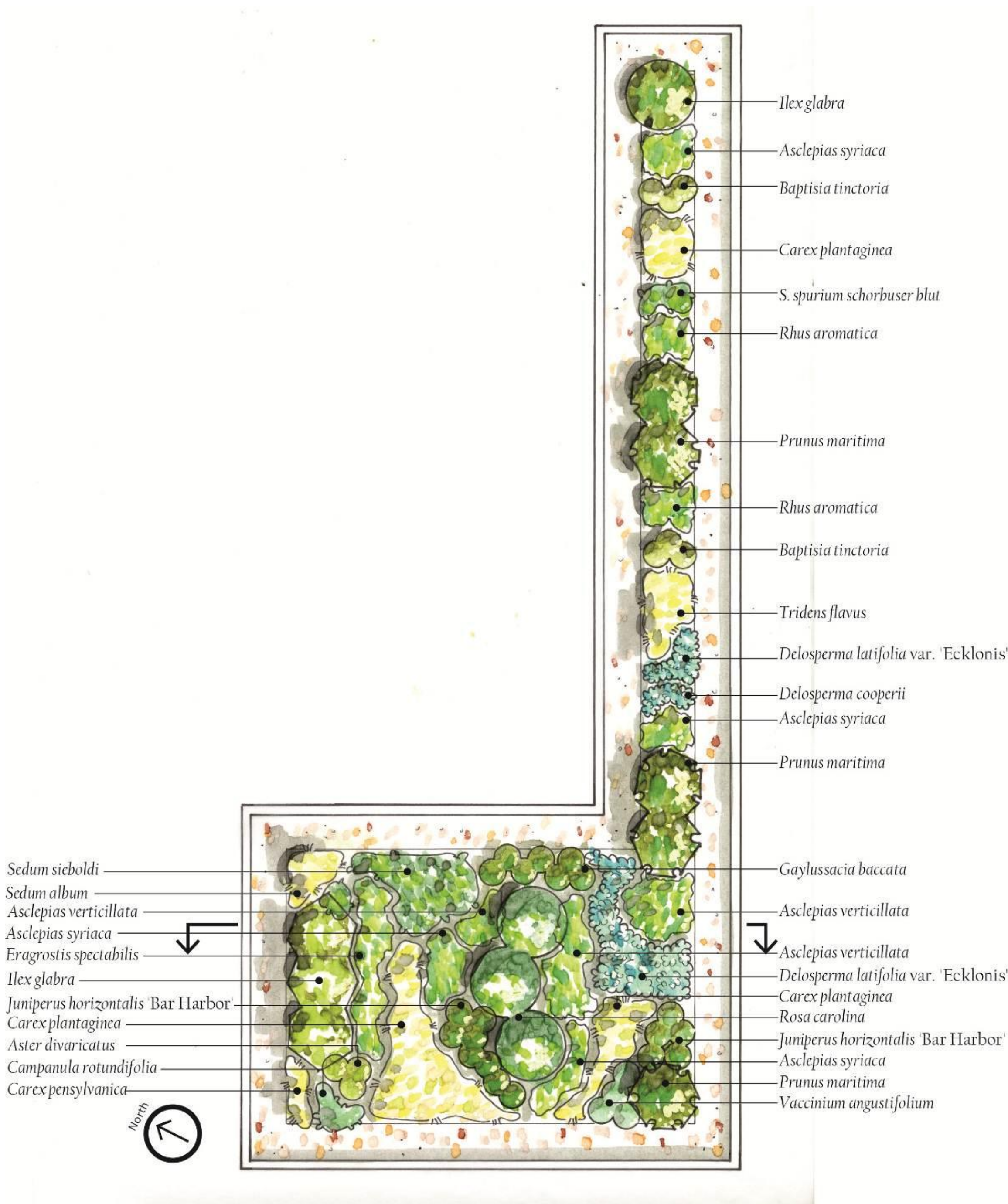

Figure 5.2.1 – "Butterfly Roof Planting Plan," 3,400 square feet, organized by season and color, illustrated by Author.

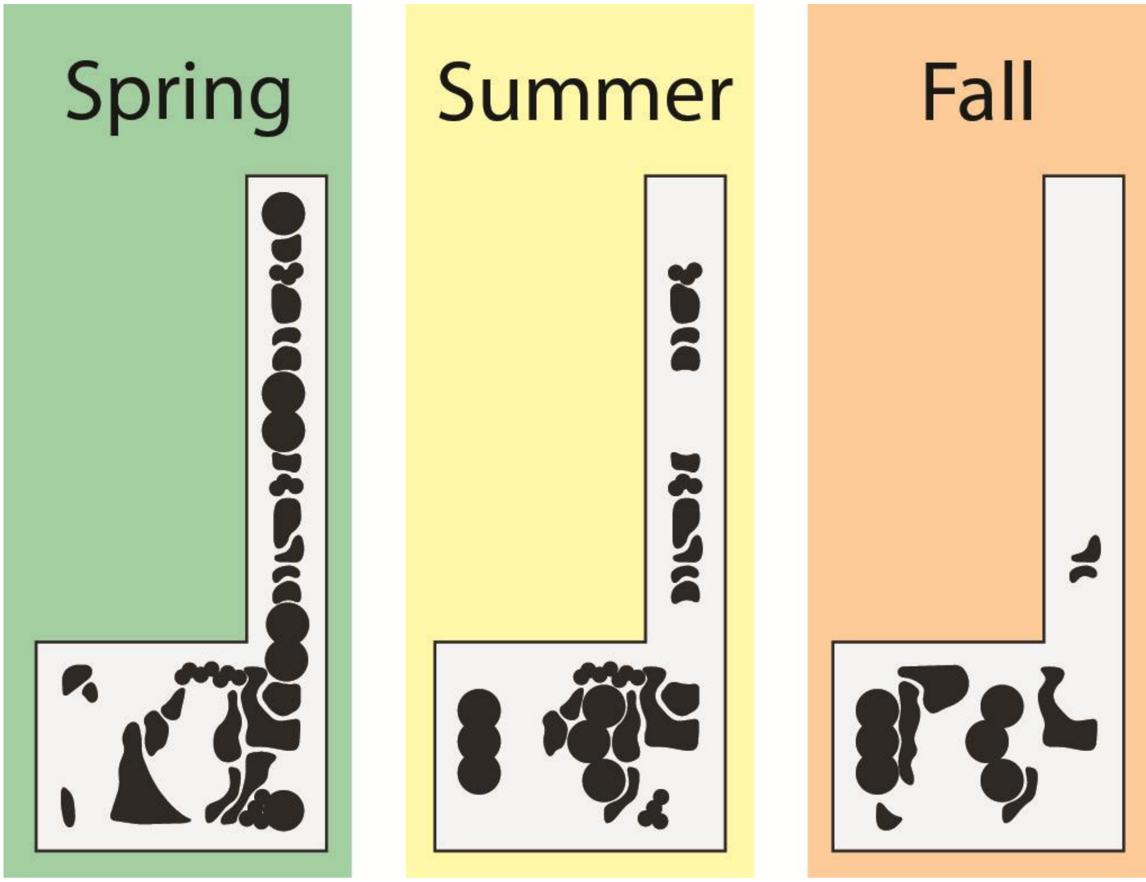

Figure 5.2.2 – "Butterfly Seasonal Bloom Diagram," illustrated by Author.

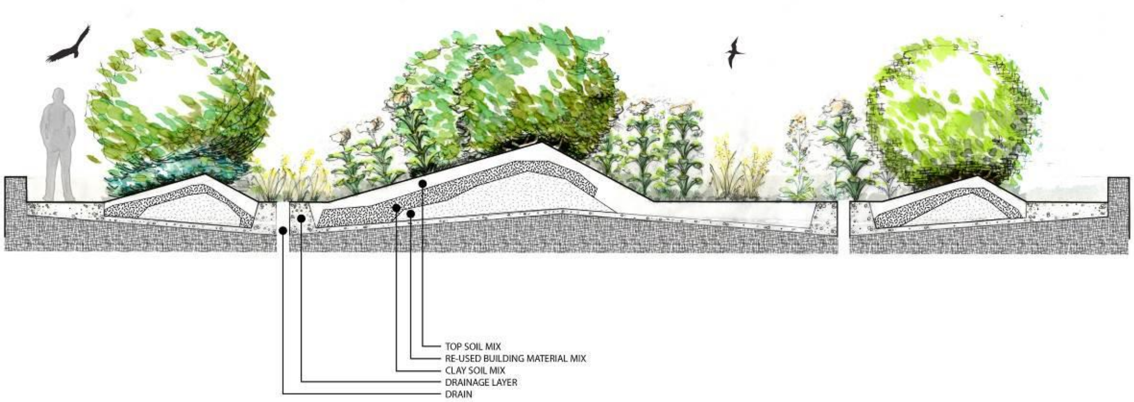

Figure 5.2.3 – "Butterfly Roof Section," showing the drain at the lowest point of the roof. The vegetation on the dunes act as wind-breaks which allow butterflies to forage, illustrated by Author.

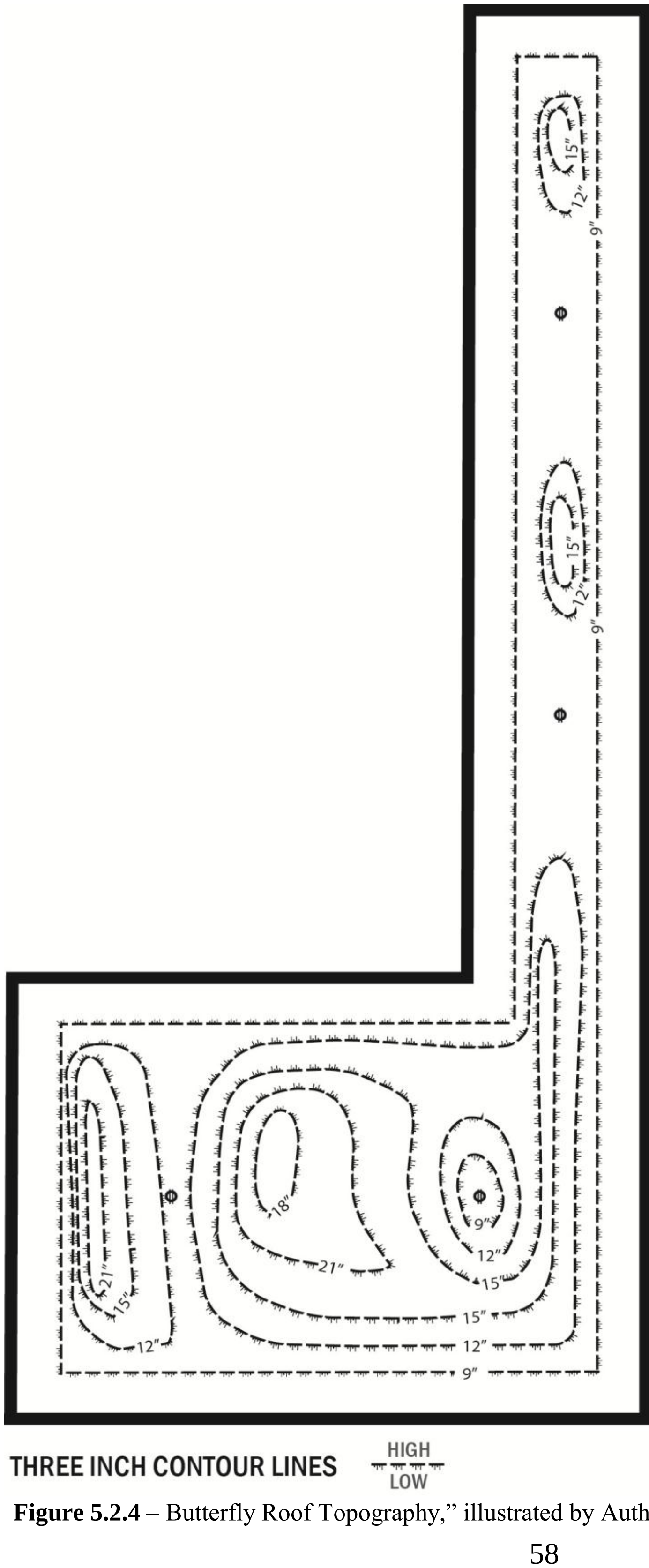

Figure 5.2.4 – Butterfly Roof Topography," illustrated by Author.

5.3 Roof Three: The Killdeer Roof

For the Killdeer Roof (fig. 5.3.1), many of the principles used for the Least Tern Roof, were employed on the Killdeer Roof. There is about a twenty percent vegetated cover, a water source, a similar substrate, and similar debris is used. The topography of this roof can be seen in figure 5.3.2. One difference between the Least Tern Roof and the Killdeer Roof is the visibility. The Least Tern Roof was not seen from above in the way the Killdeer Roof will be seen. For this reason, the Killdeer Roof was designed more with plants that provide seasonal interest.

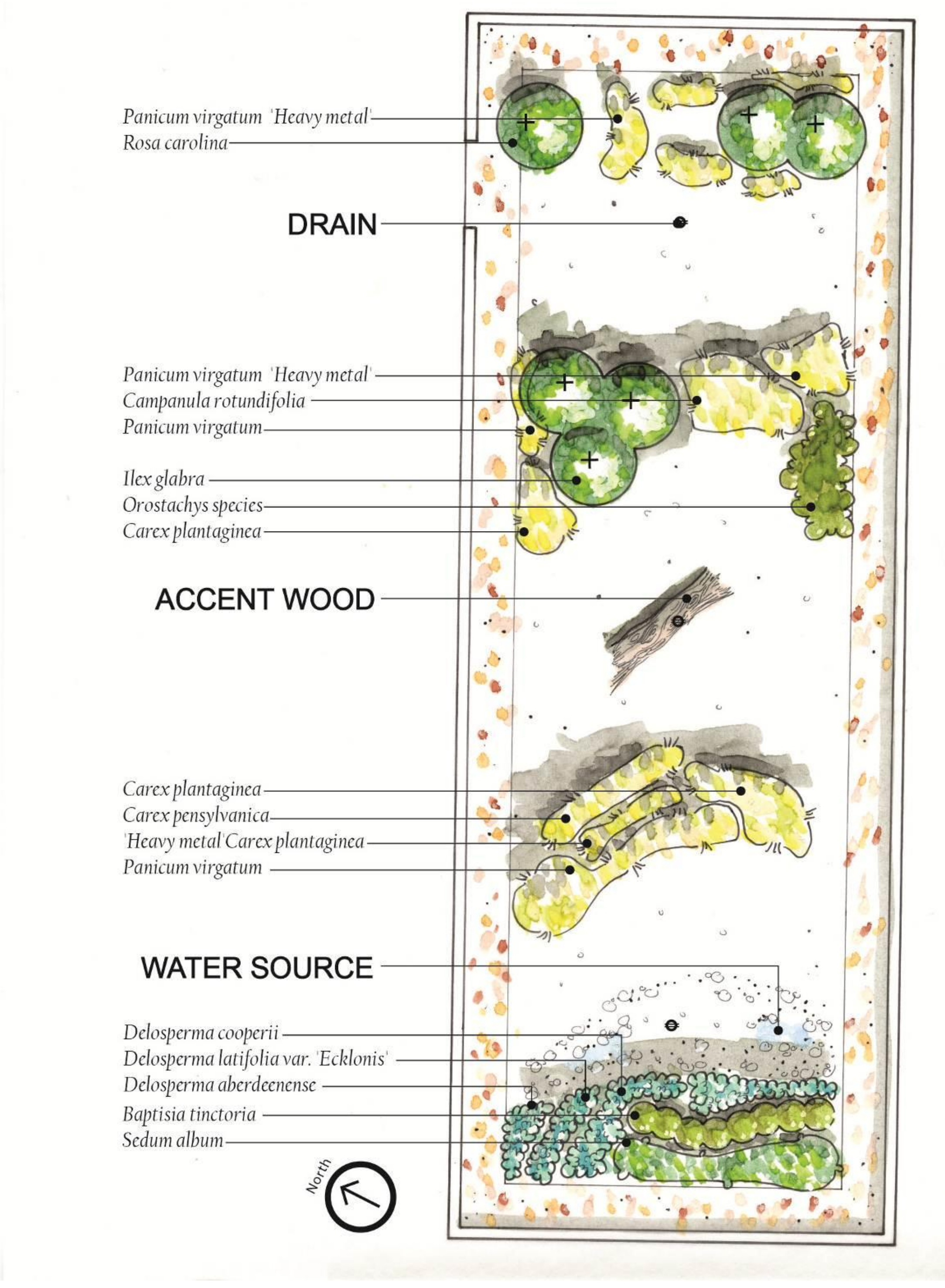

Figure 5.3.1 – "Killdeer Roof Plan," 4,400 square feet, illustrated by Author.

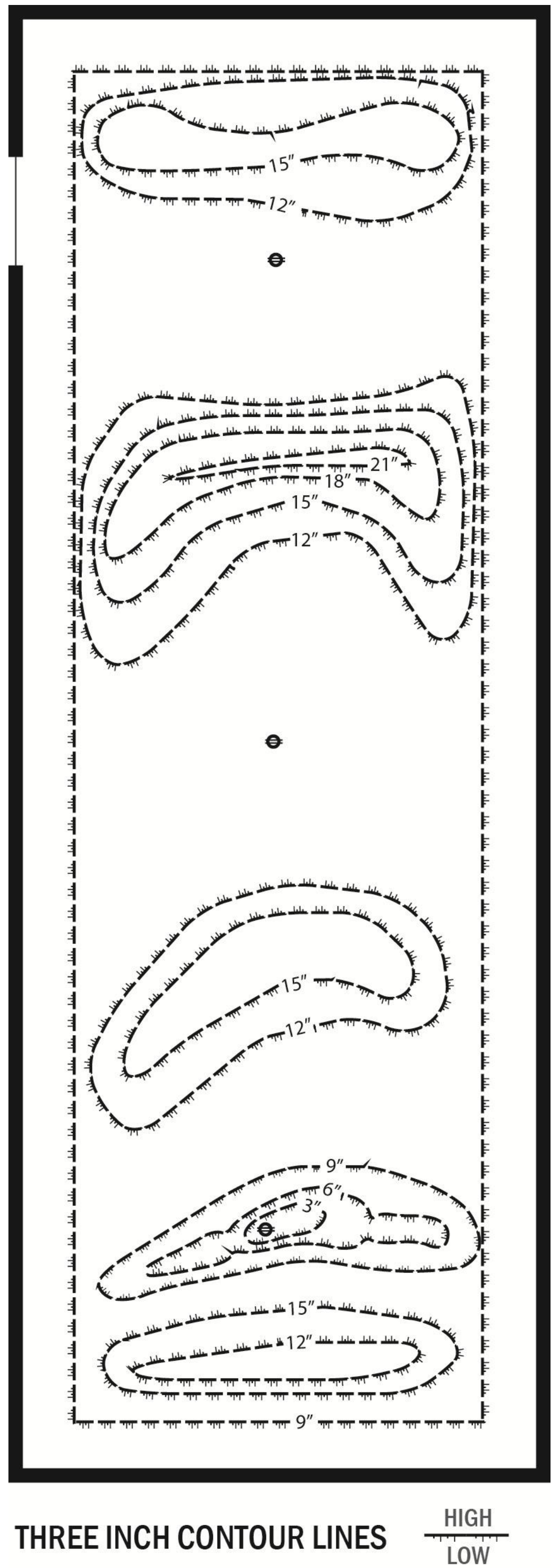

Figure 5.3.2 – “Killdeer Roof Topography,” illustrated by Author.

5.4 Roof Four: The Bee Roof

The final roof is the southernmost roof of the four. The Bee Roof, found in figure 5.4.1, has many elements desirable to native bees. Some of these elements include foraging opportunities, egg laying and nesting sites, hibernation and over wintering sites, and a habitat free from pesticides (Hunter and Hunter 2008). These elements are required for bees to complete their life cycle.

There are also some added elements—like a linear brush pile (fig. 5.4.5) and a bee nest box (fig. 5.4.6)—which may benefit certain bees. The topography of this roof is shown with three inch topography lines in figure 5.4.2.

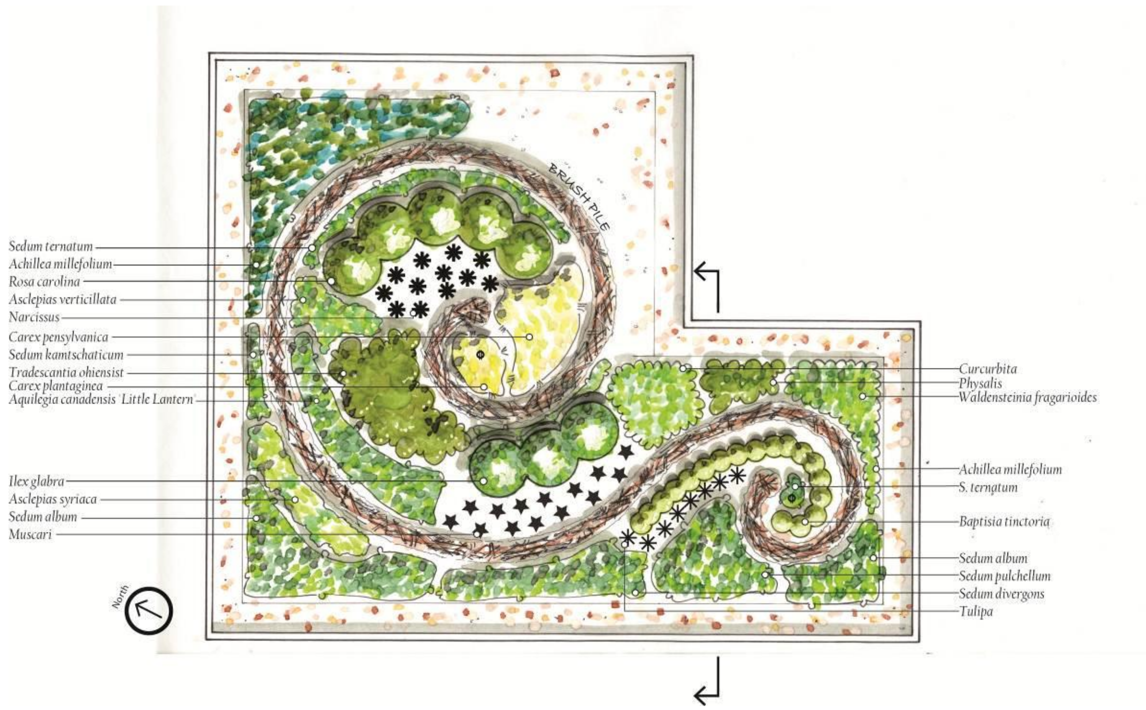

Figure 5.4.1 – "Bee Roof Plan," 6,300 square feet, illustrated by Author.

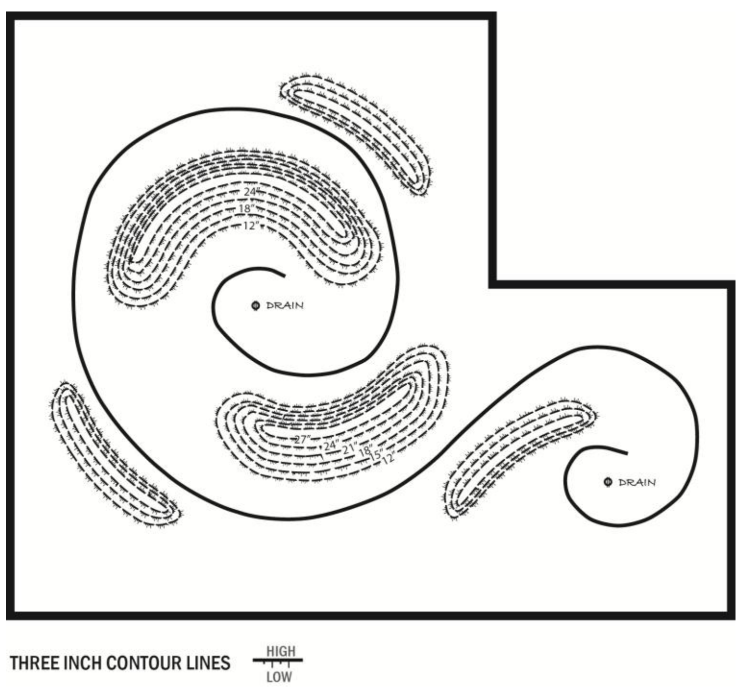

Figure 5.4.2 – "Bee Roof Topography," shows three-inch contour lines, illustrated by Author.

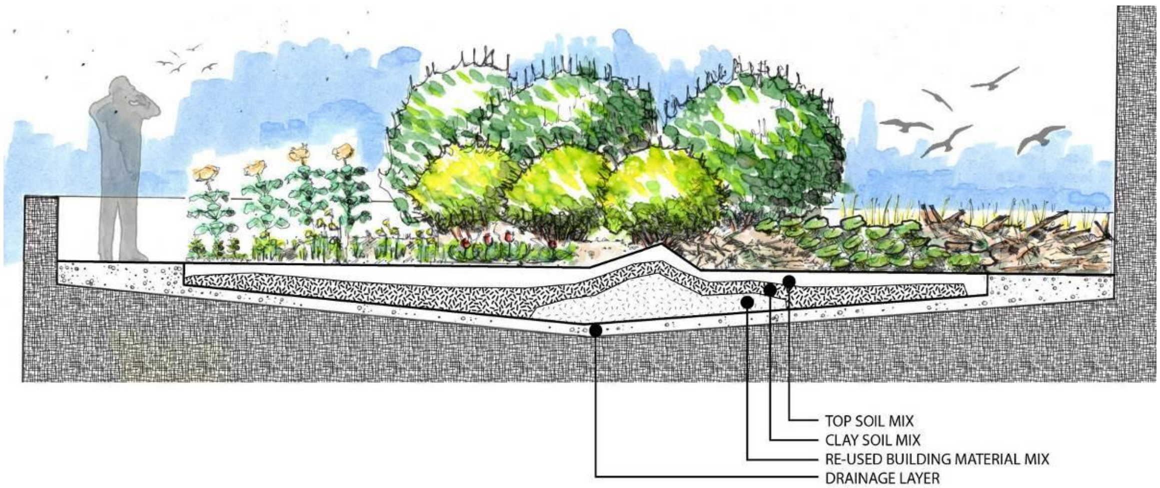

Figure 5.4.3 – "Bee Roof Section," shows the variety of substrates layered to form the topography, illustrated by Author.

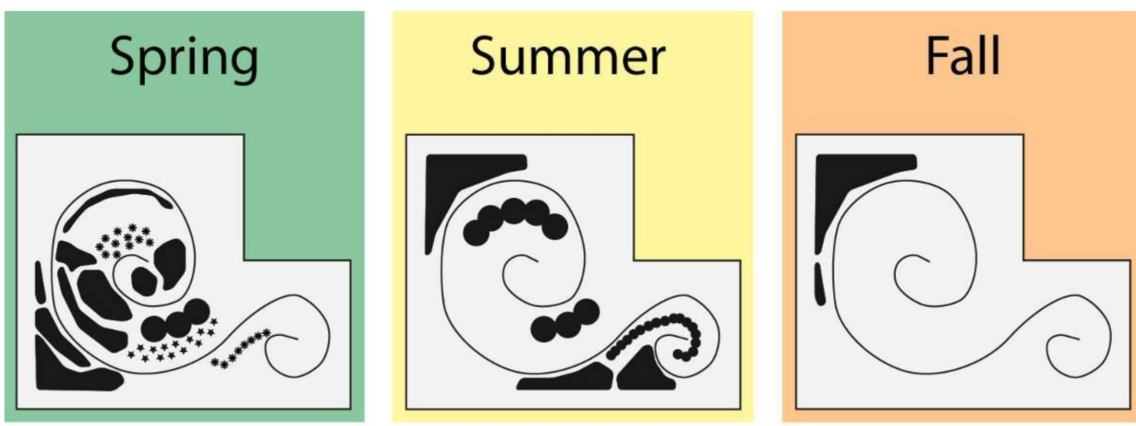

Figure 5.4.4 – "Bee Seasonal Bloom Diagram," which shows the sequence of blooming plants from spring through fall, illustrated by Author.

Figure 5.4.5 – “Brush Pile,” measuring about ten feet wide by five feet tall, constructed with branches and stems on larger logs, on a stone pile foundation (Munroe**)**, illustrated by Author.

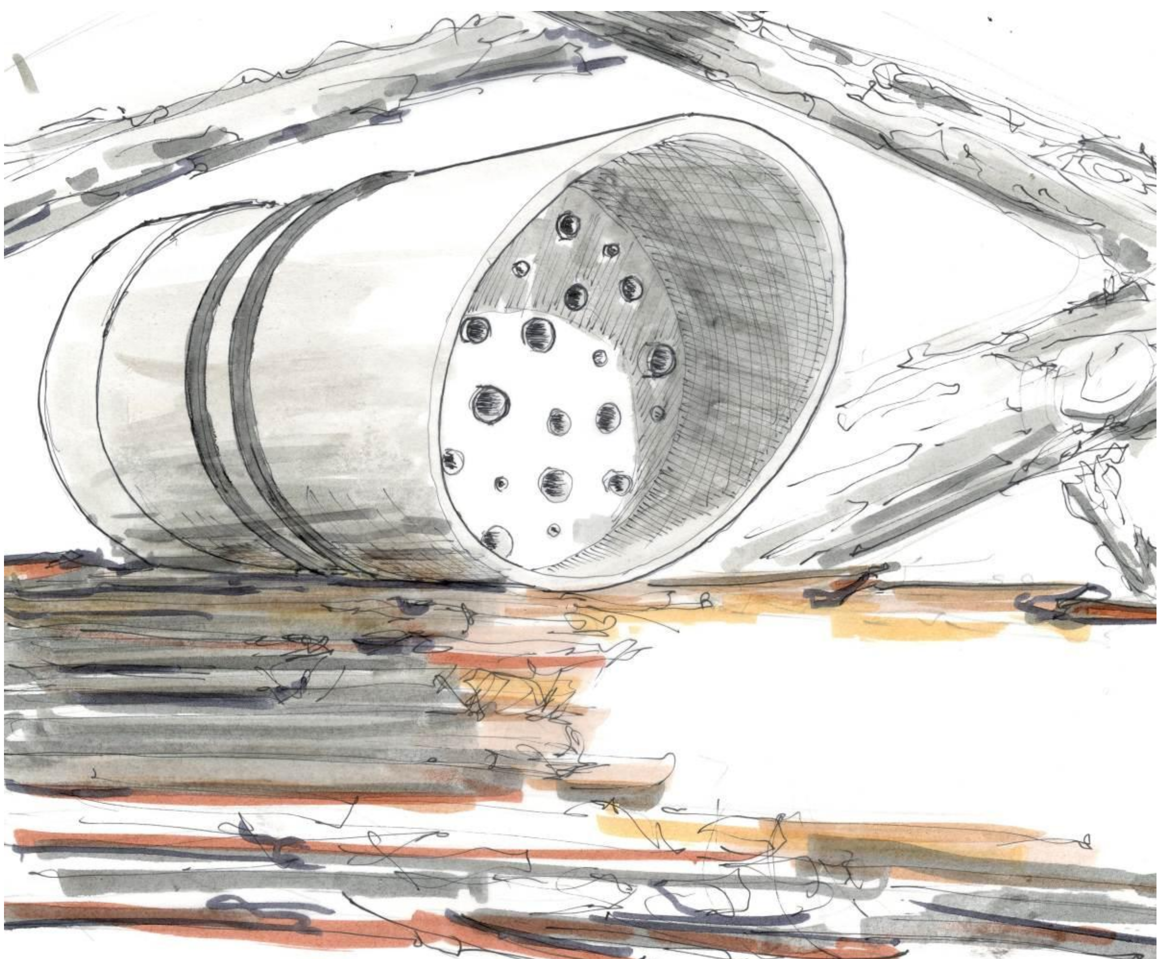

Figure 5.4.6 – "Bee Nest Box," designed for cavity-nesting bees using 3/32 and 3/8 cylinders, illustrated by Author.

Discussion

In many countries, design criteria have influenced regulations to support conservation objectives. After documenting progress made by other countries and noting precedent examples, there may be a bright future for reconciliation ecology in the United States. The designs outlined in Chapter 5, may serve as a guide for future designers interested in creating bioroofs for conservation.

When creating a bioroof the goal is to create habitat that will prevent the creation of an ecological sink (Baumann 2006; Jackson 1994). To do this, the species' basic requirements must be met, allowing for reproductive success. If this technique can be mastered, habitats could be created for certain species, not within nature preserves, but within cities.

This design inquiry has focused on four species-specific bioroofs. Through this investigation, it became clear that different species have different basic needs. Although some requirements are universal, e.g., food and water, some requirements are species specific, e.g., nesting and foraging requirements. If the design does not incorporate these elements, it may create a situation that become antagonistic to conservation.

There are many examples which demonstrate the potential for bringing reconciliation ecology into sustainable development. In the Washington, DC Area, government buildings are now required to achieve a LEED Silver certification. This is a large step in the right direction. Now it is time to use the parameters set by LEED for reconciliation ecology. This exploration is only one possible means of bringing conservation to future generations.

Helpful directions for future research may include the creation of an online database similar to eBird.org. This organization provides an international database contributed to by avian enthusiasts. This kind of information may help quantify biotic presence on green roofs in the United States. If an online database were created, the information may be of interest to sustainable developers, conservationists, or serve as a foundation of data helpful in changing legislation.

APPENDIX A

California Academy of Sciences plant list: *Armeria maritime, Carex panza, Festuca rubra*, *Frageria chiloensis*, *Prunella vulgare*, *Sedum spathilifolium*, and *Stachy bullata* (David 2008).

APENDIX B

River Rouge Ford Plant List: Gold moss stonecrop (*Sedum acre*), white stonecrop (*S. album*), gold stonecrop (*S. floriferum*), orange stonecrop (*S. kamtschaticum*), stonecrop (*S. kamtschaticum ellacombianum*), stonecrop (*S. kamtschaticum sp kamtchaticum*), diffusum stonecrom (*S. middendorffianum diffusum*), lime stonecrop (*S. pulchellum*), blue stonecrop (*S. refluxum*), coccineum two-row stonecrop (*S. spurium* 'Coccineum'), Fulda's glow stonecrop (*S. spurium* 'Fulda Glow'), superburn stonecrop (*S. spurium* 'Superburn'), and purple stonecrop (*S. telephium*) (David 2008).

APENDIX C

Oak Hammock Marsh Conservation Center Plant List is divided into high prairie, mid-prairie, and low prairie.

High prairie

Little bluestem (*Andropogon scoparus*), side oats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), Canada wild rye (*Elymus Canadensis*), June grass (*Koeleria cristata*), green needle grass (*Nasella viridula*), yarrow (*Achillea* sp.), crocus (*Crocus* sp.), coneflower (*Echinacea purpurea*), and prairie smoke (*Geum triflorum*) (David 2008).

Mid-prairie

Big blue stem (*Andropogon gerardi*), switch grass (*Panicum virgatum*), Indian grass (*Surghastrum nutans*), Little blue stem (*Andropogon scoparus*), side oats grama (*Bouteloua curtipendula*), blue grama (*B. gracilis*), prairie sand reed (*Nasella viridula*), western wheat grass (*Pascopyrum smithii*), Canada wild rye (*Elymus canadensis*), slender wheat rye (*Agropyron trachycaulum*), awned wheat grass (*Agropyron trachycaulum* v. *unilaterate*), wood's rose (*Rosa woodsii*), western snowberry (Symphoricarpos occidentalis), yarrow (*Achillea* sp.), bergamot (*Bergamot* sp.), conflower (Echinacea sp.), maximillian sun flower (*Helianthus maximillianii*), white prairie clover (*Petalostenum candidum*), and purple prairie clover (*P. purpurum*), goldenrod (*Solidago* sp.) (David 2008).

Low Prairie

Slough grass (Bechmania syzighacne), northern seed grass (Calamagrostis inexpansa), whitetop (Scholochloa festucacca), prairie cordgrass (Spartina pectinanta), little blue stem (Andropogon scoparus), and switchgrass (Panicum virgatum) (David 2008).

APPENDIX D

Eastern Tiger Swallow host plants: Wild Cherry (*Prunus spp*.), sweetbay (*Magnolia virginiana*), basswood (*Tilia americana*), tulip tree (*Liriodendron tulipifera*), birch (*Betula spp*.), ash (*Fraxinus spp*.), cottonwood (*Populus deltoids*), mountain ash (*Sorbus americana*), and willow (*Salix spp*.) (Ley 2012).

Name	Symbole	March	April	May	June	July	August	September	October	November	Bloom color	Bloom Season	Height (in.)	Height	Bees	Butterflies	Birds	Notes
Plant Choices		Spring			Summer			Fall				Sp=Spring Su=Summer Fa=Fall			W/Y/B	bright incl. R/Purple	Scarlet, orange, W	Bees: shallow flowers with landing platform, tubular. Butterflies: Narrow tube with spur; wide landing platform Missing pollinators are bats, beatles, and flies
Sedums																		
Sedum acre	SAE										Yellow	Sp	1.5	Low		-	-	Shade tolerant
S. album 'Murale'	SMM										Pink	Su	4	Low	-	-	-	
S. divergens	SDS										Yellow	Su	4	Low		-	-	
S. ewersii	SEI										Pink	Su	6	Low	-	-	-	
S. kamtschaticum	SKM										Yellow	Su	8	Low		-	-	Shade tolerant
S. lanceolatum	SLM										Yellow	Su	4	Low		-	-	
S. 'Rose Carpet'	SRC										Pink	Su	2	Low	-		-	
S. sexangulare	SSE										Yellow	Su	4	Low		-	-	
S. spurium 'Fuldaglut'	SSM										Reddish pink	Su	6	Low	-		-	Shade tolerant
S. spurium 'John Creech'	SJH										Pink	Su	4	Low	-		-	Shade tolerant
S. sieboldi	SSI										Pink	Fa	6	Low	-		-	
S. stenopetalum	SST										Yellow	Su	4	Low		-	-	
S. ternatum	STM										White	Sp, Su	3	Low		-		Shade required
S. spurium schorbuser blut	SSS										Pink	Sp, Su	4 - 5	Low	-		-	
S. weinenstephaner Gold	SWD										Yellow	Su	4	Low		-	-	
S. cauticola 'Lidakense'	SCL										Purple	Fa	-	-		-	-	
S. rupestre angelina	SRA										Yellow	Su	5 - 9	Low		-	-	
Delosperma cooperii	DCI										Purple	Sp, Su, Fa	6	Low	-		-	
D. latifolia var. 'Ecklonis'	DES										Purple	Sp, Su, Fa	4	Low	-		-	
D. aberdeenense	DAE										Pink	Sp, Su, Fa	4	Low	-		-	
Orostachys species	OSS										White	Fa	4	Low		-		
Bulbs																		
Tulipa kaufmanniana	TKA										White with yellow	Sp	8	Low		-		
Tulipa kaufmanniana 'Shakespeare'	TSE										Red with yellow	Sp	8	Low				
Tulipa saxatilis	TSS										Pink with Y center	Sp	8	Low				
Tulipa urumiensis	TUS										-	Sp	4	Low	-	-	-	
Tulipa tarda	TTA										Yellow	Sp	4	Low		-	-	Plant in sunny loactions, tolerates wet conditions
Tulipa turkestanica	TTU										White with orange	Sp	-	-		-		
Muscari botryoides	MBS										blue with white	Sp	8	Low			-	
Muscari botryoides 'Album'	MBA										All white	Sp	8	Low		-		
M. neglectum	MNM										Purple	Sp	-	-	-		-	
M. armeniacum 'Heavenly Blue'	MAH										Blue	Sp	8	Low		-	-	
M. armeniacum 'Blue Spike'	MAB										Blue with white	Sp	-	-		-		
Narcissus x odorus 'Rugulosus'	NOR										Bright yellow	Sp	-	-			-	Considered "more Robust"
N. 'Little Gem'	NLG										Golden	Sp	6	Low		-	-	
N. bulbocodium	NBM										Bright yellow	Sp	6	Low			-	
Plants Of Interest																		
Tridens flavus	TFA										Purple	Su, Fa	30 - 75	Tall	-		-	Grass, host plant for Blue-eyed Grayling, 10" root depth
Physalis	PHY	-	-	-	-	-	-	-	-	-	-	-	36 - 48	Tall		-	-	Host plant for Colletes, native tomato
Curcurbita pepo 'Baby Bear'	CUR	-	-	-	-	-	-	-	-	-	Yellow orange	-	-	Low		-	-	Host of Peponapis, pumpkin, ground vine, tendril climber
Cirsium	CIS	-	-	-	-	-	-	-	-	-	Purple	-	36	Med			-	Host plant of Melissades, sometimes invasive
Echinacea purpurea	EPA										Purple	Su	24 - 48	Med			-	Full sun to partial shade, 24" root depth
US Coast Guard Building Plant List																		
Allium cernuum	ACM										Pink-red white	Su	8 - 30	Med			-	
Asclepias syriaca	ASA										Purple	Su, Fa	72	Tall	-		-	Host of Monarch
A. verticillata	AVA										Greenish white	Su, Fa	12 - 36	Med				Host of Monarch
Achillea millefolium	AMM										White to pink	Su, Fa	12 - 39	Med				
Aquilegia canadensis 'Little Lantern'	AQM										Pink	Sp, Su	6 - 39	Med	-	-	-	
Andropogon virginicus	AVS										Redish brown	Su, Fa	48	Med	-	-	-	
Aster ericoides	AES										White rarely	Su	8 - 79	Tall		-		
Aster oblongifolius	AOS										Violet-purple	Fa	6 - 30	Med	-		-	Sunny location
Aster divaricatus	ADS										-	Su, Fa	6 - 39	Med	-	-	-	
Baptisia tinctoria	BTA										Yellow	Sp, Su, Fa	12 - 35	Med		-	-	
Campanula rotundifolia	CRA										Purpleish or white	Su, Fa	4 - 39	Med				
Carex pensylvanica	CPA										Redish, or brown	Sp, Su	2 - 16	Low	-		-	
C. plantaginea	CPL										Purple	Sp, Su	8 - 16	Low	-		-	
C. platyphylla	CLL	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Danthonia spicata	DSP										Green	Sp, Su	4 - 12	Low	-	-	-	Evergreen
Deschampsia flexuosa	DFA										Bronze / purple	Su	12 - 31	Med	-		-	Shade tolerant
Eragrostis spectabilis	ESS										Purple	Su, Fa	12 - 31	Med	-		-	
Eupatorium hyssopifolium	EHY										-	Su, Fa	1 - 6	Low	-	-	-	
Heuchera americana	HAA										Green	Sp, Su	16 - 39	Med	-		-	
Koeleria macrantha	KMA										Yellow	Sp, Fa	12 - 18	Low	-	-	-	Shade tolerant, 20" root depth
Oenothera fruticosa	OFA										Yellow	Sp, Su	-	-	-	-	-	Shade tolerant, 6" root depth
Panicum virgatum	PVM										Green or purple	Sp, Su	12 - 79	Tall	-		-	
Panicum virgatum 'Heavy metal'	PHM										Yellow	Su, Fa	36 - 60	Tall		-	-	12" root depth
P. amarum	PAM										Yellow	Su, Fa	12 - 60	Tall		-	-	16" root depth
Schizachyrium scoparium	SSM										Green	Su, Fa	20 - 59	Tall	-	-	-	
Sedum pulchellum	SPM										Roseate or white	Fa	4 - 18	Low		-		
S. album	SAM										White or pink	Sp, Su	2 - 18	Low		-		Shade or sun
S. diffusum	SDM	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
S. floriferum 'Weihenstephaner Gold'	SWG	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
S. kamtschaticum	SKM										Yellow	Fa	4 - 6	Low	-	-	-	
S. reflexum	SRM										Yellow	Su	10	Low	-	-	-	
S. ternatum	STM										White	Sp, Su	2 - 8	Low		-		
S. Spurium 'John Creek'	SJC										Roseate	Sp, Su	4 - 8	Low	-		-	
S. spurium 'Fuldaglut'	SFT										-	Su	4 - 5	Low	-	-	-	
Silene caroliniana	SCA										Pink	Sp	2 - 10	Low	-	-	-	Partial shade
Solidago sempervirens	SVN										-	Su, Fa	-	-	-	-	-	
Talinum calycinum	TCY										Bright red	Su	0.25	Low	-		-	
Tradescantia ohiensis	TOS										Purple, rose	Sp, Su	8 - 26	Med				
Uniola paniculata	UPA										-	Su	39 - 98	Tall	-	-	-	Root depth 20"
Waldensteinia fragarioides	WFS										Yellow	Sp, Su	-	-		-	-	
Shrubs																		
Arctostaphylos	APY										White or pink	Sp, Su	-	-		-	-	Evergreen
Aronia melanocarpa	AAA										White or pink	Sp	48 - 70	Tall		-	-	
Gaylussacia baccata	GBA										Red	Sp, Su	48	Tall	-		-	Black fruit, shade tolerance, 14" root depth
Ilex glabra	IGA										White	Sp, Su	39 - 96	Tall		-	-	Full sun, root depth 16"
Juniperus horizontalis 'Bar Harbor'	JBH										-	-	18 - 48	Low	-	-	-	Blue folliage turning lavender-purple in winter
Prunus maritima	PMA										Pink	Sp	12 - 100	Tall			-	Host of Eastern Tiger Swallow, full sun, root depth 20"
Quercus ilicifolia	QIA	-	-	-	-	-	-	-	-	-	Red	-	236 - 300	Tall	-		-	
Rhus aromatica	RAA										Yellow	Sp	36 - 70	Tall		-	-	
Rhus copallina 'Creels Quintet'	RCQ										Green yellow	Sp, Su	60	Tall		-	-	
Rosa carolina	ROS										Pink	Su, Fa	120 - 235	Tall		-	-	Sun to part shade
Vaccinium angustifolium	VAM										Purple	Sp, Su	2 - 15	Low	-		-	Low bush blueberry, full sun, root depth 16"
Herbaceous																		
Penstemon penstemon	PPN										Purple	Su	30	Med	-			
Sporobolus heterolepis	SPS										Yellow	-	12 - 28	Low		-	-	12" root depth minimum

Glossary

Endangered Species Act

In the early 1980's, in a process Baden (2000) calls experimental populations, endangered species were being reintroduced to their native habitats. One of many success stories of this venture is the story of the grey wolfs in Yellowstone Nation Park. These actions were taking place under the protection of Section 100 of the Endangered Species Act (ESA). Whenever releasing any predator into the wild, there is bound to be some opposition, as was the case here. This opposition was dampened by Section 100(j), which allows law makers to relax some law, "allowing, for example, reintroduced wolves to be shot when they attack livestock or assuring that certain land uses will not be restricted as a result of nearby condors" (Baden 2000, xix). It is possible for endangered plants to also be used on green roofs under the same protection.

United Nations Convention on Biological Diversity

This group consists of 193 countries, from all over the world, which "promotes nature and human wellbeing" (Goldstyn 2000, xx). The objective of this group is to encourage habitat restoration and conservation, with the aim of protecting the Earth's biological resources in the face of globalization.

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