Pollinating through art: Creating public art to restore pollinator habitats and revitalize urban communities

by

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A REPORT

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Abstract

Keywords: Pollinators, Art, Public art, Research-based design, Habitat restoration, Tactical urbanism, Urban acupuncture

The decline of pollinators and their habitats is a pressing issue worldwide. Over the past 30 years, beekeepers worldwide have recorded unusually high bee population losses (Oldroyd, 2007). Due to this decline, there is a need to increase pollinator habitats in urban areas; however, due to road infrastructure, manicured lawns, and urban development, there is little space to be utilized as restorative pollinator habitats (Sikora et al, 2020; Vaughan and Black, 2008). While colony collapse disorder in European honey bees has been explored widely in recent years, there is little research on how public art installations could address native bees and other pollinator declines in urban areas (Berenbaum, 2014). By examining creative ways to combine pollinator habitat and public art, this study aims to address the decline in native bees and other pollinators and their habitats by considering pollinator art in an ecological context through research-based design. The pollinator art created for this study integrates native plants and site context factors into hypothetical public art installations within Southeast Brush Creek, a high-vacancy area in Kansas City, Missouri. By designing functional art installations at different scales, for a typology of sites, this study examines: 1) How entomology research contributes to the form and materiality of public art as habitat. 2) How public art can revitalize pollinator habitats in urban settings. 3)How knowledge of native bees can inform the design of pollinator art for bee health and ease of maintenance.

A literature review was used to develop an evidence-based framework that informs the designs of pollinator public art that could be incorporated into specific sites in the Brush Creek neighborhood in Kansas City, MO. The findings of this study offer insight into how research can creatively inform design solutions and be translated into public art that functions as a pollinator habitat.

Pollinator art is an artistic tool that has the power to change the fabric of urban areas in a positive manner. This study contributes to the existing literature on the restoration and conservation of pollinator habitats with a broader outcome that highlights the potential implementation of pollinator art in a typology of urban settings.

Pollinating Through Art:

Creating Public art to restore pollinator habitats and revitalize urban communities

ABSTRACT

Keywords: Pollinators, Art, Public art, Research-based design, Habitat restoration, Tactical urbanism, Urban acupuncture

The decline of pollinators and their habitats is a pressing issue worldwide. Over the past 30 years, beekeepers worldwide have recorded unusually high bee population losses (Oldroyd, 2007). Due to this decline, there is a need to increase pollinator habitats in urban areas; however, due to road infrastructure, manicured lawns, and urban development, there is little space to be utilized as restorative pollinator habitats (Sikora et al, 2020; Vaughan and Black, 2008). While colony collapse disorder in European honey bees has been explored widely in recent years, there is little research on how public art installations could address native bees and other pollinator declines in urban areas (Berenbaum, 2014). By examining creative ways to combine pollinator habitat and public art, this study aims to address the decline in native bees and other pollinators and their habitats by considering pollinator art in an ecological context through research-based design. The pollinator art created for this study integrates native plants and site context factors into hypothetical public art installations within Southeast Brush Creek, a high-vacancy area in Kansas City, Missouri. By designing functional art installations at different scales, for a typology of sites, this study examines: 1) How entomology research contributes to the form and materiality of public art as habitat. 2) How public art can revitalize pollinator habitats in urban settings. 3)How knowledge of native bees can inform the design of pollinator art for bee health and ease of maintenance.

A literature review was used to develop an evidence-based framework that informs the designs of pollinator public art that could be incorporated into specific sites in the Brush Creek neighborhood in Kansas City, MO. The findings of this study offer insight into how research can creatively inform design solutions and be translated into public art that functions as a pollinator habitat.

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CHAPTER 1

Introduction

INTRODUCTION

FOREWORD

The following is a project I am very passionate about. Many hours, research, sweat, and tears went into this. This project shows how landscape architecture can break the confines of a limiting box and creatively combine art and science in an educated and thoughtful manner. This is research-based design.

I hope this report can help people see that landscape architecture is much more than one tiny box. I want people to know that a landscape architect is an environmental steward, a creative, an artist, and so much more than the designers of your backyard. From my project, I want educators to see that design research IS research and that it belongs in academic settings. Design research employs critical thinking, which can be used to better understand the world around us, underlying issues, and the people and environments we strive to serve. I followed my heart and my gut with this project, and I hope this report gives you a glimpse into my thought process, imagination, and passion for being an environmental advocate.

PROBLEM STATEMENT

If an apple is cut in half across its middle, seeds can be seen in the shape of a five-pointed star. If two seeds are found inside each point of the star shape, the apple is completely pollinated. If there are less than ten seeds in an apple, the flower was not pollinated enough to fully develop all of the apple's seeds (Lee-Mäder & Xerces Society, 2011). A poorly pollinated flower will develop into a small lopsided apple, whereas an unpollinated flower will not develop into an apple at all. This simple fact is the exact reason why all of humankind should care about the conservation of pollinators. One-third of all the food humankind consumes comes from flowering or seeding plants, and an even larger portion of that provides food for much of the earth's wildlife. About 75%-90% of flowering plants on earth rely on pollinators to have the ability to produce their fruits or seeds (Hoshiba & Sasaki, 2008; Lee-Mäder & Xerces Society, 2011).

Worldwide, there has been evidence that pollinators and their habitats are dwindling due to agriculture, mining, and human development, causing concern due to the loss of space for native vegetation. (Goulson et al., 2015; Nicholson & Egan, 2019; Potts et al., 2010). With native habitats rapidly declining, pollinators are losing essential space needed for survival (Goulson et al., 2015; Potts et al., 2010). Significant loss of native habitats is caused by increases in road infrastructure, manicured lawns, agriculture, and non-native gardens (Goulson et al., 2015; Nicholson & Egan, 2019). If declining trends continue with pollinators and their habitats, humankind will be forced to face the negative consequences and the realization that our survival depends on their survival. While pollinator decline is recognized as a dire issue worldwide, the space available to restore pollinator habitat is severely lacking due to human development, especially in urbanized areas.

A creative way to address this lack of space within urban cores is to utilize public art to develop pollinator habitats. Public art brings communities together by fostering community engagement, participation, and placemaking (Wong et al., 2009; Jackson and Esser, 2017). Public art comes in many forms, such as pieces people can play with, rearrange, change or be a part of (Wong et al., 2009; Hein, 1996). Literature is abundant on public art; however, there is a gap in the research regarding public art functioning as a pollinator habitat. This study focuses on how to creatively establish pollinator habitats in an urban core through the use of pollinator art.

GOALS OF STUDY

- Develop an understanding of native bees in North America, their life cycle, threats to their survival, and needs for survival.
- Develop a framework for pollinator art along with maintenance guidelines.
- Develop designs of public art that can function as pollinator habitat based on the created framework.

RESEARCH PROCESS

Before starting this project's research process, a real-world site based in Kansas City, Missouri, was assigned through Dr. Sara Hadavi's Master's Project Studio. A basic site history, information, and regional context were given along with the designated site.

The following research project follows a logical process, beginning with identifying a dilemma that presents a need for further research. The dilemma is assessed and approved based on how further analysis can be used and applied to future design solutions for the assigned site. A question, hypothesis, or thesis is formed to examine ways of meaningfully building upon existing research related to the topic. The research process for this project, as shown in **Figure 1**, logically builds from existing literature to identify a dilemma and seek creative resolution through design inquiry.

DILEMMA

This study examines the life cycle, foraging habits, and nesting habits of native bees. The study utilizes this research to develop an evidence-based framework that will influence and inform the design and creation of a digital prototype of pollinator art.

RESEARCH PROCESS

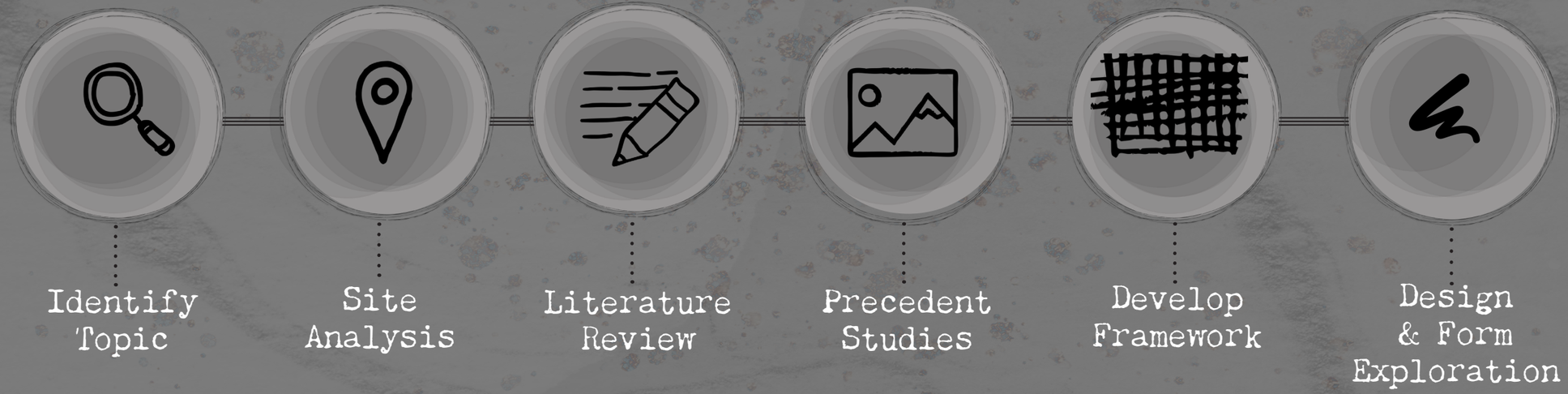

Figure 1- Diagram of the research process for this master's report project (Source: Author)

BACKGROUND

OVERVIEW

The study area for this project, shown in **Figure 2**, is located southeast of Brush Creek, Kansas City, Missouri. The site is in Jackson County, Missouri, along Troost Ave and 63rd Street. The study area runs east of Troost Ave, following Emanuel Cleaver Blvd and extending south along the Big Blue River to 63rd Street.

The study area has a population of 17,577, with a racial demographic of mostly Black or African American residents comprising approximately 69% of the study area's total population. Additionally, several large portions within the study area are considered low-income. On average, the residents of this area have an education level of high school or more (Census, 2020).

In Sara Hadavi's Fall 2021 Advanced Studio, this study area was selected due to the impoverishment of the area and its surrounding neighborhoods. Much of the blight seen and experienced within the study area is due to disinvestment linked to the redlining maps created in the 1930s by the Federal Housing Administration (Aaronson et al., 2021; González-Pérez, 2021). The redlining of Kansas City, Missouri, has caused long-lasting, damaging effects that can be seen within the study area and surrounding neighborhoods: racial segregation, poverty, high rates of vacancy, food insecurity, high crime rates, lack of occupiable greenspace, and unkempt low-quality infrastructure (Aaronson et al., 2021; Appel, 2016; González-Pérez, 2021). Although vacancy, lack of green space, and unappealing streetscape are deterrents, they also present opportunities for improvement and allow the study of pollinators in urban greenspaces within a metropolitan area.

Figure 2- Map of the study area for this project, located in Kansas City, MO (Source: ArcGIS, Adapted by Author)

SPATIAL ANALYSIS

Before conducting a spatial analysis of the site, a site visit was performed to understand the site in a real-world physical context. The site visit took place in the fall semester of 2021. Images from the site visit can be found in **Figures 3-8**. The site visit revealed many shortcomings that negatively impact the area, with vacancy identified as the primary issue. With the utilization of GIS, further investigation into the vacancy issue revealed that the study area has significant levels of widespread vacancy. There are 1,287 vacant housing units out of 8,510 housing units within the site. These units comprise approximately 4% of the total housing vacancy in Jackson County, Missouri (Census, 2020).

Visiting the site also revealed other significant issues affecting the area, such as habitat fragmentation, food insecurity, poor health and quality of water bodies, pollution, and a general unappealing streetscape character due to a lack of city maintenance. After the site visit, GIS spatial analysis tools were used to explore the issues in this area.

Figure 3- photograph taken during the initial site visit of a community garden located in the study area (Source: Author)

Figure 4- photograph taken during the initial site visit of an unkempt sidewalk on a block of vacant lots (Source: Author)

Figure 5- photograph taken during the initial site visit of an unkempt sidewalk no longer receiving maintenance form the city due to the disinvestment of the area (Source: Author)

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Figure 7- photograph taken during the initial site visit of a park without very many amenities or places to rest (Source: Author)

Figure 8- photograph taken during the initial site visit of a house with an unmanicured lawn littered with trash (Source: Author)

HABITAT FRAGMENTATION

The spatial mapping analysis provides a view of the extent of fragmented green spaces within the area. The major greenspaces located within the site boundary, shown in **Figure 9**, include Blue Hills Park, Big Blue Battlefield Park, Daniel Morgan Boone Park, and Town Fork Creek. The mapping analysis also provided an understanding of areas within the site that are home to vulnerable animal and plant species. These species are mainly concentrated along the Big Blue River, located at the eastern edge of the study area.

Legend

- Site Boundary
- Streams
- River
- Parks
- Undistrubed Natural Areas

N

Figure 9- Map of habitat Fragmentation, depicting areas of undisturbed greenspaces (Source: ArcGIS, Adapted by Author)

FOOD INSECURITY

The study area is a food desert and is considered at high risk for food insecurity. The risk of food insecurity is also exacerbated by the economic and unemployment conditions of the area. The study area is a place where fast food is more accessible and more abundant than places that sell or provide healthy, fresh food, such as grocery stores and community gardens. There is only one full-scale grocery store located within the site boundary. See **Figure 10**.

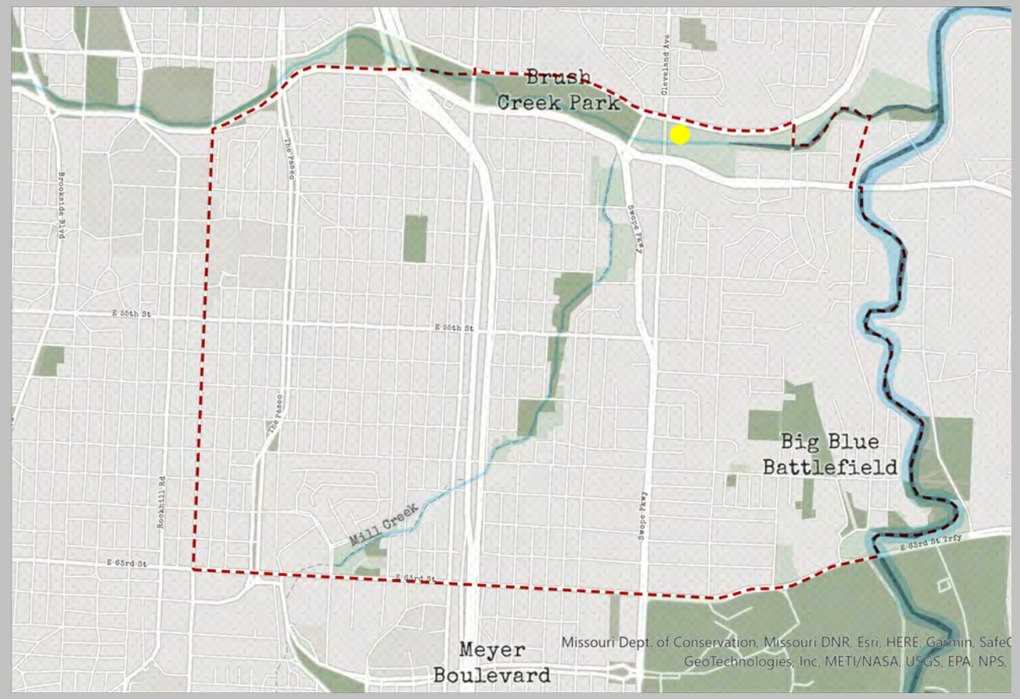


Figure 10- Map of the only Grocery store within the study area
(Source: ArcGIS and Google Maps, Adapted by Author)

SLOPE AND SOILS

The study area has a slope mostly averaging from 0-5 degrees, with some areas ranging from 6-15 degrees. Most of the study area falls in a zone of prime farmland soils that are well-draining and not excessively erodible or saturated with water for long periods. Even though the slope and soils are not negatively impacting the site, it reveals which areas could support occupiable greenspace and native plants. Layering these GIS maps (see **Figure 11**) helped guide the decision-making process in identifying which sites were most suitable for pollinator art.

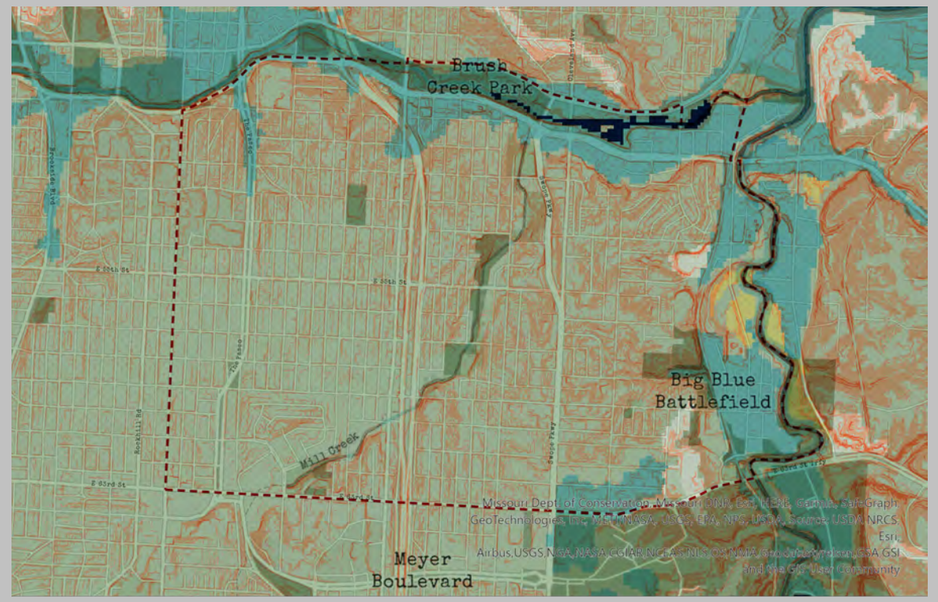


Figure 11- Map of the layered slope and soil drainage data (Source ArcGIS and USGS, Adapted by Author)

SITE SELECTION

The sites selected to potentially host and support pollinator art were first analyzed through a site visit and spatial analysis through GIS. The site analysis provided a better understanding of how and where within the study area could most benefit from the potential installation of pollinator art. Many sites were chosen and assessed as good potential locations for pollinator habitats and pollinator art, see **Figure 12**. These sites were selected based on optimality and deciphered by overlaying the maps of the social and environmental data. These sites are vacant lots experiencing habitat fragmentation, near community gardens, with well-draining soils.

Figure 12- Map of optimal locations for the addition of pollinator habitat and pollinator art, within the study area. (Source: ArcGIS and Google maps, Adapted by Author)

CHAPTER 2

Background

Chapter 2 contains the literature review, which covers pollinators, why they are essential, and which pollinators the project focuses on. This literature review aims to provide the background information used to create a research-based framework that guided and informed my designs of Pollinator Art.

LITERATURE REVIEW

This study aims to provide information on the importance of the lesser-known world of native bees, which most people have encountered less than European honey bees. Providing knowledge and research-based design ideas to increase the awareness and acceptance of native bees may encourage conservation efforts for them.

The background information on bees that follows is provided to better understand the needs of native bees. This information about their life cycles, nesting habits, and foraging habits all inform the design strategies in creating ideas for Pollinator Art.

POLLINATION

Pollination is central to the life cycle of flowering plants, and it is defined as the transfer of pollen from plant to plant by insects and vertebrates known as pollinators (Mangena & Mokwala, 2018; Saunders et al., 2019). Flowering plants rely on sexual reproduction and have both male and female structures that are essential reproductive parts of a flower. The male structure of a flower, the androecium, is made up of the stamen, which consists of a bulbous structure called an anther on the end of a filament (Rhodes, 2018). The anther produces pollen, which is made up of pollen grains that are the vessels for a plant's male gametes or sex cells. Collectively, the female components of a flower are known as the pistil, which is formed of one or more carpels (Ayasse & Arroyo, 2010). Female gametes are contained within carpels; carpels are made up of three parts: a stigma, ovules, and the style. The style is a stalk-like extension that supports the stigma. The stigma is a sticky feathery tip that allows fertilization to occur in the ovules and is located at the base of the carpel (Ayasse & Arroyo, 2010; Rhodes, 2018).

There are two types of pollination: cross-pollination and self-pollination. Self-pollination is the transfer of pollen within a flower or between flowers on the same plant. In other words, it is when the pollen of a flower is transferred from an anther to a stigma on the same flower or plant. Self-pollination usually occurs when pollinators are scarce or in closed flowers, which limits pollinator access to the sexual structures of the flower (Lee-Mäder & Xerces Society, 2011; Mangena & Mokwala, 2018). In contrast, cross-pollination is the transfer of pollen from one plant's anther to another plant's stigma, which requires pollinators to assist in this process. While self-pollination often results in undesirable recessive traits and the production of a plant with less genetic diversity, cross-pollination followed by fertilization produces healthier, genetically diverse offspring that will, in turn, produce larger amounts of viable seeds (Mangena & Mokwala, 2018; Waser et al., 1996) Although some plants can produce seeds through self-pollination, many plant species have genes that prevent its own pollen from fertilizing itself; therefore, most plants on earth require cross-pollination (Mangena & Mokwala, 2018; Rhodes, 2018).

To attract pollinators, plants evolved to develop flowers. The flowers reward pollinators by providing nectar, a sugary secretion, and pollen as a valuable source of protein. Flowers' color and shape also attract pollinators by providing cues to help them find a flower's nectar (Lee-Mäder & Xerces Society, 2011; Mangena & Mokwala, 2018). Many flowers have nectar guides that form radiating lines containing ultraviolet color patterns visible to bees but not humans (Mangena & Mokwala, 2018; Waser et al., 1996). Once a flower is fertilized, it stops producing nectar and eventually changes color, which indicates that there is no more food. This indicator allows pollinators to attend to other pollen-rich flowers (Mangena & Mokwala, 2018).

IMPORTANCE OF POLLINATORS

Pollinators are vital in maintaining global biodiversity. The literature links the parallels between the recent declines of wild and domesticated pollinators and the recent declines of the plants that rely on them (Potts et al., 2010). Lands once inhabited by abundant wildlife and pollinators have been heavily developed into agricultural and urban landscapes; now, these lands lack the habitat and viability to support a diverse plethora of pollinators (Klein et al., 2007; Potts et al., 2010).

BEES

When most people think of pollinators, they usually think of honey bees and butterflies. While those species are pollinators, there are also others, such as bats, birds, moths, beetles, wasps, and flies. These pollinators are all categorized as biotic factors, meaning that as living organisms, their actions affect their ecosystems. In addition to these factors, pollination includes abiotic, or non-living, factors such as wind and water (Mangena & Mokwala, 2018; Rhodes, 2018; Saunders et al., 2019).

The most important group of pollinators are bees, as they are the primary pollinators of most agricultural crops and wild plants. Besides a few wasp species, bees are the only pollinators that intentionally gather pollen to bring back to their nests for their offspring (Danforth, 2007). Female bees visit hundreds of flowers and transport pollen the entire distance on a single foraging excursion. However, butterflies, moths, flies, wasps, and some beetles only visit flowers to feed on nectar rather than collect pollen, which is why bees are essential pollinators; other pollinators come into contact with the flower's anther less frequently (Kearns & Inouye, 1997; Klein et al., 2007).

CAUSES OF DECLINE

HABITAT LOSS, DEGRADATION, & FRAGMENTATION

Agricultural development ranks as the most frequent cause of habitat degradation (Kearns & Inouye, 1997; 2011; Potts et al., 2010). While habitat loss is significant in urban areas, the fragmentation of habitat in rural areas due to agriculture is no less of a problem. Indeed, 36% of the world's land surface is devoted to agriculture – making it the largest component of global land use (Goulson et al., 2015; Kearns & Inouye, 1997; Lee-Mäder & Xerces Society, 2011; Potts et al., 2010; Rhodes, 2018). While some may envision green landscapes and fields when thinking of agriculture, agricultural lands hold few food and nest resources for pollinators. These lands are usually laden with pesticides and contain fewer native plant species that bees and other pollinators require (Goulson et al., 2015; Kearns & Inouye, 1997; Potts et al., 2010; Rhodes, 2018).

The second most detrimental cause of habitat loss is urban development. This usually occurs in areas with naturally high levels of biodiversity, such as along rivers, bays, streams, and coastal waterbodies (Goulson et al., 2015; Kearns & Inouye, 1997; Potts et al., 2010; Rhodes, 2018).

The habitat loss from rural and urban factors contributes to fragmenting suitable pollinator habitats. Prairie lands, once suitable habitats for pollinators, now only exist as fragments of what they once were—creating a considerable challenge for migratory pollinators. Due to the land fragmentation of suitable habitats across ecoregions, smaller migratory pollinators are therefore unable to survive the greater migratory distances (Potts et al., 2010; Rhodes, 2018; Waser et al., 1996).

PESTICIDES

An additional factor leading to pollinator decline is the use of pesticides worldwide. Pesticides kill pests and usually fall under three categories: herbicides, insecticides, or fungicides. Herbicides destroy unwanted vegetation, while insecticides kill off insects, their eggs, and larvae. Fungicides kill off or inhibit the growth of fungi and their spores (Goulson et al., 2015). Regardless of the type, pesticides negatively impact pollinators as most pesticides remain in the environment for an extended period and negatively affect generations of pollinators (Biesmeijer, 2006; Cameron et al., 2011; Goulson et al., 2015; Kearns & Inouye, 1997; Potts et al., 2010; Rhodes, 2018; Vaughan & Black, 2008). Pesticide use on plant seeds also negatively impacts pollinators because pollen grains remain contaminated from the toxins even after maturity and are no longer viable food sources for pollinators (Rhodes, 2018; Vaughan & Black, 2008). In addition to mortality, chemical poisoning from pesticides in bees causes abnormal bee communication dances and results in mistakes when indicating the distance and direction to food sources (Goulson et al., 2015; Kearns & Inouye, 1997). This misguided confusion is further amplified by habitat fragmentation and lowers bee survival rates. Pesticide use also factors into pollinator decline, especially bee decline. Since the hairs on bees easily collect residue from insecticides on flowers, bees unknowingly bring the toxins back to their colonies. Once brought back to the colony, the toxins spread from the bee's hairs and poison adult bees and larva (Kearns & Inouye, 1997; Lee-Mäder & Xerces

Society, 2011). In some cases, the toxicity levels are so high that bees within the colony perish.

Pesticides used on large agricultural lands are applied in various ways, such as backpack sprayers and crop dusters. Despite the method pesticides are applied, residual pesticide drifts onto adjacent crops and wildflowers—ultimately killing the bees foraging in those areas. Pesticide drift can cause damage to bees and their habitats up to a mile and a half from where it was initially sprayed (Rhodes, 2018; Vaughan & Black, 2008). Weather, application technique, equipment settings, and pesticide formulation are all factors that influence the extent of pesticide drift—chances of pesticide drift increase with time of day, temperature, wind currents, and wind velocity areas (Lee-Mäder & Xerces Society, 2011).

Pesticides are not only a problem within agricultural lands, but they are an issue within urban and suburban areas as well. Studies performed by the U.S. Geological Survey have detected higher concentrations of pesticides in urban streams than in streams near agricultural areas (Lee-Mäder & Xerces Society, 2011). The disproportionate toxins in streams near urban areas versus agricultural lands are due to the application methods. Pesticides sprayed on farms can only be sprayed by licensed and trained applicators. Because of this, farmers usually want to save as much money as possible and use as little pesticide as possible. Additionally, there are laws that regulate the use of pesticides on agricultural lands (Barbosa et al., 2015). Homeowners, however, do not have regulations or licensing requirements for pesticide use and have access to an array and abundance of pesticides. In addition to having unlimited access to a wide range of pesticides, there are no educational opportunities for homeowners to learn about the impacts of their pesticide spraying (Barbosa et al., 2015; Rhodes, 2018; Vaughan & Black, 2008). Pesticides are a huge detriment to the environment because their slow degradation period allows for more opportunities for pollinators and other wildlife to be exposed to these hazardous toxins (Barbosa et al., 2015).

NON-NATIVE PLANT SPECIES

Another threat to pollinators is non-native plant species, which have the potential to outcompete native plants and wildflowers (Potts et al., 2010). Non-native species are harmful as they may draw pollinators away from more nutritious native plants, potentially lowering the pollination rates of native pollinator habitats. Lower pollination rates of native plants could eventually allow non-native species to take over native habitats (Potts et al., 2010; Vaughan & Black, 2008).

PARASITES AND DISEASES

While bees naturally suffer from a wide range of parasites and pathogens, most research has focused on the parasites and diseases associated with honey bees (Goulson et al., 2015). Most parasites and pathogens that spread amongst honey bees occur inadvertently from commercial long-distance transport of honey bees for agriculture (Goulson et al., 2015). Despite quarantine processes implemented for transport procedures, parasites and pathogens continue to spread (Goulson et al., 2015).

One of the more well-known parasites of honey bees is the Varroa mite, also known as the Varroa destructor. Originally, the Varroa mite was associated with the Asian honey bee *Apis cerana* but has become more commonly associated with the European honey bee *Apis mellifera* due to their low resistance rates to the pest (Ellis & Zettel Nalen, 2010; Goulson et al., 2019). Since the 1960s, the Varroa mite has spread from bees in Asia to Europe, to the Americas, and most recently to parts of New Zealand (Ellis & Zettel Nalen, 2010). Varroa mites are detrimental to the survival of bees and their colonies because the mites act as vectors for diseases such as the deformed wing virus or DWV. The combined effects of the mite and the pathogen(s) it transmits contribute significantly to honey bee colony losses, specifically in North America and Europe (Goulson et al., 2015; Kearns & Inouye, 1997). Fortunately, research has shown that the mites are limited to honey bees as the parasites cannot survive on bees outside of the genus *Apis* (Ellis & Zettel Nalen, 2010; Goulson et al., 2015). Due to little being known about the pathogens and parasites of native bee populations, more studies and research are needed.

HONEY BEES

This study primarily focuses on bees because they are the world's primary pollinators. However, due to extensive research, support, and funding, this study will not focus on honey bees and will instead focus on North American native bees. The well-known honey bee is not native to North America; it is native to Europe. European honey bees were introduced to most of the world as crop pollinators and serve an essential role in the agricultural industry. Despite the honey bee's agricultural importance, scientists are beginning to recognize and examine ways in which they negatively impact the native bees of North America (Kearns & Inouye, 1997). Honey bees have impacted native bees in several ways; 1) competition for native floral resources, 2) increased competition for nesting sites, 3) the transmission of shared parasites and or pathogens, 4) pollination of non-native plant species (Goulson, 2003; Mallinger et al., 2017). Honey bees play an essential role in the world's economy. However, due to their potential impact on native bees, more research is needed to examine how extensive their impact has been on native bee populations (Goras et al., 2016).

This study aims to provide information on the importance of the lesser well-known world of native bees. I believe that providing knowledge and research-based design ideas through this study will increase awareness and acceptance of native bees and hopefully encourage others to join in the efforts aiding in their conservation.

The following information on bees is provided to understand the needs of North American native/wild bees. The literature in this section was used to develop the framework that informs the designs for Pollinator Art.

MORE ON BEES

BEES ANATOMY

Bees, like all insects, have three main body segments: a head, thorax, and abdomen (Johnson et al., 2014; Lee-Mäder & Xerces Society, 2011). Bees have six legs and two pairs of wings; the larger fore-wings and the smaller hind-wings are all attached to the thorax (Danforth, 2007; Johnson et al., 2014). On their heads, bees have highly specialized mouthparts and long, cylindrical, segmented antennas that aid in their reception of taste, feel, and smell (Johnson et al., 2014). Some bees have specialized hairs on each hind leg or underneath their abdomen called scopae (singular scopa) that aid in transporting pollen efficiently. When looked at underneath a microscope, scopae appear as branched or feathered long stiff hairs. These hairs are long and dense like a brush and are perfect for holding pollen (Johnson et al., 2014; Thorp, 1979). A few examples of bees with scopae on their legs are sweat bees, long-horned bees, and mining bees. Bees with scopae on the underside of their abdomens include mason bees and leafcutter bees (Michener, 1999).

Bees such as honey bees and bumble bees have corbicula, also known as a pollen basket (Michener, 1999). A ***corbicula*** is a cavity located on each hind leg surrounded by fringes of long inward-curving scopal hairs used to store pollen (Danforth, 2007; Michener, 1999). All bees do not have scopae, so other bees, such as yellow-faced bees, transport pollen internally in the crop or honey stomach (Michener, 1999; Thorp, 1979). Additionally, parasitic bees, such as female cuckoo bees, lack scopial hair and do not collect their own pollen (Michener, 1999). Parasitic bees do not forage for food or make their nests; instead, they steal other bees' pollen by invading their nests (Danforth, 2007; Michener, 1999).

TYPES OF BEES

Worldwide, there are over 20,000 known bee species, and 4,000 species are native to the United States (Pimentel et al., 1997). Bees are essential pollinators as they collect nectar and pollen from flowers to feed their offspring and unintentionally transmit vast amounts of pollen from flower to flower (Danforth, 2007; Mangena & Mokwala, 2018). While both male and female bees feed on nectar, female bees are the only ones that gather pollen. Bees are incredibly diverse insects and fall into the taxonomy of *Hymenoptera*, including ants, wasps, and sawflies (Mangena & Mokwala, 2018). In North America, bee species range in length from one twelfth of an inch

to more than one inch and may also vary in color. Some bees are dark brown to black, red, or metallic green and blue (Danforth, 2007). Some bees are named after how they build their nests, such as the plasterer bee, leafcutter bee, mason bee, carder bee, digger bee, or carpenter bee. Other bees are named after their behaviors, such as the sweat bees, which are attracted to human sweat. Bumble bees also fall into this category and are named for how they loudly hum as they fly. Honey bees are also included as they are named for the way they make and store honey (Lee-Mäder & Xerces Society, 2011).

Bees are categorized in three ways: social habits, nesting habits, and foraging habits (Fowler, 2016). Bees are either generalists or specialists, with the majority categorized as generalists. Generalists gather nectar and pollen from a wide range of flower species. Specialist bees differ from generalists as they use a single plant family to meet their pollen needs. Additionally, the life cycle of specialist bees is tied closely to the life cycle of their flowering host plants (Fowler, 2016).

SOLITARY BEES

Most native bees are solitary bees, meaning they live without a colony or hive. In North America alone, 90% of bee species are solitary bees (Watanabe, 2013). Solitary bees usually live for about a year; they spend the early stages of their lives hidden away in a nest as they grow through the egg larval and pupal stages. Humans typically see solitary bees during their active adult stages, which last about three to six months (Danforth, 2007).

SOLITARY BEE NESTING

Solitary bee species can exhibit a range of nesting behaviors. Some solitary bees share nesting sites in clusters, such as the alkali bee *Nomia melanderi*. With well-established nesting sites of alkali bees, there can be 200 or more female bees in one square yard of ground, with each bee tending to a separate burrow (Batra, 1984; Linsley, 1958; Strickler, 1979; Youngsteadt, 2020).To construct their nests, about 30 percent of solitary bee species use tunnels in dead trees, abandoned beetle burrows, or may chew out a nest in the soft centers of stems and twigs (Danforth, 2007). The remaining 70 percent nest in the ground by digging tunnels in well-drained soil in sparsely vegetated areas.

Usually, every bee nest has several separate brood cells where female bees lay their eggs. Brood cells are chambers within a bee nest where larva grow through their pupal stages and develop into adult bees (Batra, 1984; Linsley, 1958; Strickler, 1979; Youngsteadt, 2020). The number of cells within a nest varies depending on the bee species, with some having a single cell while others contain five or more. Female wood-nesting bees, such as the carpenter bee (genus *Xylocopa*), construct their cells in a single line that fills the tunnel. In contrast, female ground-nesting bees, such as the mining bee (genus *Andrena*), dig complex branching tunnels (Danforth, 2007).

Before closing developing larva into their cells, female bees will provide each cell with food. The food female bees leave for their offspring is called bee bread, a mixture of nectar and pollen (Batra, 1984; Danforth, 2007; Linsley, 1958; Strickler, 1979; Youngsteadt, 2020). Female bees lay one egg on each ball of bee bread and then seal the cell shut. To protect the developing larva from drying out, excessive moisture, fungi, or disease, some bee species also line each cell with a protective layer. The protective layer a cell is lined with varies by bee species. Protected cell linings range from waxy glandular secretions, waterproof plastic-like secretions, pieces of leaf or petal, mud, or chewed-up wood (Batra, 1984; Danforth, 2007; Linsley, 1958).

Once each cell within the nest is sealed off, the female bee seals the entrance to the nest and leaves (Youngsteadt, 2020). In some species, a female will guard the nest's entrance instead of leaving once she is finished sealing off each cell. Despite dying in the winter, the bee's body will remain in place—thereby blocking the entrance to the nest (Batra, 1984; Linsley, 1958).

LAYING

In one lifespan, solitary female bees can lay up to 20 or 30 tiny white eggs. When laying their eggs, the female can control if the egg will hatch into a male or female, made possible due to a special sac called a *spermatheca* (Youngsteadt, 2020). The spermatheca is a sac where the female bee stores sperm after mating (Batra, 1984). Female bees only release the sperm during their egg-laying. For the eggs that the bee wants to be female, she will fertilize

with the sperm, and the eggs she wants to hatch as males will not be fertilized with the sperm (Lee-Mäder & Xerces Society, 2011; Youngsteadt, 2020).

LARVA TO PUPA

All of a bee's growth occurs during its larval stage; once an egg is laid, it can take up to one to three weeks to hatch. Once the egg hatches, a grub-like larva will emerge and feed on the bee bread for several weeks as it rapidly grows (Xu et al., 2021). During this growth period, the larva will go through four or five developmental stages before maturing into a pupa. A larva's body naturally prevents the contamination of its food supply because it does not fully develop the internal anatomic connections that allow defecation until the final stage of development (Batra, 1984; Linsley, 1958; Youngsteadt, 2020). The final stage of development for a larva is called prepupa, occurring after the larva has defecated. Prepupa produces silk to form a cocoon. Once enclosed in the cocoon, they begin the life stage called pupa. Within the cocoon, pupa transform into fully formed adults. In unfavorable conditions such as the winter months or periods of drought, prepupa can remain dormant for extended periods (Xu et al., 2021). Generally, solitary bee species complete pupation or the act of changing from a larva to an adult by the end of the summer. During the winter, they stay dormant as fully formed adults and emerge from their nests in the spring (Batra, 1984; Linsley, 1958; Youngsteadt, 2020). In regions with arid climates, the emergence of adult bees coincides with the sporadic blooming seasons of desert flowers. The cues that trigger the emergence of adult bees are triggered by a variety of factors such as internal clocks and environmental cues like moisture level and temperature (Kemp & Bosch, 2000). When male bees emerge from the nest, they find nearby patches of flowers in hopes of mating with female bees foraging for pollen and nectar. When a female bee emerges, she will mate and begin the process of creating and provisioning for her nest, in which she will eventually lay her eggs (Xu et al., 2021; Youngsteadt, 2020).

FORAGING HABITS

Solitary bees are typically generalists and gather pollen and nectar from a variety of plants (Ritchie et al., 2016). When foraging for food, bees search for nectar and pollen to feed themselves and their offspring (Mallinger et al., 2016). Another food source some bees collect for themselves and their larva is a special oil from flowers. However, a bee's size plays a huge role in how far they are able to travel to forage for food and nesting materials. For bees to successfully construct and provision nests, the foraging area and nest site must be within flight distance (Brian, 1954a; Mallinger et al., 2016). Large bees are able to fly farther than smaller ones. Large Carpenter bees (*Xylocopa*) and bumble bees (*Bombus*) can travel distances up to a mile or more from their nests to forage. Medium bees such as mining bees (*Andrena*) or leafcutter bees (*Megachile*) can fly up to 400-500 yards. In contrast, small bees like the sweat bee (*Halictus*) or the small carpenter bee (*Ceratina*) usually do not fly more than 200 yards from their nests (Strickler, 1979).

When foraging, solitary bees collect nectar based on the structure of the flower and if that structure allows them to reach the nectar. Whether or not a bee can collect nectar from a flower depends heavily on the length of its tongue, the glossa. The glossa is a part of a highly specialized segmented mouth-part called the proboscis. A bee's tongue is hairy and is used to lap up nectar (Pignata et al., 1998; Wang et al., 2021). Bees with short tongues are only able to drink nectar from open flowers such as flowers in the aster family, such as daisies and sunflowers. Long-tongued bees can drink nectar from flowers that are more tubular in shape or complex such as *penstemon*, *lobelia*, and *lupines* (Cariveau et al., 2016; Spiesman & Gratton, 2016; Stang et al., 2006).

Bees do not only forage for food but also forage materials to construct their nests. Mason bees, for example, search for areas with damp clay soils; from these sites, they gather and carry balls of mud back to their nests. Other bees gather materials like pieces of leaves, plant resins, or pebbles for the same purpose (Bosch, 1994; Harmon-Threatt, 2020).

SOCIAL BEES

Social bees live in colonies. ***Colonies*** are defined as having two or more females living in the same nest and sharing the work of provisioning for it. Usually, one of the females is the queen with the duty of laying eggs. The other female bees are workers that contribute to constructing, provisioning, and defending the nest (Calderone & Page, 1991; Michener, 1963). The most well-known social bee is the European honey bee, *Apis mellifera*. Honey bees have a caste system with a singular queen, multiple female worker bees, and

a few male drone bees that are only used for mating purposes (Calderone & Page, 1991). Another well-known social bee is the bumble bee (genus *Bombus*). Bumble bees are the best-known native bees in North America (Calderone & Page, 1991; Michener, 1963).

The colonies of social bees are considered to be super-organisms because each bee works together to function as a whole (Calderone & Page, 1991). Within the colonies of social bees, individual bees are organized into a complex distribution of labor. Some bees have the task of constructing and repairing the nest, others guard the hive, some have the role of caring for the larvae, and others have the task of foraging for food and nest material (Calderone & Page, 1991; Michener, 1963).

Bumble Bees

Bumble bees (genus *Bombus*) are social bees that live in annual colonies with overlapping generations and a reproductive division of labor. Generally, bumble bees produce one colony per year and are established in the spring by an individual queen after she emerges from hibernation (Ayasse & Jarau, 2014; Brian, 1954b). Bumble bee nests are typically located in dry cavities such as abandoned rodent nests, hollow areas in trees, or even under dense clumps of vegetation (Krivda, 1981). However, if the need to adapt arises, they will. Bumble bees will nest in walls, cavities in rock piles, and even in discarded mattresses and car seats (Ayasse & Jarau, 2014).

Once a nest site is located, the queen secretes wax-like secretions from glands in her body to create a cluster of various-sized round pots where she will later lay her eggs. Sometimes bumble bees store nectar in these pots; however, they do not convert it to honey (Brian, 1954b). The small amounts of nectar stored in a bumble bee nest are there to provide a few days' worth of food in case foraging is prevented by inclement weather (Brian, 1954a; Brian, 1954b). In addition to the wax pots, sometimes a wax covering or canopy called an involucrum can be found covering the entire nest (Brian, 1954b).

The life-cycle of a typical bumble bee colony begins with a queen emerging from hibernation in the spring and finding a new nest site, such as an abandoned mouse burrow (Ayasse & Jarau, 2014; Brian, 1954a). Once a nest site is located, the queen will create wax pots to hold nectar and incubate the eggs she will lay on pollen balls (Ayasse & Jarau, 2014). To incubate the eggs, the queen sits on top of the wax pots and engages their flight muscles to vibrate and generate heat (Ayasse & Jarau, 2014; Brian, 1954a; Brian, 1954b). After a month, the larvae pupate and emerge as adults as worker bees. The newly emerged workers bees take over the foraging and the work of expanding the nest, which allows the queen to stay safe inside and conserve energy for laying more eggs (Ayasse & Jarau, 2014). Later in the summer, the queen produces a new generation of reproductive individuals; males and a small number of new queens (Ayasse & Jarau, 2014; Brian, 1954b). The males leave the nest to search for mates and do not return. The new queens remain in the nest and only leave to mate. In the fall, most of the bees die, including the old queen. The queens that have mated leave the natal nest and prepare for winter. To survive the winter months, the queen goes into hibernation by digging herself several inches underground or beneath leaf litter. The following spring, she will emerge and begin a new colony life cycle (Ayasse & Jarau, 2014; Brian, 1954a; Brian, 1954b).

Parasitic Bees

There are two types of parasitic bees, or bees that lay their eggs in the nests of other bees (Sless et al., 2022; Wood et al., 2016). Parasitic bees, like other native bees, can be categorized as either solitary or social. The majority of parasitic bees are solitary and are called *cleptoparasites*. Cleptoparasites, or cuckoo bees, lay their eggs in the nests of other solitary bees. The solitary cleptoparasite enters a host's nest to lay her eggs when the female host species is not present. Most cuckoo bees leave once they have laid their eggs (Plateaux-Quénu, 2008; Sless et al., 2022; Uboni et al., 2012; Wood et al., 2016).

Usually, once A cuckoo bee's larva is hatched, it will kill the host bee's egg or larva. However, an exception would be the (genus *Spheecodes*), whose female destroys the host's egg before laying their own. After hatching, the parasitic larva feeds off the host's food provisions and remains in the brood cell through its larval and pupal stages before emerging as an adult (Plateaux-Quénu, 2008; Sless et al., 2022; Uboni et al., 2012; Wood et al., 2016).

The social parasitic bee is known as the social parasite. Social parasites enter the nests of social

or semi-social bees, replacing the queen and having her worker bees rear the parasitic offspring. An example of a social parasite within North America is the Cuckoo bumble bee (Lhomme & Hines, 2018). Cuckoo bumble bees do not have the ability to collect pollen or construct nests, so to survive, they enter established colonies of bumble bees and takeover by overthrowing the queen (Gjershaug, 2009; Lhomme & Hines, 2018). In order to successfully control the host's colony, cuckoo bumble bees use pheromones and physical attacks to force the host's worker bees to raise their parasitic larvae as if they were their own (Lhomme & Hines, 2018; Urbanová et al., 2004).

When cuckoo bumble bee larvae hatch, they disperse, mate, and enter hibernation. Adult cuckoo bumble bees emerge from hibernation later than their host species, allowing the host species to establish nests and raise the colonies' first generation of workers (Lhomme & Hines, 2018). The life-cycle and methods of the cuckoo bumble bee may seem detrimental to bumble bee populations; however, the presence of the cuckoo bumble bee is a sign of healthy host populations and a healthy ecosystem (Lee-Mäder & Xerces Society, 2011).

CONSIDERATIONS FOR DESIGN FRAMEWORK

To research pollinator art, there needs to be a design inquiry process. However, before designing, a guide or specific criteria to be developed to provide a design framework. The framework will ensure that the pollinator art created for this project is optimally designed for native pollinators and the site context. The criteria for this framework were developed through researching native plants optimal for a type of urban zone in a specific hardiness zone. Additionally, developing the design inquiry framework will aid others in their future designs of pollinator art. The framework is a design guide that can be built upon for future research. The categories of the design inquiry framework are; urban zone, materials, and native plants.

URBAN SETTINGS :

For this project, urban settings will be defined as areas commonly found within a metropolitan area. These spaces vary between public and private property. The urban settings for this project are based on spaces found within or near the study area located in Kansas City, Missouri. These urban settings are labeled; bus stop, community garden, residential, and natural areas.

Bus stop:

A space adjacent to a public street containing signage and/or seating indicating it as a stop for public transportation.

Community garden:

A space or lot allocated to the cultivation, growth, and maintenance of plants, fruits, and or vegetables for the community and led by the community.

Residential:

An area zoned by the city for residential use. These spaces may or may not have housing units on them.

Natural areas:

A space that provides habitat for flora and fauna of a given area, such as; parks, unkempt vacant lots, managed landscaping, preserved forests, river banks, and ponds.

These urban settings were selected to reflect practical examples of spaces within an urban setting that can be used as connectors to fragmented pollinator habitats. Additionally, they were chosen because urban natural areas, where pollinators inhabit, are most effective when linked by some form of a corridor (Dylewski et al., 2020). These corridors are usually habitats connecting two or more blocks of undisturbed naturalized space, allowing pollinators to rest and seek refuge while traveling or foraging in urbanized spaces. Shorter trips for pollinators would lessen the fatigue or other dangers they experience while foraging or flying in urban spaces. Lessening the stressors on pollinators by adding habitat gives them a better chance to survive and thrive (Banaszak-Cibicka & Żmihorski, 2011; Basteri & Benvenuti, 2010; Dylewski et al., 2019; NeameEAME et al., 2012; Strauss, 2009). This category was chosen not only because the study area for this project is located in an urban area but also because recent studies have shown that urban areas are potentially attractive habitats for pollinators (Banaszak-Cibicka & Żmihorski, 2011; Dylewski et al., 2019; Lizée et al., 2011; McFrederick & LeBuhn, 2006). With the development of urban areas increasing, fragmentation and isolation of suitable habitats are also increasing, ultimately decreasing pollinator

populations. Development (Kremen et al., 2004; Rands, 2014; Zurbuchen et al., 2010).

NATIVE PLANTS

Native plants are integral to the framework because it is best to choose plants well-suited and non-invasive to the location they will be planted. The idea of the right plant right place is essential for pollinator art and pollinator habitats because native plants are thought to be the most suitable resource for native pollinators (Staab et al., 2020). However, some studies do not view native plants as most suitable for pollinators (Kendle & Rose, 2000; Schlaepfer et al., 2011). The native plants listed in the framework for this project are sorted based on qualities most beneficial for the urban zone they would be used in.

NATIVE PLANTS BASED ON URBAN ZONE:

Bus Stop

The native plants used for bus stop urban settings should be salt-tolerant. During winter, roadways and sidewalks are salted to prevent slick and icy conditions. However, the salt used can potentially result in plant injury. Plants near roadways may also suffer injury from the salt through aerial drift from fast-moving cars. It is common for salt to leach into the root zones of plats used near roadways during winter. The plants listed below have a moderate to high salt tolerance and are either native to the Midwest or broadly native to North America. Please note: this plant list is not complete or definitive; many native plants could work in this urban zone. The plants listed below were chosen for their specific quality of being salt tolerant.

Wildflowers

Asters (***Symphyotrichum*** spp.)Beardtongue (***Penstemon*** spp.)

Bee Balm (***Monarda fistulosa)***

Goldenrods, showy & stiff (Solidago speciosa & Oligoneuron rigidum)

Mexican hat (***Ratibida pinnata***)

Black-eyed Susan (***Rudbeckia hirta***)

Milkweeds, butterfly & marsh/swamp (***Asclepias tuberosa & Asclepias incarnata***)

Phlox (***Phlox*** spp.)

Purple coneflower (***Echinacea purpurea***)

Purple prairie clover (Dalea purpurea)

Rattlesnake master (Eryngium yuccifolium)

Rough blazing star (***Liatris aspera***)

Yarrow (***Achillea millefolium***)

Grasses

Broom sedge (***Andropogon virginicus***)

Grama grasses (***Bouteloua*** spp.)

Horsetail (***Equisetum hyemale***)

Indian grass (***Sorghastrum nutans***)

Little bluestem (***Schizachyrium scoparium***)

River oats (***Chasmanthium latifolium***)

Switchgrass (***Panicum virgatum***)

Shrubs

Black chokeberry (***Aronia melanocarpa***)

Buttonbush (***Cephalanthus occidentalis***)

Clove currant (***Ribes odoratum***)

Elderberry (***Sambucus canadensis***)

Spicebush (***Lindera benzoin***)

St. John's wort (***Hypericum prolificum***)

Vines

American bittersweet ***(Celastrus scandens)***

Trumpet creeper ***(Campsis radicans)***

Virginia creeper ***(Parthenocissus quinquefolia)***

Community Garden

Community gardens offer many opportunities to accommodate pollinator populations. For example, flowers grown along the plots' margins or unused plots can help support bees by being a site for ground-nesting bees. Adjacent parks, vacant lots, or privately owned land near community gardens can also be used to benefit pollinators by planting appropriate flowers. Keeping community gardens pesticide free will also aid in supporting pollinator populations. Pollinators are beneficial to urban spaces such as community gardens because they will pollinate the vegetation in the gardens and around them, ensuring large healthy yields of the crops. A wide range of native plants can be grown in or near community gardens that would benefit pollinators in this urban zone.

Residential

Residential settings are prime areas to plant for a succession of blooms throughout the year. Since native bees have varied life cycles and life spans, different species emerge from their nests at different times in the year. It is important that pollen and nectar resources are provided from early spring to late fall; this can be done by strategically planting for overlapping blooms. The plants listed below are only suggestions and provide only a few flower suggestions based on their blooming periods.

Mid to Late Spring

Wild Columbine (***Aquilegia canadensis L.)***

Wild Geranium (***Geranium maculatum)***

Creeping phlox (***Phlox stolonifera)***

Wild indigo (***Baptisia)***

Early Summer

Beardtounge (Penstemon)

Spiderwort (Tradescantia)

Coreopsis

Asclepias

Mid-Summer

Purple Coneflower ***(Echinacea)***

Blazing Star ***(Liatris)***

Mountain Mint ***(Pycnanthemum)***

Joe Pye Weed (***Eutrochium purpureum)***

Late Summer and Fall

Sunflower ***(Helianthus)***

Coneflowers ***(Rudbeckia)***

Aster ***(symphyotrichum spp.)***

Goldenrod ***(Solidago)***

Natural areas

Urban natural areas usually serve as parks and open green spaces in the city. Green spaces in the city are crucial for human well-being and other species. In urban areas, green spaces are where most flora and fauna are restricted to. Natural areas in an urban setting are usually maintained by removing invasive species, and they are shaped to provide ample habitat for plants and animals. Urban natural areas have the most potential to serve as educational tools to raise the public's awareness. Suppose these spaces prioritize pollinator habitats, especially for native bees. In that case, the opportunity arises to change the public's perceptions about bees while raising awareness of the importance of native bees and their decline.

The conservation of solitary bees is vital for adequate crop pollination. Conservation also aids in increasing the public's awareness of the importance of native bees (Eeraerts, 2020; Garibaldi et al., 2020). It is crucial to provide evidence-based guidelines for the future implementation of pollination management (Eeraerts, 2020). The purpose of this table on cavity materials is to provide research-based findings on different types of natural and artificial nesting materials. Choosing the correct material(s) for man-made cavity nests is crucial to being an effective pollinator management practice. If the correct measures are not taken to maintain man-made bee nests, efforts of this conservation method could become more harmful than helpful to native bee populations (Eeraerts, 2020; Lee-Mäder & Xerces Society, 2011; Miloje Krunič & Stanisavljevič, 2006). Many materials are not suitable for making cavity nests for solitary bees. However, research is still ongoing to find the most suitable materials to create nests for solitary bees. It has to be remembered that native bees vary in size and shape, and so do their needs, habits, and vulnerabilities. Therefore, nesting materials for one species may not work for a different species. The cavity sizes of man-made nests are also important due to the variation in the size of native bees (Rhodes et al., 2009).

Due to the gap in research on testing and comparing cavity nests by materiality, some of the materials listed in **Table 1** do not have adequate research supporting a material's effectiveness. However, the materials listed are based on man-made and natural materials in which bees have been found to nest. The listed materials with an asterisk next to it are materials that have yet to be widely researched and tested through scientific studies.

CAVITY MATERIALS

CAVITY MATERIAL	DESCRIPTION	PROS	CONS
Wood	Solid wooden block with drilled cavities or Wooden grooved boards	Drinking straws, plastic tubes, or corrugated plastic sheets	Cannot be opened easily for cleaning. Can be a breeding ground for parasites, mites, and mold
Cardboard	Rolled tubes, corrugated strips, or milk cartons	Thick cardboard walls help to reduce the ability of parasites to enter the nest (MacIvor, 2016; Stubbs et al., 1994)	Not long lasting in weather conditions
Glass	Thinly blown glass tubes, plugged at one end with a stopper	Permits viewing of nest building behavior (Balfour-Browne, 1925; Frolich & Parker, 1983; Hartman, 1943; MacIvor, 2016)	Expensive, easily broken, condensation (MacIvor, 2016; Medler & Fye, 1956)
Clay*	Fired or unfired brick or structure with drilled cavities	Successfully used by Marlène Huissoud in her project 'Please stand by' (found on pg*)	More testing and research is needed
Paper*	Paper drinking straws placed inside of wood, brick, glass, or plastic	Easily disposed of however more research and testing are needed	If there are gaps between the paper and outermost material, it may allow parasitic wasps to enter the cavity (Alton & Ratnieks, 2020)
Plastic*	Drinking straws, plastic tubes, or corrugated plastic sheets	More testing and research is needed	Non-permeable and plastic straws had a 90% mortality rate (Fye, 1965)

Table 1- Design framework cavity materials pros and cons (Source, Author)

CAVITY MATERIALS CONTINUED

CAVITY MATERIAL	DESCRIPTION	PROS	CONS
Adobe/Brick*	Mud bricks dried in the sun with drilled cavities	Bees have been found to nest in cracked bricks and in crumbling wall foundations (Williams, 1981)	More testing and research is needed
Styrofoam*	A plastic based product with drilled nesting cavities	More testing and research is needed	Not permeable, and less availability compared to natural materials such as wood (MacIvor, 2016)
Hollow Stems	Cut segments of bamboo, reeds or pithy stems that are dried and bundled together. Usually has a diameter of 20 mm or less	Free and widely available	Cracks in stems allow for exposure to parasites (MacIvor, 2016)

PUBLIC ART

IMPORTANCE

Public art creates an attachment to one's community and enhances social cohesion (Hunt & Vickery, 2011). Additionally, public art is influential as it engages the community, and community engagement is a polymer that can connect neighbors and create a sense of community culture. One primary advantage of community involvement in revitalizing urban spaces with public art is that the final design reflects the concerns and ideas of residents (Naghibi et al., 2020). Public art can transform mundane places into landmarks or icons that express the depths of human imagination.

TYPES OF PUBLIC ART

Art is anything created with imagination and expresses creativity surrounding ideas and feelings (Merriam-Webster, 2019). Public art is shared free of charge in a public space. It can be interactive and ever-changing, making it more dynamic and compelling for onlookers (Gschwend, 2015). Public art is a powerful tool with many functions; it expresses civic identity and symbolism, incites community participation, offers an affordable or low-cost attraction, or enhances plazas and grand buildings (Hunt & Vickery, 2011). In recent years, the commissioning of public art has increased, while its production has become more site-specific—shaping cities to be recognized for their unique cultural traits. Public art stimulates global tourism and can usually be found in civic events, festivals, and cultural exhibitions (Hunt & Vickery, 2011). Murals, sculptures, statues, memorials, community art, and landscape architectural work are all types of public art; public art can be temporary, permanent, or interactive (Russell, 2004).

Street Art

Street art is a type of public art that can also come in varying forms. It has become much more prevalent in recent years, as seen in popular culture (Bengtsen, 2014). Street art is made up of un-commissioned artworks in public spaces. The most well-known variants of street art include graffiti; however, it can be presented in various forms such as murals, sculptures, yarn bombing, sticker art, reverse graffiti, and sidewalk chalk art. Because street art is created on public city-owned surfaces, many street artists must remain anonymous or use pseudonyms, rendering the artists unidentifiable or challenging to contact. Despite some forms of street art being considered vandalism, street art is vibrant, creative, beautiful, and can add to the character of a city (Bengtsen, 2014; Hunt & Vickery, 2011; Riggle, 2010).

Interactive Art

Interactive art is an art form that expands beyond the limits of the participant›s visual perception and encourages participants to explore their curiosities and create an experience. Interactive art allows users to experience it through multiple senses, such as touching, listening, moving around, and breathing (Grammatikopoulou, 2016; Wong et al., 2009).

Permanent Art

Permanent public art is an art form that exists in that space to remain unchanged indefinitely. While permanent public art is not initially installed with intentions to be removed, external factors can affect how permanent an installation can be. Current events and changing viewpoints can alter people›s feelings about existing public art (McGonagle, 1990; Phillips, 1989).

Temporary Art

Temporary public art is an art form installed with the expectation that it will eventually be removed. The beauty of temporary public art is that it brings the community outdoors to invigorate a space for a short period of time—only those who see the installation get to experience it until it is gone. Sometimes, with temporary art, the range of time is not given; one day, the installation could be there, and the next day it could be gone or replaced with something else (Guthrie, 1894; McGonagle, 1990; Phillips, 1989).

SOCIAL PRACTICE ART

Social practice art, also known as socially engaged practice or socially engaged art, is an art form that usually involves communities in some form of collaboration, participation, debate, and or social interaction (Green, 1999; Helguera & Jorge Pinto Books, 2011). Arguably, all art is participatory in some way because it requires the presence of spectators, and simply being in front of an artwork is a form of participation (Helguera & Jorge Pinto Books, 2011). Participation is a crucial element of social practice art, and depending on the extent of the viewer's engagement, levels of participation can be understood as follows (Lacy, 1996);

Nominal participation:

The viewer reflects and contemplates the artwork in a passive detached manner

Directed participation:

The viewer completes a task contributing to the creation of the artwork

Creative participation:

The viewer provides content falling within the established criteria from the artist for a component of the artwork

Collaborative participation:

The viewer shares the responsibility of developing the content and or structure of the artwork and interacts with the artist directly.

Often, nominal and directed participation develop over a single encounter. In contrast, the creative and collaborative types of participation can span and develop over more extended periods such as days, weeks, months, or years (Helguera & Jorge Pinto Books, 2011; Lacy, 1996). Additionally, the level of participation utilized does not determine the level of success or desirability of an art piece (Helguera & Jorge Pinto Books, 2011; Lacy, 1996).

CONCLUSION

Pollinator habitats are crucial to the survival of pollinators. With the advancement of human development, we have effectively pushed pollinators out of their natural native habitats. Because urban and rural development has pushed pollinator numbers to the point of severe decline, we must learn how to coexist with them. The concept of pollinator art finds a novel way to bring awareness of pollinators and their habitat needs while also combining and integrating those needs into the fabric of rural and urban communities.

CHAPTER 3

Methods

APPROACH

The approach taken for this project is artistic research. Artistic research is the combination of research and artistic creation (Kingery-Page, 2011). This approach was chosen to gain a deeper analysis of the needs of North American native pollinators; through producing a work of art. The approach to this project was artistically experimental and was used to find a creative method to address pollinator decline. Although artistic research is controversial design philosophy, many scholars argue for proper respect and recognition of the research method within academia (Eisner, 1981; Melvin & Kingery-Page, 2013). This project has taken this specific approach believing that artistic research is just as valid and legitimate as scientific research. Both methodologies are equally legitimate as they can both be utilized in an exploratory way to gather and analyze information to propose solutions or improvements to a dilemma (Kingery-Page, 2011).

SITE CONTEXT

The sites selected for this project were chosen based on the preliminary GIS analysis done in Sara Hadavi's Fall 2021 Studio. The study area was assessed for multiple areas that could potentially host pollinator art based on the four urban settings for the Design Framework: bus stop, residential, natural area, and community garden. After the potential sites were selected, design inquiry took place, starting with the precedent study.

PRECEDENT STUDY

A precedent study was conducted to gain awareness of existing artistic projects incorporating pollinators or pollinator habitats. The goal of the precedent study was to find innovative and unique projects that were artistic and designed beyond the typical bee hotel. In the beginning, the approach to the precedent study was broad. Many images of artistic bee home installations were gathered. During this collection stage, materiality considerations were yet to be applied. This broad approach enabled a review of different approaches artists have taken to design bee hotels and pollinator habitats outside the norm. After the broad collection of images, the examples were narrowed down to five projects. The five examples chosen for the precedent study were based on specific criteria. The criteria included: materiality, form, innovative application, acknowledgment, and appeal.

Materiality: Project must use materials other than or more than bamboo, wood, or wood-based materials.

Form: Project must take shape or form of something other than a typical wooden bee hotel.

Innovative Application: Project must serve a separate purpose additional to pollinator habitat or nesting.

Acknowledgment: Project must have received recognition through publication, showcasing, or prestigious awards and honors.

Appeal: Project must be visually engaging and thought-provoking.

The four projects selected provided a diverse range of work to reference during the design inquiry. The precedent study exemplifies innovative ways to support, design, or enhance pollinator habitats. Ultimately, the precedent study reveals alternative ways to incorporate pollinator habitats and homes in ways that can be applied in an urban setting.

DESIGN FRAMEWORK

After selecting a site for pollinator art within the study area, information gathered from the literature review was synthesized to provide the foundation for the project's design framework. The literature provided background information on pollination and pollinators, including their importance, life-cycles, needs, habits, and causes of their decline. Research was also conducted to provide background information on public art and its importance.

A design inquiry framework was synthesized after writing a literature review on relevant research related to pollinators and public art. The framework is a table that lists materials and native plants optimal for man-made pollinator habitats or homes based on a listed urban zone type. The framework's materials list includes explanations of the pros and setbacks of each material, along with explanations of why the listed native plants are most beneficial to the urban zone it would be located in. The native plants listed within the framework are optimal for the site's regional location and the specific urban zone under

which it is categorized. The framework's purpose is to guide this project's design inquiry and future design applications based on varying site contexts that can easily be found within an urban metropolitan area.

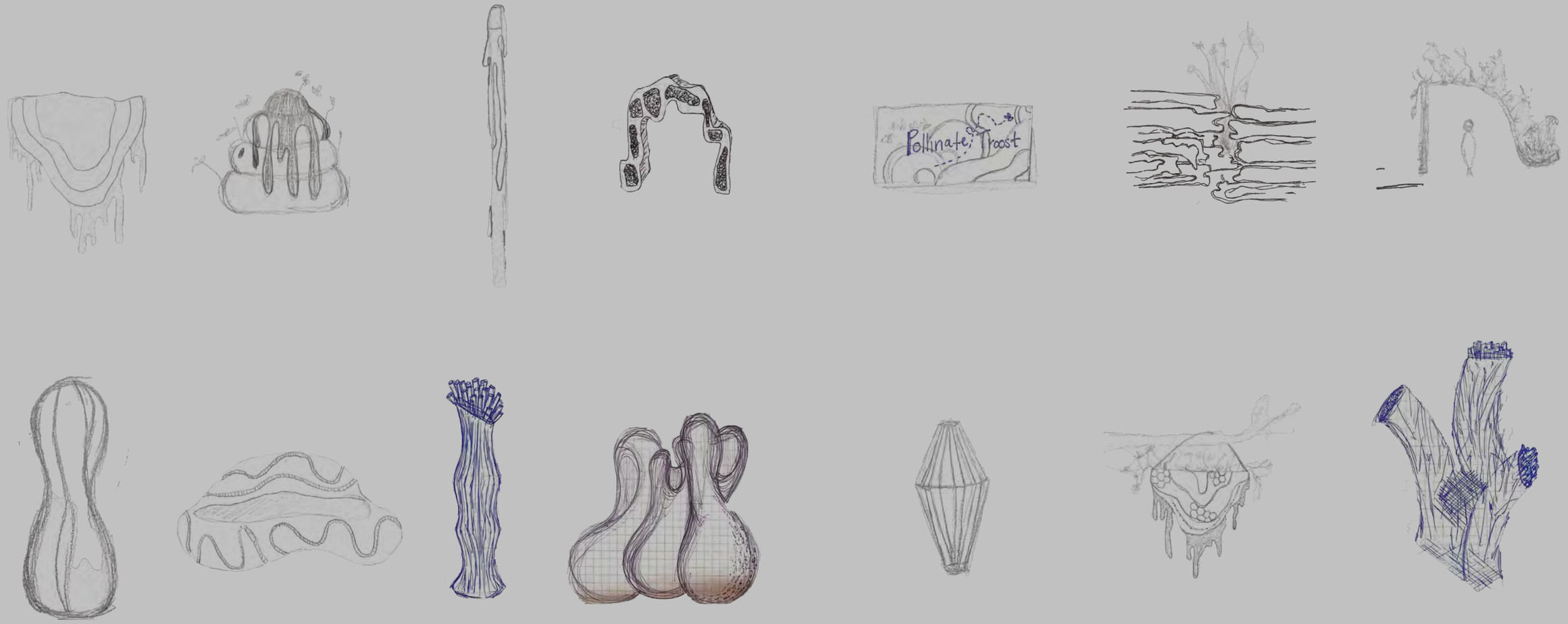
DESIGN INQUIRY

The design inquiry was an iterative process that began with quick drawings of initial ideas in a sketchbook—quickly drawing out ideas helped to get all ideas out and see them on paper, even if they did not make sense, see **Figure 13**. After getting all ideas out in a sketchbook, the framework was revisited. Additional designs were sketched based on the urban settings of the design framework. The sketches based on the design framework's urban settings were then shared with the committee chair for suggestions and critique. Suggestions From the committee chair aided in making the decision of which idea this project would focus on.

DESIGN DEVELOPMENT

To further design development, modeling clay was utilized to experiment with the form and shape of the design. This small-scale model-making aided in further understanding the design in the third dimension. Small-scale model crafting allowed experimentation, enabling a quick process to test how the art piece could be put together. After the small-scale model making with clay, AutoCAD 2023 was used to draw an abstract footprint of the modular art piece. Sketchup and Lumion were used to create a 3D design model to solidify the design's form and potential materials. Modeling the design three-dimensionally helped develop a name for the design; The Bee Barnacle. Throughout the design development for The Bee Barnacle, its future maintenance was considered and integrated into the design idea. A few tips were also provided to guide others wanting to utilize the nesting cavities of The Bee Barnacle. Ideally, the methodology for this project and the tips given about maintaining it, can be used to replicate, design, and maintain other creations of pollinator art.

Figure 13- Early exploration of pollinator art designs through sketching whichever ideas came to mind. The design framework was not applied to these early free-flow sketches (Source: Author)



CHAPTER 4

Precedents

PRECEDENT STUDY

The following works of art were chosen based on the design accommodations created to host living organisms such as native bees and/or native plant species. Some of the works selected for this precedent study exemplify how pollinator foraging and/or nesting habits can be supported by public art. Other works selected for this precedent study exemplify how different materials can be utilized to support the conservation of native bees. The Criteria used to select the following precedents include materiality, form, innovative application, acknowledgment, and appeal.

Materiality: Project must use materials other than or more than bamboo, wood, or wood-based materials.

Form: Project must take shape or form of something other than a typical wooden bee hotel.

Innovative Application: The project must serve a different purpose in addition to pollinator habitat or nesting.

Acknowledgment: Project must have received recognition through publication, showcasing, or prestigious awards and honors.

Appeal: Project must be visually engaging and thought-provoking.

BEE BRICKS

Designer: Green&Blue

Location: Brighton, England

Material: Brick

Description: Bee bricks have become the new planning requirement for new buildings in Brighton. Bee bricks, shown in **Figure 14**, are the size of regular bricks; they are incorporated with narrow openings suitable for solitary bee nesting. Bee bricks were designed to mimic the natural cavities in old brickwork, where solitary bees have been found to nest. The creators of bee bricks aim to bridge the gap between fragmented pollinator habitats.

Figure 14- Bee Bricks are cement blocks with holes of vary diameters drilled into it. Bee bricks are integrated into exterior walls of homes to serve as shelter for native bees (Source: Bee Brick by London Permaculture, 2016, Available through creative commons)

SCULPTURAL CHAIRS

Designer: Marlène Huissoud

Location: London

Material: Unfired clay, natural binders, wood

Description: 'Please stand by', shown in **Figure 15**, is an installation that is both sculptural and functional. The pieces of this project are made of unfired natural clay, coated with a natural binder for weather protection. The main goal of this project is to provide a space of refuge for native pollinators. These sculptural pieces were created with the help of scientists Robert Francis and Mak Brandon from King's College London. The colors of the materials used for this project were chosen to reflect colors pollinators are attracted to in nature. This sculptural installation was sustainable and organically made with the intention to provide nesting and hibernation spaces for London's native pollinators. Ultimately, this project aims to encourage biodiversity and increase ecosystem productivity.

Figure 15- Art installation created by Marlène Huissoud to provide shelter for solitary bees, encourage biodiversity, and increase ecosystem productivity (Source: 'Please stand by' by Marlène Huissoud, Available at https://www.marlene-huissoud.com/please-stand-by)

GREEN-ROOFED BUS SHELTERS IN UTRECHT

Designer: City of Utrecht

Location: Utrecht, Netherlands

Description: The city of Utrecht implemented a wide-scale project installing green roofs on city bus stops. See **Figure 16**. The green roofs store rainwater, provide cooling when it is hot, and promote urban biodiversity. The main goal of this project is to promote pollinator biodiversity in the city. The city implemented this wide-scale project to make the city greener and more appealing. The bus stops were designed with sustainability in mind and contain features such as LED lighting, solar panels, bamboo benches, recycled concrete, and sedum, a drought tolerant plant that requires little to no maintenance. The City of Utrecht also wanted the maintenance of these bus shelters to be sustainable and have ensured that all maintenance teams drive electric cars. On a larger scale, The City of Utrecht has future goals and initiatives to which the implementation of these bus stops contributes. The city's future initiatives include; a carbon-neutral Utrecht, facilitating low energy consumption, and generating feelings of safety, positivity, and comfort through the development of nature-inclusive designs.

Figure 16- In Utrecht, bus stops with green roofs were installed to serve as pollinator habitats and places of refuge for migrating pollinators (Source: Green bus stops in Utrecht by uitdragerij, 2019, Available through creative commons)

THE POLLINATORS PAVILION

Designer: Harrison Atelier.

Location: Old Mud Creek Farm, Hudson, NY

Size: **18ft** x 14ft x 9ft on 2,500 acres

Materials: Ductal Concrete panels, Wood, Solar panels, AI software

Built: 2019

Description: The Pollinators Pavilion, shown in **Figure 17**, is a bee sanctuary that utilizes AI to automate insect identification. The pavilion is made up of an innovative system of panels containing hundreds of nesting tubes for solitary bees. The Pollinators Pavilion is a solar-powered electronic system that monitors the diverse populations of cavity-dwelling native bees. The monitoring system contains motion sensors that capture a photograph through an endoscopic camera when triggered by insect movement. The images captured are processed into the database of an artificially intelligent system that learns and seeks to identify native bee species without trapping and killing the bees. The monitoring system also monitors the micro-conditions that develop within the pavilion and its nesting structures. The Pollinators Pavilion was created and designed to address the gap in research regarding native bees while promoting biodiversity and ecosystem restoration. The data collected from the pavilion's monitoring system is used to bring awareness of native bees to the general public.

Figure 17- The Pollinators Pavilion integrates AI technology and pollinator habitat into pollinator habitat to track native bee species visiting the installation (Source: Harrison Atelier, Available at https://www.pollinatorspavilion.com/page08)

CHAPTER 5

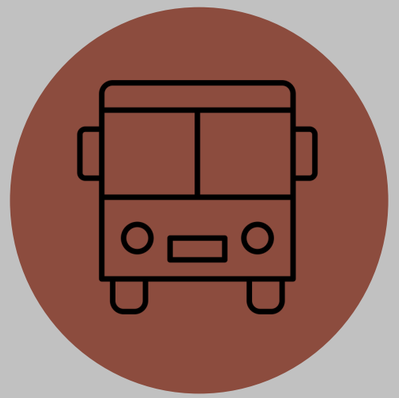
Designing

The designs created for this report were all designed based on how they could exist within an urban setting. The following are four types of urban settings the designs could potentially exist. See **Figure 18** for a map of urban settings within the study area.

COMMUNITY GARDENS

Community gardens offer many opportunities to accommodate pollinator populations. A wide range of native plants can be grown in or near community gardens that would be beneficial to them. See **Figure 19**.

BUS STOPS



Bus stops are prime areas to implement pollinator habitats and beautify urban areas. Additionally, bus stops can be used to educate the public about native bees and their importance. See **Figures 20** & **21**

NATURAL AREAS

Natural areas are prime spaces to plant for a succession of blooms throughout the year. Since native bees have varied life cycles, different species emerge from their nests at different times in the year. See **Figure 22**

RESIDENTIAL

Residential settings can be utilized to provide pollinator habitats in front and back yards and vacant lots. The addition of pollinator habitats can aid in the beautification of residential street scape while closing the gaps of fragmented pollinator habitats. See **Figure 23**

Figure 18- Map of urban setting types within the selected study area (Source: adapted from Arc GIS and Google Maps)

URBAN SETTINGS

RESIDENTIAL

Residential zoning

BUS STOPS

Existing Bus route

Existing Bus stops

COMMUNITY GARDENS

Existing community gardens

NATURAL AREAS

Existing parks or natural areas

COMMUNITY GARDEN

THE DRILLED HOLES CAN BE EASILY CLEANED FOR YEARLY MAINTENANCE, TO PREVENT THE SPREAD OF DISEASE AND PESTS

DRILLED HOLES IN RECYCLED CEMENT BLOCKS PROVIDE NESTING CAVITIES FOR SOLITARY BEES

POLLINATORS ARE NOT ONLY BENEFICIAL TO FLOWERS, BUT THEY ALSO HELP TO POLLINATE CROPS

THE ADDITION OF POLLINATOR HABITAT GARDENS WILL AID IN THE GROWTH AND ABUNDANCE OF FRUITS AND VEGETABLES

UTILIZING THE CEMENT BLOCKS AS PLANTERS FOR NATIVE PLANTS PROVIDE ADDITIONAL FLORA FOR NATIVE BEES TO POLLINATE

Figure 19- Digital rendering of an early visualization of a pollinator art design within an urban community garden setting (Source: Author)

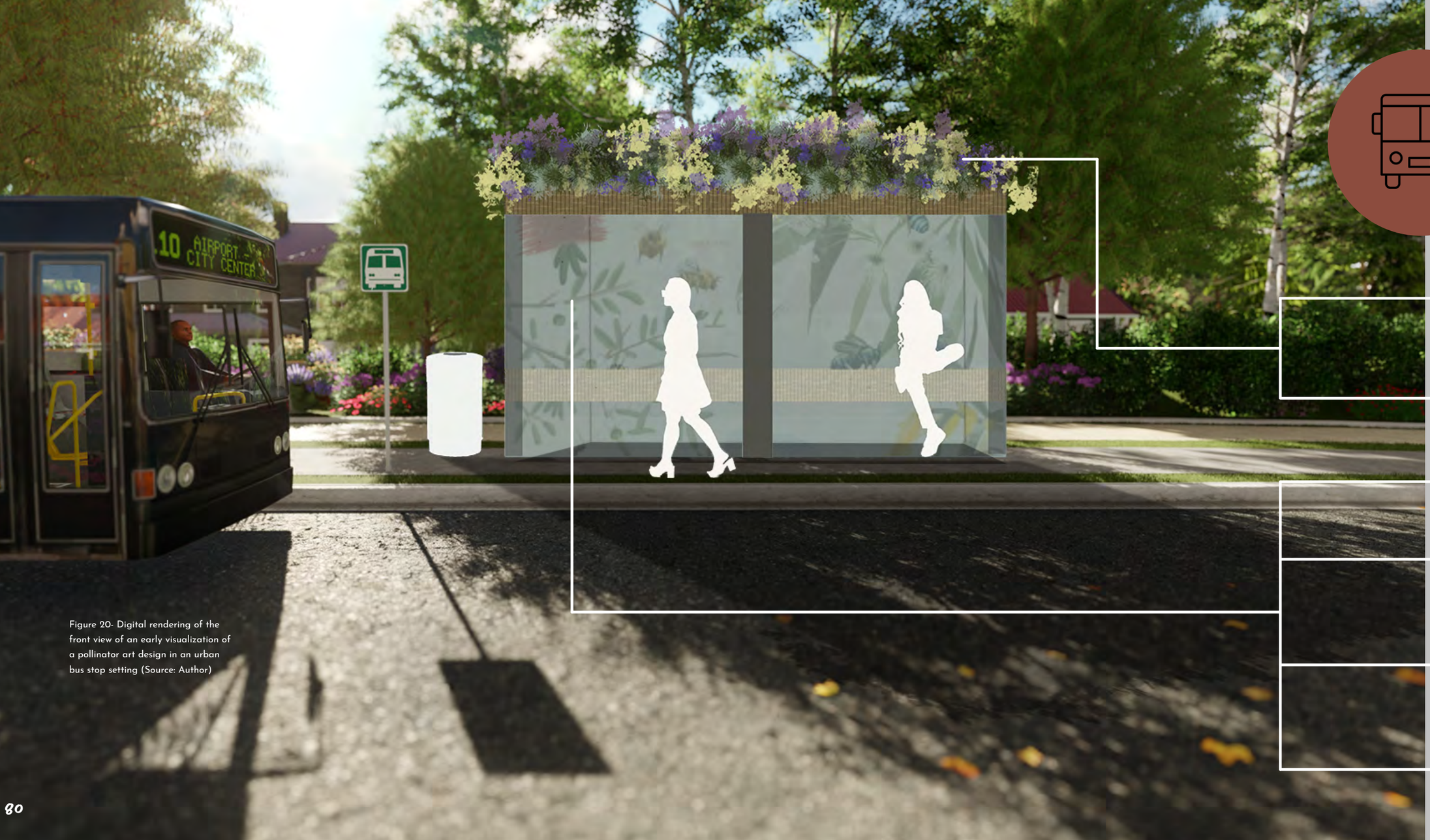


Figure 20- Digital rendering of the front view of an early visualization of a pollinator art design in an urban bus stop setting (Source: Author)

BUS STOP

SALT-TOLERANT PLANTS SHOULD BE USED FOR THIS INSTALLATION

UTILIZING SALT-TOLERANT PLANTS HELP TO PREVENT PLANT INJURY DURING THE WINTER MONTHS, WHEN ICY ROADS ARE SALTED

A MURAL IS PAINTED ON THE INTERIOR OF THE BUS SHELTER

THE PAINTED MURAL PROVIDES INFORMATION ON VARIOUS SPECIES NATIVE BEES AND

THE INFORMATION PROVIDED ON THE MURAL WILL CONTAIN IMAGES AND NAMES OF BEE SPECIES AND A FUN FACT ABOUT THEM

INFORMATION WILL BE PROVIDED WITHIN THE SHELTER ABOUT THE INSTALLATION'S PURPOSE.

BUS STOP

NATIVE PLANTS ARE USED TO PROVIDE HABITAT FOR THE NATIVE BEES TO FORAGE FOR FOOD AND NESTING MATERIALS

DRILLED WOODEN CAVITIES ARE FILLED WITH HOLLOW REEDS AND STEMS OF VARIOUS SIZES TO PROVIDE NESTING CAVITIES FOR NATIVE BEES

THE HOLLOW STEMS AND REEDS ARE REMOVABLE TO MAKE Annual CLEANUP AND MAINTENANCE EASIER

SOIL SUBSTRATE IS USED AS A MATERIAL TO PROVIDE HABITAT SPECIFICALLY FOR GROUND NESTING BEES

DRILLED HOLES IN ADOBE AND CLAY BRICKS PROVIDE NESTING CAVITIES FOR NATIVE BEES AND ARE EASY TO CLEAN

Figure 21- Digital rendering of the back view of an early visualization of a pollinator art design in an urban bus stop setting (Source: Author)

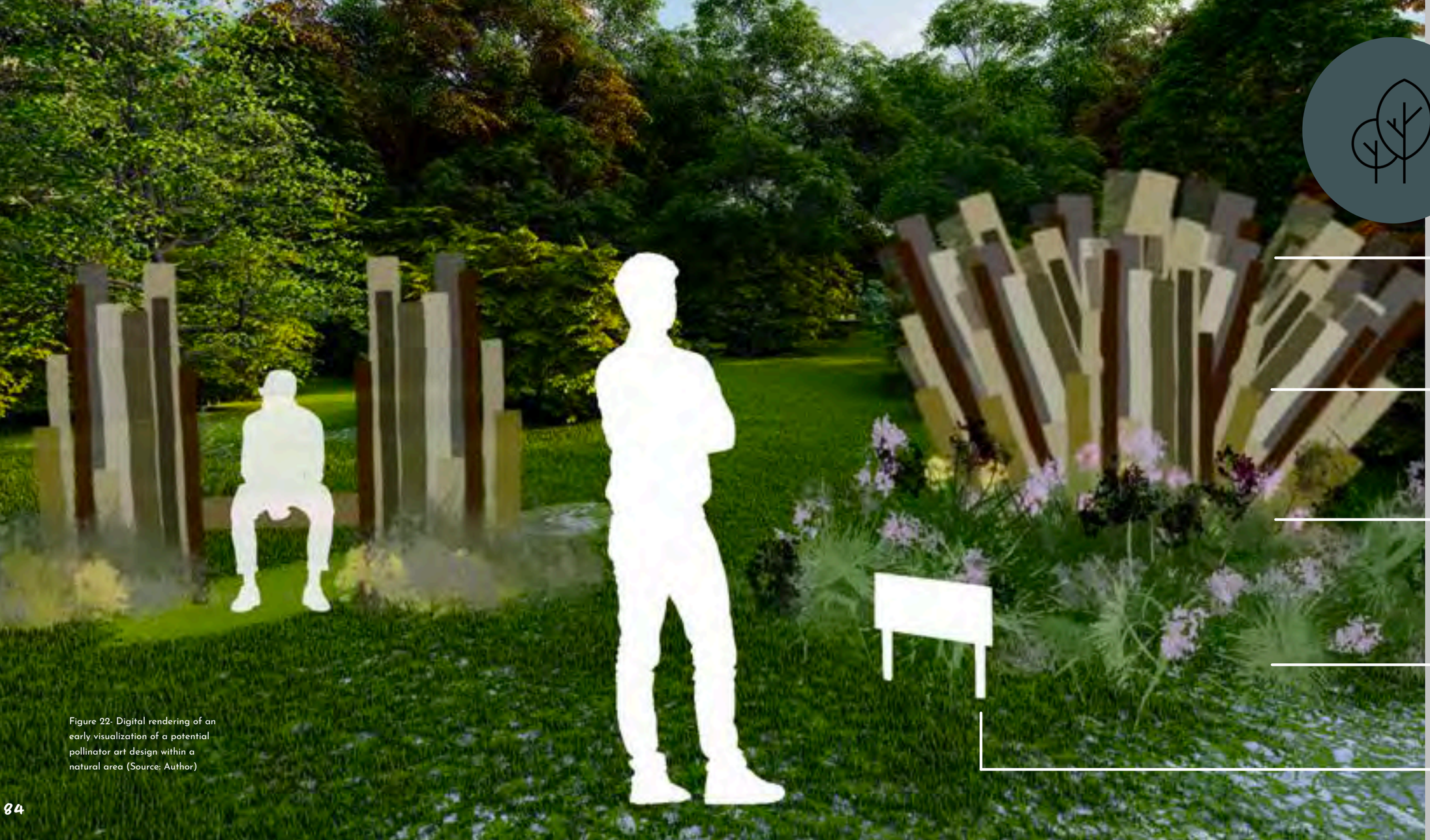


Figure 22- Digital rendering of an early visualization of a potential pollinator art design within a natural area (Source: Author)

NATURALIZED AREA

PIPES ARE FILLED WITH CONCRETE. HOLES OF VARIOUS SIZES ARE DRILLED INTO THE CONCRETE TO PROVIDE NESTING HABITAT FOR NATIVE BEES.

HOLES ARE DRILLED INTO CLAY. FIRED CLAY IS USED FOR EASY ANNUAL MAINTENANCE AND CLEANUP TO PREVENT THE SPREAD OF DISEASE

BAMBOO-ESQUE PIPES RADIATE OUTWARD TO CREATING AN ARTISTIC SCULPTURE THAT CAN EXIST IN AN URBAN NATURALIZED AREA, SUCH AS PARKS OR VACANT LOTS

NATIVE PLANTS ARE PLANTED NEAR THE BASE OF THE SCULPTURE PROVIDING ADDITIONAL FLORA TO POLLINATE. NATIVE PLANTS ALSO PROVIDE FORAGING MATERIALS FOR THE BEES

SIGNAGE IS PLACED NEAR SCULPTURE TO INFORM THE PUBLIC OF ITS PURPOSE AND BENEFITS TO THE AREA AND POLLINATORS

RESIDENTIAL AREA

HOLLOW STICKS ARE FILLED WITH CEMENT. SHALLOW HOLES ARE DRILLED TO PROVIDE NEST CAVITIES

THE OUTER SHELL OF THE STRUCTURE INTEGRATES NATIVE PLANTS TO PROVIDE FORAGING MATERIAL FOR POLLINATORS

POLLINATOR HABITATS IMPLEMENTED INTO IN URBAN STREET SCAPE IS BENEFICIAL; AS IT BRIDGES GAPS BETWEEN POLLINATOR HABITATS

Figure 23- Digital rendering of an early visualization for a potential design of pollinator art in a residential area (Source: Author)

BEE BARNACLE

The Bee Barnacle is a versatile modular sculpture. See **Figure 24**. This rendition of pollinator art can be made at various scales, allowing it to exist in many urban settings. The modular aspect of this design allows it to be a dynamic multi-purpose public art piece. The Bee Barnacle's primary purpose is to provide a habitat for native bees within an urban setting. The Bee Barnacle is also a public art installation that intends to engage the public and educate its visitors on its importance and benefits. The Bee barnacle is designed to pique the public's curiosity and encourage thought-provoking discourse about native bees, pollinator decline, and how public art can be further utilized to raise awareness.

At first glance, perceptions of pollinator habitats are not usually positive, and it is common for the public to deem pollinator habitats as having a weedy or unkempt look. My goal is to change those perceptions by providing resources to educate the public on native bees, native habitats, and their importance. Through artistic design, I aim to shorten distances between pollinator habitats and revitalize blighted urban areas.

Figure 24- Depiction of the plain form of The Bee Barnacle (Source: Author)

BEE BARNACLE DESIGN PROCESS

The process of designing iterations of The Bee Barnacle, shown in **Figure 25**, began with sketching, followed by small-scale clay model making and digital drawings. The idea for Bee Barnacle started with a simple sketch depicting the design's physical form and essential elements. Two small-scale clay models were made to explore the form and language of the art piece. This step in the design process provided clarification that the art piece would work best as a modular sculpture for ease of use and versatility. Digital iterations aided in the exploration and depiction of what occurs within the interior and exterior of the modules. AutoCAD enabled artistic exploration of Bee Barnacle's footprint. The AutoCAD line-work provided an abstract rendition of what Bee Barnacle modules could look like if they behaved as one unit.

Figure 25- Diagram of iterative design process for The Bee Barnacle (Source: Author)

INSPIRATION FOR BEE BARNACLE

The design shown in this report for The Bee Barnacle was inspired by four different things. See **Figures 26-29**. Each inspiring factor contributed to an element of the Bee Barnacle's design

GREEN WALLS

Figure 26- Green walls inspired the function of the bee barnacle modules containing plants (Source: Green wall at Semiahmoo Library. Surrey, BC by Danna § curious tangles, 2013, Available through creative commons)

MURALS OF BEES

Figure 27- Murals of bees inspired the idea of using public art as a way of spreading awareness of pollinator decline (Source: Manchester Bees Mural by David Dixon, 2017, Available through)

BUMBLE BEE NESTS

Figure 28- The form and function of Bumble bee hives inspired the form of The Bee Barnacle modules (Source: Hive by Photo Munki, 2008, Available through creative commons)

REED AND STEM NESTING CAVITIES

Figure 29- the hollow reeds and pithy stems used for commercialized bee hotels inspired the form of the nests on the nest modules (Source: Mason Bees by Dale Calder, 2012, Available through creative commons)

Native plants are planted within the modules of the Bee Barnacle shown in **Figure 30**. Native plants are suggested to be used in combination with The Bee Barnacle due to how beneficial they are to native bees.

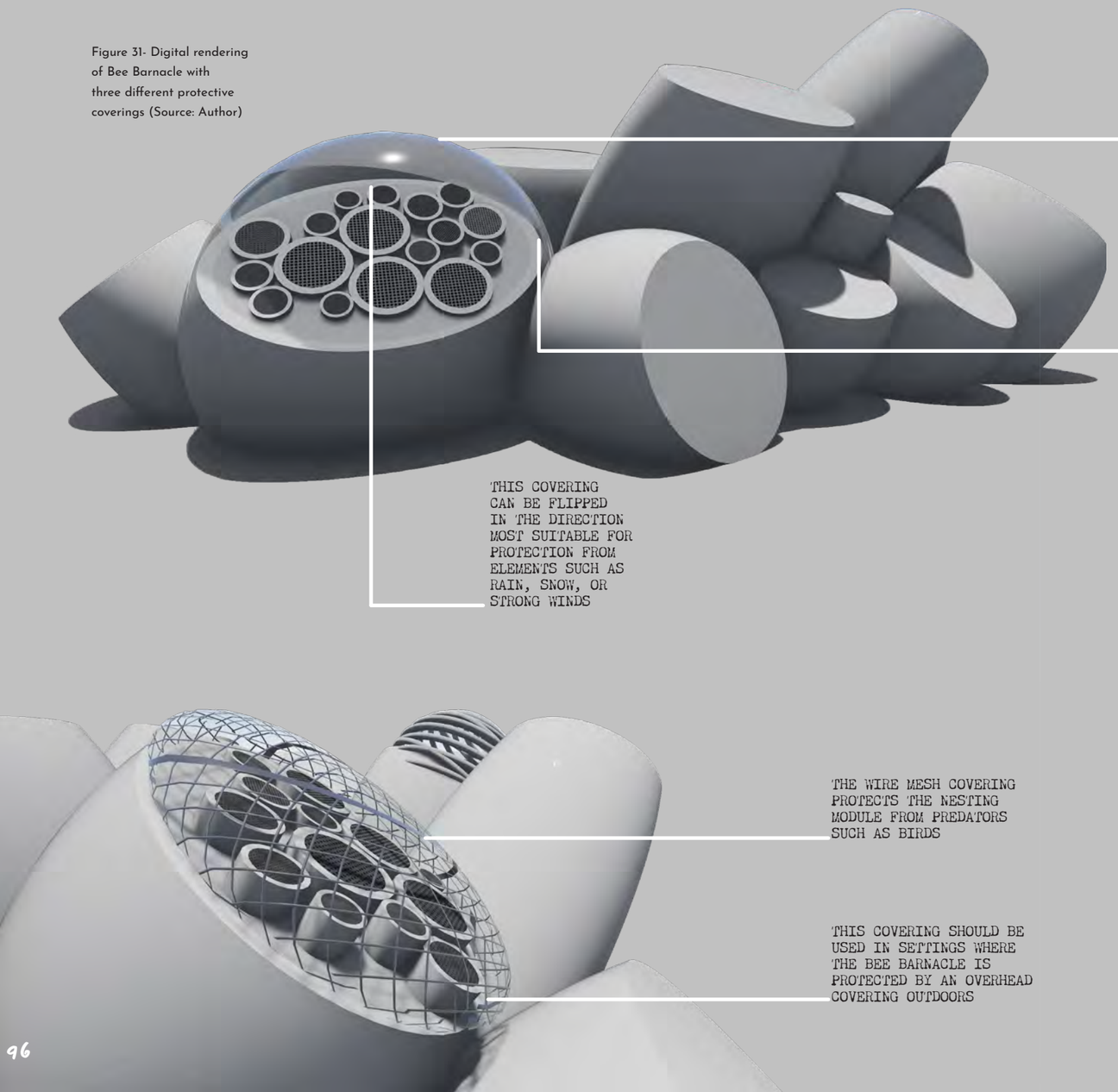
Purple coneflower
(*Echinacea purpurea*)

Asters
(*Symphyotrichum*)

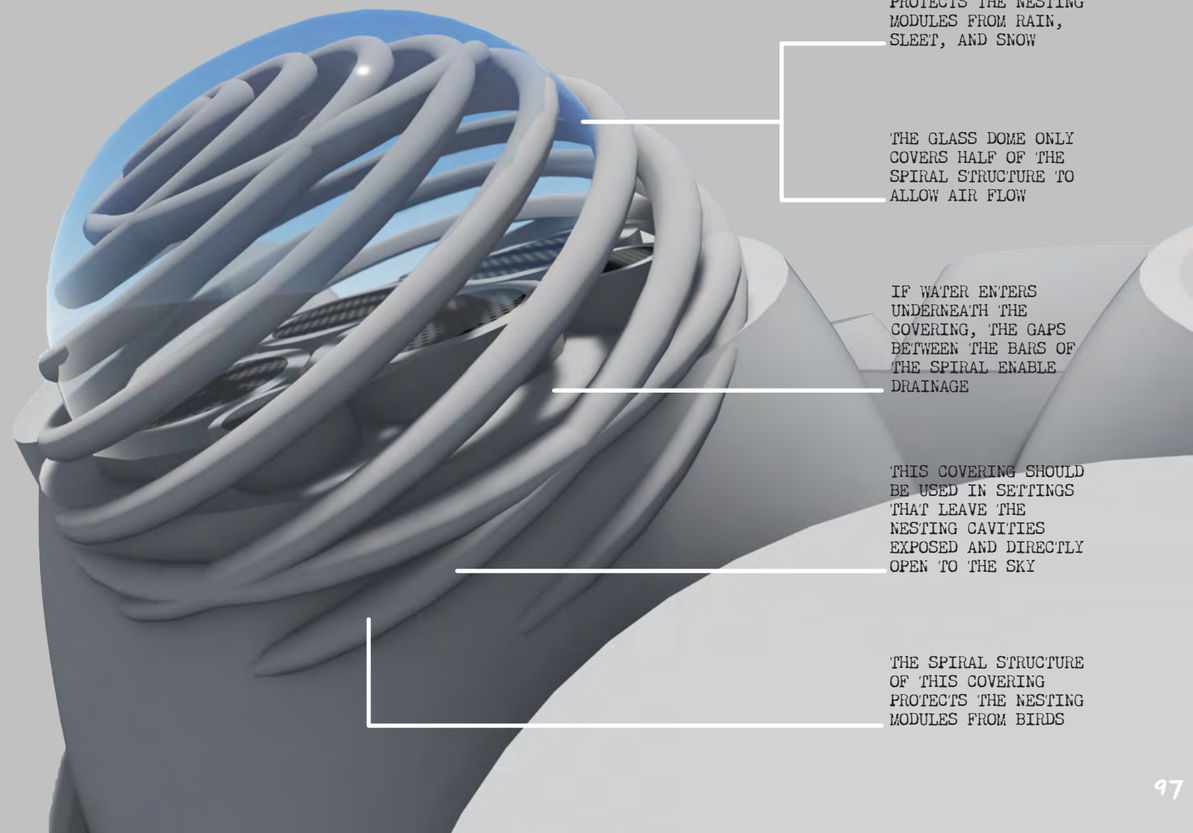
Black-eyed Susan
(*Rudbeckia hirta*)

Figure 30- Digital rendering of native plants planted within The Bee Barnacle along with images of a few plants (Source: Author)

Figure 31- Digital rendering of Bee Barnacle with three different protective coverings (Source: Author)



The Bee Barnacle can be used in various settings; therefore, three different types of coverings, shown in **Figure 31**, were designed to protect the modules containing nesting cavities. Each covering is removable to ensure ease of annual cleaning to maintain a healthy nesting environment for native bees.



The Bee Barnacle is a versatile modular sculpture that can be used in various settings. One example of a setting in which Bee Barnacle can be used is in residential areas near homes, as seen in **Figure 32**. It is common for people to fear bees; however, the Bee Barnacle is geared toward serving native bees, primarily consisting of sting-less bees. Users of the Bee Barnacle should remember that most bees that sting or swarm are bees protecting a hive and a colony, and solitary bees do not have colonies or hives. The Bee Barnacle would be beneficial to any home or garden, with the addition of native grasses and flowers and nesting habitats for solitary bees. If residents are interested in attracting other native bees, users may leave a protected perimeter of undisturbed soil for ground-nesting bees to dwell.

Figure 32- Digital rendering of Bee Barnacle used as planters in a residential garden (Source: Author)

Another example of Bee Barnacle's versatility is exemplified in a street scape setting. Bee Barnacle modules can be used as planters along streets, helping to beautify and liven up barren city sidewalks. See **Figure 33**. Adding Bee Barnacle modules to urban sidewalks creates refuge points for native bees and pollinators on their foraging journeys. Using the Bee barnacle as plants on sidewalks will help to bridge the gaps between suitable land for pollinators.

Figure 33- Digital rendering of Bee Barnacle used as planters on a sidewalk (Source: Author)

In addition to The Bee Barnacle's versatile uses, it can also be used as a sculptural element shown in **Figure 34**. The urban settings in which The Bee Barnacle can be used sculpturally include campus lawns, plazas, botanical gardens, zoos, sculptural parks, etc. The Bee Barnacle is a public art piece and can be installed in spaces where public art typically resides. The Bee Barnacle is not only for the benefit of pollinators but also for the enjoyment of visitors and onlookers. In addition to its enjoyability, the Bee barnacle benefits native bees and other pollinators, which in turn benefits human health.

Figure 34- Digital rendering of Bee Barnacle used as sculptural element (Source: Author)

The Bee Barnacle is a public art piece that can serve as public art in various ways. One of the ways The Bee Barnacle can serve as a public art piece is as a green wall mural, shown in **Figure 35**. Due to the modularity of The Bee Barnacle, a green wall mural can become a very dynamic piece existing at various scales.

Figure 35- Digital rendering of Bee Barnacle used as a green wall on the outside of building sidewalk (Source: Author)

Figure 36- A closer look at the digital rendering of Bee Barnacle depicting smaller details (Source: Author)

A CLOSER LOOK

The following is a rough representation of the modular form of The Bee Barnacle's nesting module; see **Figure 36**. The materiality, form, and scale may vary for a commissioned art piece, depending on the piece's use.

Section Cut AA

To deepen the understanding of the inner-workings of The Bee Barnacle, a horizontal section cut was made across the base model. See **Figures 37** & **38.**

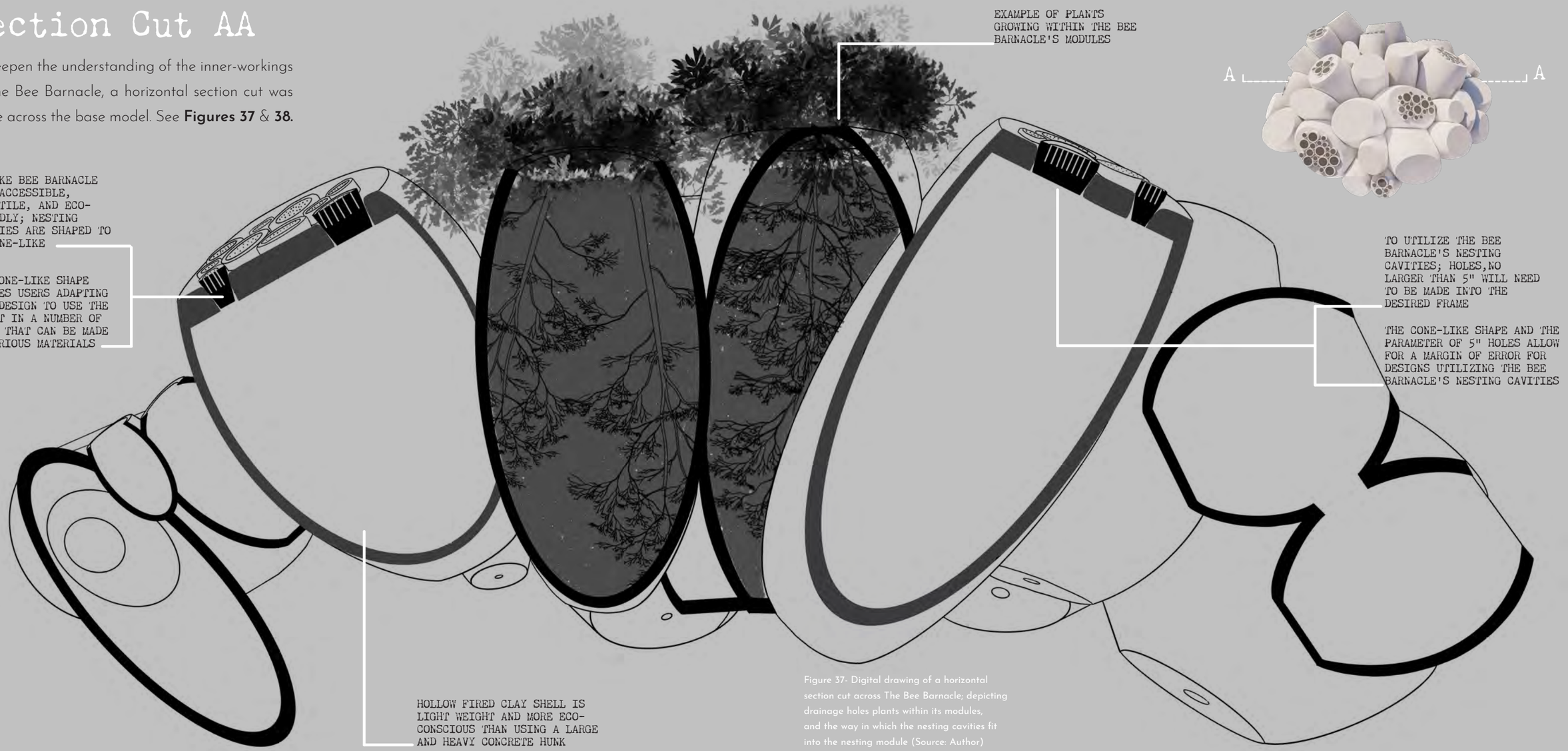


Figure 37- Digital drawing of a horizontal section cut across The Bee Barnacle; depicting drainage holes plants within its modules, and the way in which the nesting cavities fit into the nesting module (Source: Author)

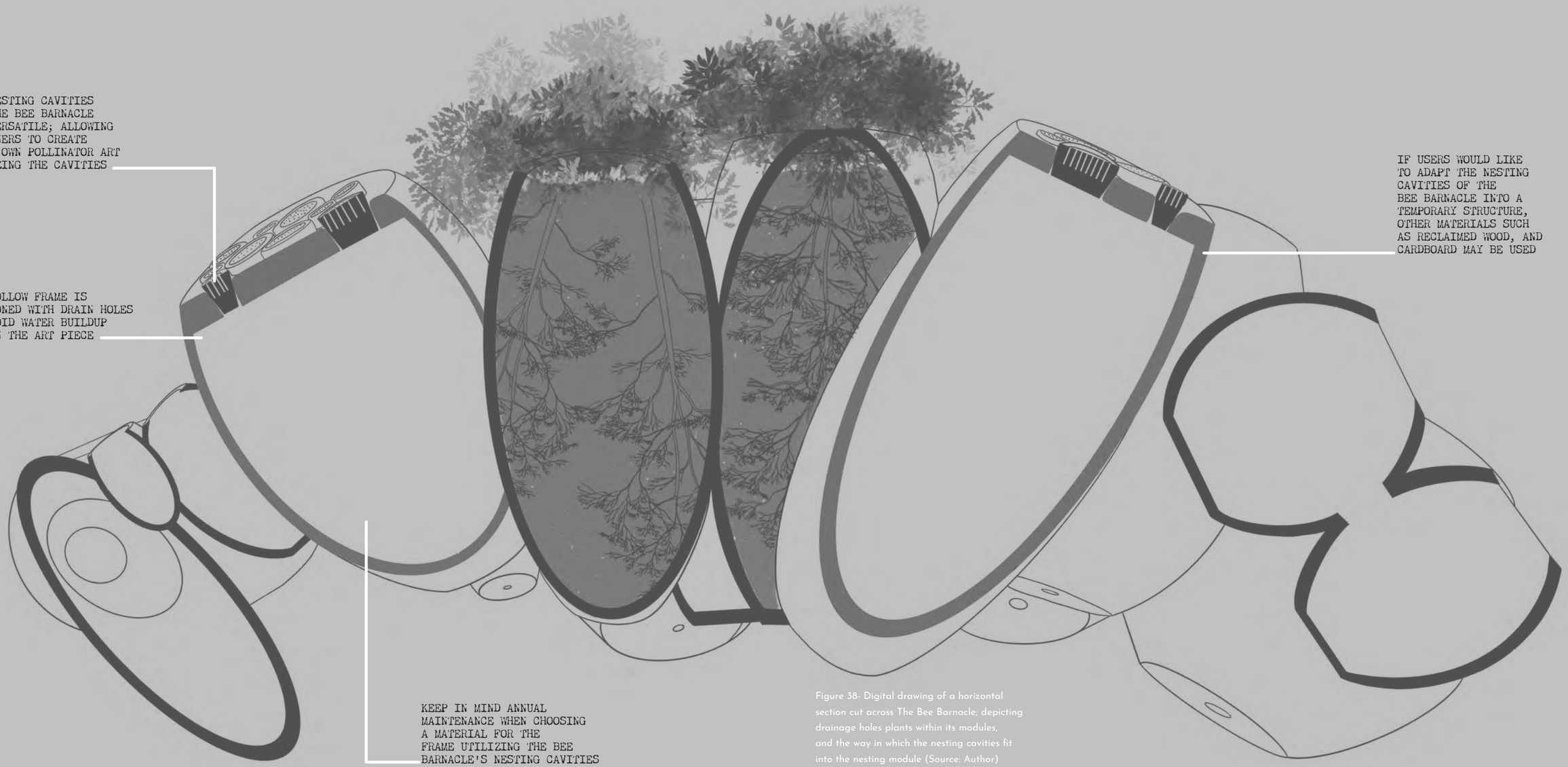


Figure 38- Digital drawing of a horizontal section cut across The Bee Barnacle; depicting drainage holes plants within its modules, and the way in which the nesting cavities fit into the nesting module (Source: Author)

CHAPTER 6

Conclusion

DISCUSSION

The decline of pollinators should be a concern to all of humankind. Native bees and other pollinators are vital to maintaining ecosystems, environmental equilibrium, and human health and well-being. We must realize that our lives rely heavily on pollinators, and our survival depends on their survival. Pollinators do not only help to sustain our favorite plants and flowers, but they also aid in sustaining crops. As agriculture and urban development continue to thrive and expand, less habitat remains for pollinator populations. Increasing conservation efforts and public awareness of native bees ensure pollinator survival.

Most of the current pollinator conservation is geared toward honey bees and butterflies. While honeybees and butterflies serve an essential purpose in pollination, the focus must shift to highlight the crucial importance native/wild bees serve worldwide. An effective method to further conservation efforts and raise public awareness is incorporating pollinator habitats back into human ecosystems, especially in urban areas. Efforts to incorporate pollinator habitats into the human ecosphere have not always been received well. Often, pollinator habitats in human-dominated spaces have been criticized and deemed ugly, unappealing, and messy. It is common for public opinion to regard pollinator habitats as having an unmanicured or weedy appearance. There needs to be an increase in the public's awareness of native bees and other pollinators, resulting in the public's support for implementing pollinator habitats within human-dominated spaces. Pollinator art can help raise public awareness and support for the conservation of native bees. With the ability to be visually appealing, stimulating, and interactive, pollinator art can potentially aid in improving the public's opinion, awareness, and support. Increasing support and awareness of native bees, their habitats, and pollinator art may help urban pollinator habitats be better received and accepted. Higher approval rates of pollinator habitats in urban spaces increase the chances of pollinator art being widely accepted by the public. With the public's acceptance of pollinator art, there is potential to see installations scattered throughout urban landscapes, helping bridge the gap between fragmented pollinator habitats.

Due to the research gaps explicitly pertaining to the conservation of native bees, this report looks into their habits and life cycles to inform a design inquiry framework for pollinator art. The design inquiry framework was developed to help and encourage future designers to experiment and test different materials to discover and innovate effectively safe pollinator art habitats. Maintenance for The Bee Barnacle was also considered and integrated into the design. The maintenance tips given are to inform designers of pollinator art and the best sanitation practices to ensure its safety for native bees and other pollinators.

REFLECTIONS ON GOALS

Goal 1: Develop an understanding of native bees in North America, their life cycle, threats to their survival, and needs for survival

Reflection

Being able to extensively research native bees was extremely rewarding. I learned so much about bees, their life-cycles, and their role in human and ecosystem survival. Before this process, I did not know much about there being various bee species at all. In my early years of schooling, I had only learned about honey bees; I knew there were a few other types of bees, such as bumble bees and carpenter bees. However, due to my limited knowledge, I was under the impression that the decline of bees only pertained to honey bees. I honestly thought that honey bees were the world's most significant contributor to pollination. I know that many people worldwide are under the same impression as I was and probably have limited knowledge of the 20,000 + species of bees that exist globally. That is why being able to extensively research native bees means so much to me.

Limitations

I found it difficult to be satisfied with the amount of research that went into the literature review because there are over 20,000 bee species. Due to time constraints, it would have been challenging to include additional research on other bee species and thoroughly synthesize it for the design framework. It would take me at least a year to research and synthesize information on the 46 species of bumblebees native to North America. Despite being limited in my ability to research every bee native to North America, the information provided in this report is essential. I am not an Entomologist; however, the public can use the research provided to gain a broader knowledge of native bees.

Goal 2: Develop a framework for pollinator art along with maintenance guidelines

Developing a design inquiry framework became essential for designing research-informed pollinator art. Each material in the design inquiry framework was chosen based on existing research studies on the material's effectiveness for the usage of native bee trap nests. The design framework highlights the limitations of materials used in past projects or studies using artificial cavity nests, enabling a research-informed decision-making process. Overall, the design inquiry framework illustrates materials used in the past; while also addressing why they failed or fell short in their effectiveness. The framework also provides a few other materials that have not been widely used and further testing through research studies. If time and resources permitted, I would have liked to team up with a group of entomologists, product designers, and artists to conduct a much larger study. This research project would simultaneously test multiple materials and designs to gather tracking data documenting which art installations and materials are the most attractive and safe for native bees.

In addition to the design inquiry framework, site context was provided about potential urban settings pollinator art installations could exist. The urban settings include; bus stops, community gardens, natural areas, and residential areas. A list of native plant species was also provided based on the urban zone; due to the potential micro climates that could impact the ecosystem of a pollinator art installation. This portion of the design framework was developed to provide a general idea of potential site selections within an urban area. The examples of urban settings provide insights to consider when choosing a site for an installation of pollinator art.

Limitations

One of the most significant limitations I experienced developing the design framework was the limited number of existing studies specifically testing different materials for artificial native bee nests. Most studies I found used either wood or cardboard, each time noting the drawbacks of each material. I am aware that there may not be a "Goldilocks" material; however, it would be highly beneficial for conservation efficiency if scientific studies tested the viability of other materials. Through increased focus on mindful design, scientists and designers can produce user-friendly pollinator art designs for the public.

Goal 3: Develop designs of public art that can function as pollinator habitat based on the created framework

Art is subjective based on whoever designs the installation; designs will function and look different. This thought process can be applied to pollinator art, despite the design inquiry framework and maintenance guidelines for my specific design. The design inquiry framework was not developed to dictate pollinator art designs but to guide the design process of experimenting with materials, textures, function, and construction. Through the precedent study, I was able to see existing installations and inventions geared toward native bee and pollinator conservation. The precedent study enabled me to gain a broader perspective of what my design of pollinator art could look like and how it could function in a real-world setting. The design inquiry process allowed me to sketch out and imagine ideas for a pollinator art installation based on my research and examples found during the precedent study. Numerous designs were sketched; a few were developed further and presented. However, only the modular sculptural piece resulted in further exploration through digital prototyping using AutoCAD and digital rendering.

Limitations

The limitations I experienced with developing designs for pollinator art mostly revolve around the time constraints for this research project. There was a quick turnaround between writing the literature review, synthesizing it for the design framework, and developing designs. Given more time, I would have developed designs for each type of urban zone listed in the design framework.

Goal 4: Make a small-scale study model of the pollinator art

I digitally rendered the modular installation of pollinator art by using AutoCAD, Sketchup, Lumion, and Photoshop. This method was conducted later in the research process and was severely limited by the project's time constraints. When I initially began this project, I envisioned being able to develop and fabricate my design physically. However, for that option to be possible, I would have needed an extra semester to complete its construction. The extra time would have been needed due to my limited knowledge of fabrication. Despite having limited fabrication skills, I think having the opportunity and time to construct my design would have been an enriching, fulfilling experience. I hope one day I receive the opportunity to build upon my research and fabricate my design. I also hope that one-day, pollinator art installations will be implemented in various cities and utilized globally. I know these are big dreams and goals. However, I conducted this research project knowing that plenty of people in the world have a desire and passion for art, conservation, knowledge, science, and design. I genuinely hope that others can utilize this research to raise awareness and support for native pollinators on a global scale.

This research project taught me about native bees and other pollinators outside honeybees and butterflies. I gained knowledge of their life-cycles, habits, and needs, all to further broaden my perspective on their importance and significance. This project has motivated me to raise awareness and support for the conservation of native pollinators. I have learned that I cannot care about my existence and survival without caring about the decline in pollinator populations. Essentially, their survival ensures the survival of many living things, including humans.

If I were to do anything differently with this project, I would have planned my time out better to develop my design further and fabricate it. However, I am satisfied with the end product, and I believe it is a starting point for me to construct my design.

This research project had a logical process; identifying a dilemma, conducting a literature review, precedent study, establishing a design framework, design inquiry, and digitally prototyping. I thoroughly enjoyed the topic of my research project, and I believe that my research process was the best method for me based on time constraints. Overall I think this project was worth my time, and I am incredibly grateful to have received tremendous support from my committee, department, professors, and from my friends and family.

FUTURE APPLICATIONS & RESEARCH

Due to the limited time to conduct this study, further research is needed to explore the effectiveness of materials listed and unlisted in the design inquiry framework. Future research should investigate how well pollinator art performs in various urban settings; furthermore, expanding on the different functions pollinator art installations can have. If an optimal material for pollinator art is ever discovered, future studies should survey the public about the impact pollinator art has on their personal lives and communities. Additionally, interviews can be conducted to gauge the public's perceptions, thoughts, awareness, and support regarding pollinator art. Additional studies on pollinator art can also be used in design competitions, class projects, science experiments, and even as a fun activity to explore with community groups or families. There are many ways for pollinator art to be designed and applied in urban settings. Future research could also explore designs, and possible outcomes of pollinator art applied in rural settings. There is much hope for continuing the research within this study. I genuinely believe that future findings from further exploratory studies on pollinator art will significantly impact the future of public art, landscape architecture, and the conservation of native pollinators.

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