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Bees in the Big City: The History, Politics, and Infrastructure of Colony Collapse Disorder and Potential Solutions

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Abstract

This paper discusses the phenomenon known as Colony Collapse Disorder, or CCD, the causes of CCD, and how to mitigate the causes of the phenomenon while increasing the population of pollinators in cities, specifically in NYC. Chapter 1 analyzes the reasons behind the issue of pollination decline, examining well-established theories such as habitat loss and climate change, as well as other theories such as the prevalence of radio waves and how they interfere with the internal navigation of pollinators. Case studies of other nations and their situations are also included. Chapter 2 examines the history of New York City's pollinators from its inception to the present day, citing which pollinators are present in this area and the major fluctuations in the levels of these pollinators and the reasons behind them, up to the reasons for the major pollinator decline in the city in the present day. Chapter 3 introduces the field of urban planning and architecture, analyzing how existing and new infrastructure can be optimized with new installations such as green roofs and hanging and community gardens which work to expand the floral land area of the city, which is just one way in which to augment the number of pollinators in the city. Chapter 4 delves into the politics of the matter, examining which policies are active in the city currently, and how the policies have been designed to allocate more resources to groups seeking to mitigate the current state of pollinator decline and ensure that significant changes are made so the current state of decline is not reached once again. Chapter 5 expands on Chapter 4, analyzing which policies the city has implemented have been helpful, which have been harmful, and what more can be done not only by the city government but also by the inhabitants of the city and what they can do to push the government at the city and state level to increase the levels of pollinators in the greater New York City area.

Keywords: Colony Collapse Disorder, Pollinator, Urban Planning

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Introduction: Clipped Wings

The warming of the planet has put extreme pressure on many species that cannot adapt to the increasing temperatures in time. Humans have impacted the world at such an extreme rate that the International Commission on Stratigraphy agreed that the concept of the Anthropocene, a geological epoch that can be individually identified through the impact that humans have made on the land, is real. Among the many extremely significant impacts of this new epoch and the heating of the world that has come alongside it is the sixth mass extinction, driven by humans, which insect species are not immune to (Marshman et. al. 2018). The most pressing aspect of this issue is that we are running out of time. Only now, 150 years after Charles Darwin first understood the significance that pollinators held for plants, we are beginning to understand how interconnected ecosystems are.

However, we are also now just starting to see the collapse of some of those interconnected ecosystems, as the death of pollinators in some of these environments has led to cascading effects and damage to the ecosystems they used to inhabit (Marshman et. al. 2018). The acronym HIPPCO is used to describe the six most significant contributors to biodiversity loss: habitat destruction/habitat fragmentation, invasive species, population loss, pollution, climate change, and overpopulation. The pollinators of the world are being affected by all six of these effects, and the intersection of these and several other factors has created a phenomenon of bees abandoning their hives, leaving behind the young, the queen, and a small cluster of young adults, who are insufficient in number to care for the young. The collapse of these colonies is characterized specifically by a mostly empty hive, insufficient adults to care for the young, and greatly reduced foraging behavior. These characterizations have been dubbed Colony Collapse Disorder, or CCD. The number of pollinators in New York State, and around the country, is decreasing at an alarming rate due to this phenomenon. The total bee population in the US has fallen 61% from 1947 (5.1 million colonies) to 2008 (2.39 million colonies), while the rate of loss of managed pollinator populations is around 50%, and the rate of loss of commercial migratory pollinators in some colonies have exceeded 70%, while the background acceptable rate of loss is 20% (Lee et. al, 2015; New York State Department of Environmental Conservation (NYSDEC 2016); Seitz et. al, 2016). While the exact cause of CCD is unknown despite scientists around the world searching for an answer, it is believed that this phenomenon is caused by a combination of some, or all, of the following factors: Habitat loss and fragmentation due to the cutting down of forests for human use, pesticides, specifically a class of insecticides called neonicotinoids, nutrient deficiencies, poor management practices, and a lack of genetic diversity (NYSDEC 2016). This is significant because some 75% of the world's crops rely on insect pollination, with bees providing most of that pollination service (Aizen et. al. 2022).

I chose this research topic because I believe that the mass loss of pollinators can be avoided by implementing the correct policy and building the right infrastructure. I hope to angle this paper more heavily towards the lens of infrastructure and revivalist architecture, for I believe that by increasing the amount of pollinator-friendly architecture available in cities while simultaneously aggressively passing policy that combats every hypothesized aspect of CCD, we can increase the number of pollinators present in cities around the world, and specifically in New York City and State. I think that it is important to consider augmenting the number of pollinators in cities as well as the number of pollinators in rural areas that are more accessible to farmers because the number of pollinators in cities are of the utmost importance in both bolstering the resilience of bee species and ensuring the building of a more just and equitable city (Zuniga-Teran et. al, 2021). I plan to approach this broad topic by focusing on some examples of pollinator decline from around the United States to help me describe the major issue of CCD in chapter 1 and then describing each contributing cause of CCD in detail. Chapters 2-4 will broach the topic from the lens of the history, urban planning, and politics of the issue, respectively. Chapter 2 will narrow in from chapter 1 to focus on the northeastern US, while chapters 3-5 will narrow in on my specific study area, NYC. Chapter 4 will not only describe which policies have been put into place but also how faithfully some of those policies have been executed. This is the necessary framework for chapter 5, where I will analyze which policies I think are an efficient use of time, money, and resources, and which policies are not based on the information my research has provided, and what more we could be doing to protect the pollinators of the state and the nation.

Chapter 1: The Intersectionality of Colony Collapse Disorder

This chapter will discuss, in respective order, the exact kind of ecosystem services that pollinators such as the Western Honey Bee (*Apis Mellifera*) provide and what impact on human development and well-being those services create. The second section will discuss the many varied hypothesized causes of CCD, or Colony Collapse Disorder, and how the causes of this phenomenon lead to bee death. This section will also explain how these causes intersect with one another and will discuss how several of these factors working together can also lead to CCD. This in-depth explanation will be followed by an explanation of the impact of reduced bee population numbers on crop production, and what that means for human health and well-being. This section will be followed by a general overview of the solutions I will put forth later in the paper to mitigate the effects of CCD and increase the level of bees found in cities.

A. Pollinators and Ecosystem services: Crucial Providers. As mentioned in the abstract, this paper will discuss CCD, its causes, effects, and how to mitigate the causes of the phenomenon while increasing the population of pollinators in cities. As mentioned in the introduction, CCD is a phenomenon that results in bees abandoning the hive which results in abnormally high levels of bee death. Bees are pollinators, falling under the regulating class of ecosystem service (Millennium Ecosystem Assessment Board (MEAB 2005)). There are four categories of ecosystem service, supporting, provisioning, regulating, and cultural; all four of these categories serve different functions (MEAB 2005). As the name suggests, provision services provide resources for humans to use like food, water, timber, fiber, and fuels (MEAB 2005). Regulation services regulate the systems of the Earth, performing things like climate, flood, and disease regulation, and carrying out other systems such as water purification (MEAB 2005). Cultural services is an umbrella term to describe the emotional benefits humans obtain from being in or looking at nature; this class of services describes aesthetic, spiritual, educational, and recreational value (MEAB 2005). The final class of services, support services, is an umbrella term to describe all of the cycles that the Earth regulates to enable the other three services to exist; services like nutrient cycling, soil formation, and primary production fall under this category, and without these services, the other three categories of services would likely not exist (MEAB 2005). Humans rely on these ecosystems for our well-being and survival. Without these services, humans could not obtain food, would not have fresh water to drink, there would be no nature to enrich our lives, and no systems to regulate the climate in the sky or the nutrients in the ground (MEAB 2005). Life as we know it for us would most likely not be possible without these services. Bees provide pollination, which falls under the category of regulation. Without this category of services, there would be no nutrient cycling, soil formation, or, of course, primary production, as insect pollination is needed for some primary production (NYSDEC 2016). Pollination is required for the growth of fruits, nuts, and fibers, and significantly augments the yield of many other crops like oranges (Hein 2009). Because pollination provides humans with a massive amount of variety in their diets and is needed constantly to ensure that this variety is readily available at all times, this service is considered a regulating service.

B. The Causes of CCD and its Effects on Crop Production. The causes of CCD that will be discussed in this paper are as follows: pesticide exposure, parasites/pathogens, nutrient deficiencies, climate change, and habitat loss and fragmentation. Subheadings will be allocated, and causes will be grouped according to their relation to one another.

1. Habitat Loss and Fragmentation/Nutrient Deficiency/Climate Change. These three contributors to CCD are interrelated. It is well documented that habitat loss directly leads to decreased levels of pollinator species diversity (NYSDEC 2016), and an upward trend in monoculture agriculture to feed an ever-growing population means that pollinators must simultaneously contend with decreased amounts of habitat and less nutritious options available for their diets because the diversity of local flora has been sharply reduced (NYSDEC 2016). This decrease in habitat and food availability also leads to dehydration and exhaustion as pollinators have to fly further distances to look for flowers, but said dehydration and exhaustion consequently result in poor health, a reduced ability to fight pathogens and pests such as *Varroa destructor (V. destructor),* otherwise known as the *varroa* mite, and potentially colony death (NYSDEC 2016). In addition to eliminating land available for bees to live and forage, it also reduces the amount of available land for breeding (NYSDEC 2016). Many species of wild bees, which are instrumental pollinators in New York State, are ground nesting and burrowing, which means that they need exposed soil and foraging materials like leaves and twigs for nesting, which anthropological development reduces the availability of (NYSDEC 2016). It is difficult to understate how severe and rapid habitat loss has been for all species on Earth. Between the years 1950 and 1980, more land was converted into cropland than from the years 1750-1800, and cultivated systems, areas where a minimum of 30% of the land is used for human food production, now total 25% of Earth's total land surface (MEAB 2005). This led to a decrease in biodiversity and genetic diversity, especially among cultivated species, which includes bees (MEAB 2005). Looking to the near future, it is estimated that in the next half-century demand for food crops, for which more land will have to be cleared and more habitat for pollinators destroyed, is set to grow by 70-85% (MEAB 2005). Habitat destruction of pollinators is expected to increase in the coming years, meaning that all of its aforementioned effects will have an increased toll on pollinators. Climate change only exacerbates this issue. It is expected that climate change will further degrade the quality of the ecosystem services provided by the planet (US Global Change Research Program). In fact, one study found that climate change is a direct predictor of bee abundance, with 1 degree of urban warming decreasing bee abundance by 41% in urban areas; the study also found that temperature was one of the best predictors of bee community composition and abundance (Hamblin et. al. 2018). In addition, bee habitat ranges have contracted northward due to climate change, meaning that climate change and habitat loss are both exerting pressure on pollinator populations by jointly shrinking their habitat ranges (Hamblin et. al. 2018). Climate change is expected to worsen in the near future, with the IPCC estimating that at the current rate of emissions, the world is set to exceed 1.5 degrees Celsius of warming in this century, and the only way to avoid this is to reach global net zero carbon emissions by 2050, and net zero carbon emissions by 2070 to limit warming to 2 degrees Celsius (IPCC). However, the IPCC also estimates that following the current trends, the world is set to heat up by about 2.2-3.5 degrees Celsius by 2100

(IPCC). Following the current emission trends, the impacts of climate change on bees are most likely only going to be magnified shortly, and extremely magnified in the far future.

2. Parasites/Pathogens. The first parasitic threat to pollinators is *Varroa destructor (V. destructor),* or the *Varroa* mite. This is currently the most harmful and widely dispersed parasite that harms bees (NYSDEC 2016). *V. destructor* feeds on bee's hemolymph, or blood, and while draining them it also transfers viruses into the bees which can be fatal independent of the harmful effects of *V. destructor* (NYSDEC 2016). These mites affect the worker bees and male larvae and affect the reproductive abilities of the queen (Johnson 2010). Left untreated, these mites will ensure colony deaths within six months to two years (Johnson 2010). In New York State, *V. destructor* has developed immunity to two of the three pesticides commonly used for its elimination (NYSDEC 2016). *V. destructor* is also a vector for the IAPV, the Israeli Acute Paralysis Virus, which was first found in 2004 in Israel (Cox-Foster et. al, 2007). Causing shivering wings, which led to paralysis, and eventually death, IAPV is a significant indicator of CCD (Cox-Foster et. al, 2007). Another parasite, *Apocethephalus borealis, (A. borealis),* or the Phorid fly, is on the rise (Core et. al. 2012). This fly parasitizes honey bees, which results in them exhibiting abandonment behavior, leaving the hive and dying outside of it (Core et. al. 2012). The parasitism of *A. borealis* has also been found to infect honey bees with a fungus, *Nosema ceranae,* and with deformed wing virus (Core et. al. 2012). Chalkbrood fungus, *Ascosphaera apis,* is also known to weaken bees so they are more susceptible to death (Aaronstein et. al. 2010). Once infected with the fungus, bee larvae activate their immune responses, which depletes their nutritional resources in a vital stage of development (Aaronstein et. al. 2010). The fungus is able to outlast and overcome the immune response of the bee larva, leading to a reduction of feeding at 24 hours post-infection, a significant reduction of activity at 36 hours, and death at 48 hours post-infection (Aaronstein et. al. 2010). The chalkbrood fungus is able to accomplish this by infecting the larvae, thus prompting it to activate its immune response which expends valuable nutrients and leads to decreased levels of feeding (Aaronstein et. al. 2010). The fungus then feeds off the food stores of the larvae, leading to starvation of the larvae and subsequent death (Aaronstein et. al. 2010). *Nosema ceranae* is a new threat to bee populations, a more lethal fungus than the recognized *Nosema apis* (NYSDEC 2016). American foulbrood and European foulbrood are two other fungal infections that threaten bees, but *Nosema ceranae* is recognized to be the most dangerous currently, with its ability to exacerbate the effects of pesticides and the fact that fungal treatments can lead to increases in *Noesma* infections (NYSDEC 2016).

3. *Effects on Crop Production.* All of the effects discussed in this chapter have, thus far, analyzed how the various causes of CCD are impacting bees. It is now necessary to discuss how these harms to bees cascade and subsequently impact humans. It is important to note here that the amount of insect-pollinated global agriculture has increased 600% since 1961, meaning 75% of the most widely cultivated crop species now rely on animal population while in the same amount of time, the amount of managed bees has only increased 80% (Aizen et. al. 2022). Ironically, this extreme expansion is due to the proliferation of pollinator-dependent monocultures; which humans cleared the land for by destroying pollinator habitats and spraying with insecticide to be able to plant, naturally leading to the decline of native pollinators, which in turn encourages farmers to introduce managed pollinators to ensure the success of their crops, which act as competitors and disease vectors for the native pollinators, sending their population numbers further down (Aizen et. al. 2022). Some studies suggest that the current increase in the percentage of pollinator-dependent agriculture underrepresents their growth rate, as the rate of

pollinator-dependent agriculture is exponentially increasing in demand as the world becomes more globalized (Aizen et. al. 2022). Therefore, if the current trend of a major discrepancy between the growth rate of demand for, and planting of, pollinator-dependent crops, and the growth rate of actual insect pollinators to ensure that they grow continues, the world could be facing a pollinator crisis as there are not enough insects to pollinate the crops that were planted to meet the demands of a globalized population (Aizen et. al. 2022). As of now, the value that pollinators bring to crops is estimated to be greater than $1.5 billion in the US, with some estimates reaching as high as $40 billion, and the value of pollinator-dependent crops is estimated to be over $50 billion a year (Reilly et. al 2020). However, this figure was derived from a study that only examined seven different crops, so the value of pollinators to all crops is most likely in the double-digit billions (Abrol 2012; Reilly et. al 2020). This study also found that wild bees and managed bees provide similar levels of pollination service to crops, suggesting that the importance of conserving wild bee populations is equivalent to conserving bees that are explicitly used for agricultural pollination (Reilly et. al 2020). The importance of pollination services, while rising in general, varies by crop. The same study found that pollination is very important for crops such as apples, cherries, and pumpkins, but not important for almonds (Reilly et. al 2020).

4. *Pesticide Exposure*. Pesticide exposure is in general harmful to bee health, but a specific class of insecticides, neonicotinoids, are extremely harmful to bee health (NYSDEC 2016). Sub-lethal amounts of exposure to this class of pesticide can damage bee’s central nervous system, learning behaviors, memory, and navigational ability, impact brood and larval development, reduce foraging success, and increase susceptibility to parasites and pathogens such as *V. destructor* and *Nosema ceranae* (NYSDEC 2016). In addition to treatments for *Noesma*

ceranae paradoxically potentially increasing the number of *Noesma* infections, the fungicide used to combat *Noesma* can also augment the harmful effects of other pesticides, specifically neonicotinoids, on bees, creating a feedback loop where the bees are more susceptible to the harmful effects of those pesticides in the future. Trace amounts of neonicotinoids have been found to cause disorientation, impact communication and longevity, honeybee brood cycles, and queen production of bees, which reduces colony growth (Farooqui 2012). Other physiological effects include the impact on the development of proper body shape and the ability to walk properly (Farooqui 2012). Given all of these impacts on bee well-being, it is rather concerning that 99.8% of all corn seeds in America are sprayed with neonicotinoids and the fact that the chemical has a half-life of 148-1155 days, depending on soil conditions (Farooqui 2012). However, perhaps the most significant impact of pesticides is the fact that bees exposed to them exhibit inhibited olfactory learning, which is responsible for navigation and foraging performance; exposure to neonicotinoids in particular has been found to result in the failure of bees to distinguish between recognized and foreign odors which is an indicator of significantly impaired memory and learning ability (Farooqui 2012). Other pesticide compounds such as imidacloprid, amitraz, formamidines, and biogenic amines-based pesticides have all been found to also impact olfactory learning and memory in honey bees (Farooqui 2012). The significance of this discovery is that these chemicals are applied in the field, at varying amounts and concentrations, and are sometimes applied together (Farooqui 2012). If honey bees are exposed to many of these compounds at once the effects could be severe as high concentrations of any singular compound are toxic and deadly to the bees (Farooqui 2012). The way these pesticides reduce olfactory learning and memory is through repeated activation of amine receptors via exposure to amine-based pesticides (Farooqui 2012). This will cause repeated activation of the receptor which will spike the production of calcium ions, which in turn eventually increases stress levels, causing neuronal damage which impairs the cognitive functions of olfactory learning and memory (Farooqui 2012).

C. Overview of CCD Solutions. While the challenges facing pollinator colonies are daunting and numerous, many different groups of scientists, farmers, corporations, and governmental agencies have committed to mobilizing as fast as possible to face these threats head-on. Generally, the solutions to CCD include climate change mitigation, the cessation of overconsumption, both at the personal and industrial levels, and the integration of new pollinator infrastructure and new pollinator policies. For the immediate future, the success of these solutions will directly require all industries and institutions across the globe to immediately switch to renewable energy, the extraction of fossil fuels to cease, and for these industries to adopt new technologies and processes that focus specifically on energy and material conservation. However, this is only a short-term solution. The true issue is the exponentially increasing rate of consumption of Earth's resources. In light of this, long-term responses to combat one of the most overarching factors contributing to CCD, climate change, include a sharp decrease in the consumption of resources and manufactured goods. The other solutions to fighting CCD are constructing new pollinator infrastructure and implementing policies that support the construction of this infrastructure.

These solutions will be addressed in detail in this paper. As the paper begins with a general focus on the Northeastern region of the US and then focuses on NYC, chapters 3 and 4 will focus on NYC while chapters 1 and 2 will provide more regional information. Green architecture, both new theories, such as DeMo and the Ecological Planning method, and an example of the implementation of these theories, Cross Laminated Timber, will be discussed in chapter 3. Chapter 4 will analyze current pollinator policies at the city and state levels, and then discuss the conservation efforts of grassroots pollinator movements, both organizations that have worked with and independently of the aforementioned governments. Chapter 5 will analyze the policy decisions outlined in chapter 4, but the foci of the paper are architecture, infrastructure, policy, and design.

Chapter 2: A History of Bee Pollinator Populations

This chapter will review a brief history of the populations, distributions, and ranges of multiple different species of bees. Each study used in this paper approaches the challenge of long-term population analysis differently, and the goal of this section is to overlay the information of as many different papers as possible to cross-reference different data sets and thus be able to draw wider conclusions. The first section will cover a historical background of both how CCD and some of its factors developed in the US over time, as well as what the initial reactions of the scientific and political community were and what steps were taken to combat this new threat to bee colonies. The second section will cover bee populations in the northeastern US from 1972-2002, and the third section will cover bee populations in the same region from 2002-2011. These two time periods were chosen mainly because the effects of the widespread use of neonicotinoids can be seen after 2002 (Wood and Goulson 2013). The final section will analyze the bee population trends discussed in the previous two sections in the context of CCD to highlight the extent to which CCD is responsible for bee colony death.

A. Historical Background of CCD and its Causes. While the majority of the first reports of unusually high rates of bee mortality were in late 2006, Cox-Foster et. al found that all of the bees used in their study were either directly imported from Australia or had come into cross-contact with Australian bees at some point, which is significant because this team of researchers found that the practice of importing bees from Australia to the US began in 2004, and this is the same year that the very first patterns of unusual colony declines began to emerge (Cox-Foster et. al, 2007; Johnson 2010). Commercial beekeepers began reporting massive increases in honey bee mortality rates soon after by February 2007 (Johnson 2007). In 2007, colonies in 35 different states experienced the effects of CCD (Johnson 2007). In 2006 commercial beekeepers controlled 2 million bee colonies (Johnson 2007). 20% of these colonies were in California, 10% in Florida, 14% in North and South Dakota combined, and Minnesota, Idaho, Michigan, Washington, Wisconsin, Oregon, and New York combined accounted for another 20% (Johnson 2007). Each year, 2 million colonies are rented for crop pollination, with the crops that most require these bees for pollination in the US being apples and almonds (Johnson 2007). Clover seeds, cherries, and pears also require a strong pollinator presence to augment their yields and flavors (Johnson 2007). However, 1.4 million colonies of bees are used for California almonds alone (Johnson 2007).

By February 2007 commercial beekeepers in multiple states reported losses of 30%-90%, massively higher than the background death rate of 10%-30%, which occur due to the stresses of transportation (Johnson 2007). The average rate of loss during the winter of 2006-2007 was 38% among surveyed beekeepers (Johnson 2007). Among this 38% death rate, 25% of this loss is believed to be due to CCD (Johnson 2007). The most common factor affecting commercial beekeepers was reported to be pest diseases (Johnson 2007). Given that the value that bees provided to humans was valued at $15 billion annually in 2007, swift action was taken (Johnson 2007). Several committees in the US government, including the House Subcommittee on Horticulture and Organic Agriculture and the Subcommittee on Fisheries, Wildlife, and Oceans of the House Committee on Natural Resources held hearings to review information and take stock of the declines so far (Johnson 2007). Discussed in these hearings were mainly policy options to allocate federal funding for research and further bee monitoring, resources to help beekeepers, including honey in crop insurance, a potential one-time payment for losses, improving USDA conservation programs to better sustain wildlife and their habitats, placing specific emphasis on pollinators and highlighting their importance (Johnson 2007).

In addition to these political responses, the US EPA found that some compounds in imidacloprid, a neonicotinoid insecticide, to be highly toxic to bees (Johnson 2007). Ubiquitous neonicotinoid use in the US is a relatively recent development (Douglas and Tooker 2015). Neonicotinoids were introduced in 1994, but their use rapidly increased in the United States between 2003 and 2011, following the introduction of seed-applied products in field crops (Douglas and Tooker 2015). The increase in the use of this class of insecticides aligns with the first reported cases of CCD, indicating that these insecticides could be a major contributor to CCD (Johnson 2007). Beekeepers in the US, France, and the UK reported impacts on bee olfactory memory, foraging, coordination, and recruitment after bees were exposed to this insecticide (Johnson 2007). As a result of these findings, calls for the banning of imidacloprid led to its discontinuation in parts of Europe, but bee colony losses are still occurring in those areas (Johnson 2007).

Another major contributor to the phenomenon of CCD are parasites and pathogens, specifically *Varroa* mite, *V. destructor*. (Johnson 2010). Also, a relatively new threat, the first report of *V. destructor* infestation was in 1987 (Johnson 2010). These mites were reported to have eliminated most feral bee colonies in the mid-1990s (Johnson 2010). As aforementioned in chapter 1, these mites affect the worker bees, male larvae, and the reproductive abilities of the queen, with colony death occurring within six months to two years without treatment (Johnson 2010).

B. Bee Populations from 1972-2002. Every study about long-term bee analysis was conducted differently, not only did each study use different methods, but they also focused on different bees, some focusing on massive collections of species, while others focused on three or four species (Bartomeus et. al, 2013; Cameron et. al, 2011; Nooten and Rehan 2019). From the period from 1972-2002, one study found that from the non-*Bombus* species sampled, a total of 1000 specimens across all time periods, increased from 200 to about 223, the number of *Bombus* species, a total of 400 specimens across all time periods, increased from 15 to 16, and the number of exotic species, a total of 1000 specimens across all time periods, increased from 4 to 11 (Bartomeus et. al 2013). This study examined a total of 438 species, all in the Northeastern United States (Bartomeus et. al, 2013). While many potential factors could contribute to the increase in bee populations across this time, it can be inferred that these bee populations increased during this time because neonicotinoids were invented in the 1990s, and were not widely used until the 2000s, thus, the decline in bee populations, due partly to the aforementioned widespread use of this class of chemicals, had not manifested yet (Wood and Goulson, 2013; Jacobson et al, 2017). However, even though genera increased, individual species increased or decreased depending on specific circumstances. For example, the western honey bee *Bombus occidentalis* was shipped to Europe in the early 1990s to be raised with another pollinator, the buff-tailed honey bee *Bombus terrestris.*While the two were being raised together, *B. occidentalis* obtained a new parasite called *Nosema bombi*, and when *B. occidentalis* was brought back to America, the parasite spread across the colonies of this bee, rendering the bee commercially extinct and leading to *B. impatiens*, the common eastern bumble bee, to be used in the place of *B. occidentalis* as a commercial pollinator (Jacobson et. al, 2017). The result of this collapse was massive; due to the collapse of *B. occidentalis*, *B. impatiens* was found to be an essential generalist in every period in which it was present (Jacobson et. al, 2017). *B. terricola*, the yellow-banded bumble bee, and *B. bimaculatus,* the two-spotted bumble bee, were also found to be important bee species in the Northeastern United States during this time (Jacobson et. al, 2017). Unlike other bees during this period, *B. terricola* decreased in relative abundance and specimen count collected, with 105 specimens and a relative abundance of 6.8% (Jacobson et. al, 2017). The abnormal decrease in the specimen count and relative abundance of this bee is due to exposure to fungicides (FWS). Another individual bee of note is *B. affinis,* the rusty patched bumble bee, which experienced severe disease during this period and ostensibly went wholly extinct in New Hampshire, with the last sample collected in 1993 (Jacobson et. al, 2017). More generally, the period of 1972-2002 displayed very high species richness and a large number of individual samples (Jacobson et. al, 2017).

C. Bee Populations from 2002-2011. In this period, it is much easier to see more general trends. The first of these trends arose from the Bartomeus study, which examined bees from a period of 1872-2011 (Bartomeus et. al 2013). In this study, the 223 non-*Bombus* species present in 2002 crashed to 180 by 2011, the 16 *Bombus* species in 2002 fell to 12 by 2011, and the number of exotic species rose from 11 in 2002 to 12 in 2011 (Bartomeus et. al 2013). In the same study, nine of the 87 rare species were not recorded in the last 10 years of the study, from 2001-2011, but the species that can tolerate human disturbance enjoyed an increase in relative abundance over this period (Bartomeus et. al 2013). Ultimately the species in the genus *Bombus* experienced a 30% decrease in species richness, but the exotic species saw a ninefold increase throughout the period examined by the study, 1872-2011 (Bartomeus et. al

2013). One study, which examined five species in the Northeast and Midwest from 1900-2009, *B. pensylvanicus*, the American bumblebee, *B. affinis*, *B. terricola*, *B. bimaculatus*, and *B. impatiens*, found that *B. pensylvanicus* suffered an estimated range reduction of 23%, most of this reduced range being in the Northern and Eastern parts of its range (Nooten and Rehan 2019). *B. affinis* was not found in its historical range of the Northeast at all and instead was only sampled in three locations in the Midwest (Nooten and Rehan 2019). *B. terricola* shifted away from its historical range in the Midwest and traveled to a higher elevation, increasing its abundance in the Northeast and experiencing a range reduction of approximately 31% (Nooten and Rehan 2019). Specifically, the decline of bees in the Northeast seems to be primarily larger bees, and the bees from the late 1900s to the early 2000s are, on average, 15% smaller than their ancestors from the late 1800s to the 1920s (Nooten and Rehan 2019). In this study, the smaller bees that displayed increases in their population sizes were *B. impatiens* and *B. ternarius*, or the orange-bellied bumble bee (Nooten and Rehan 2019). The larger bees that experienced decreases in their population sizes were *B. vagans* and *B. terricola* (Nooten and Rehan 2019). The species of declining bees had bodies that were about 20% larger than the species of bees that increased in population size over this period (Nooten and Rehan 2019). Interestingly, the factors of body size, population size, and elevation seem to be related, as species that increased in population size over the 1900s shrank in body size and were also more likely to inhabit areas of higher elevation (increases in elevation ranged from 53m-283m) (Nooten and Rehan 2019). The results of this study suggest that the factors that result in CCD are more impactful to bees with larger bodies and that the impacts of climate change are beginning to manifest in the form of bees inhabiting areas of higher elevation, which are more likely to be cooler than the ever-increasing temperatures found at lower elevations (Nooten and Rehan 2019).

D. Bee Population Analysis in the Context of CCD. While it is beneficial to understand the general trend of bee population decline outlined in the previous section, the specific patterns of loss from year to year starting in 2006 also ought to be outlined. Starting in 2007, when it became widely and well understood within the scientific community that CCD was a major issue that would have massive ramifications on the bees and farms of the US, researchers began conducting annual surveys of the beekeepers of the United States to gather a greater understanding of the threats that their bees face and to see if any trends would reveal hints to better understand how to mitigate the many theorized causes of CCD. A summary of the findings of these surveys is highlighted below:

Table 1: Summary of CCT Annual Reports

Time Period	All Risk Factors	Total Number of colonies in the US	Percentage Beekeepers reporting	Losses due to CCD within reporting beekeepers/Beekeepers who reported CCD being a significant factor in loss	Percentage of total loss due to CCD
Fall 2007-Spring 2008	poor queen, starvation, mites, CCD, weather, stress, management, weak fall colonies, pesticides, viruses	2.44 million colonies	9%	117,124 colonies	48.2%

Fall 2008-Spring 2009	Same factors as previous year except for the inclusion of *Nosema* infection this year	2.3 million colonies	20.1%	107,509 colonies	36.4%
Fall 2009-Spring 2010	Same factors as previous year	2.46 million colonies	20%	135,367 colonies	28.9%
Fall 2010-Spring 2011	Starvation, weak fall colonies, winter conditions, poor queen, *Varroa*, *Noesma*, CCD, pesticides, small hive beetle	2.68 million colonies	11.5%	30,135 colonies	26.3%
Fall 2011-Spring 2012	Same factors as previous year	2.49 million colonies	14.2%	21,716 colonies	20.5%
Fall 2012-Spring 2013	Same factors as previous year	2.491 million colonies	25.5%	117,960 colonies	51.3%
Fall 2013-Spring 2014	Weak queen, starvation, *Varroa*, *Noesma*, small hive beetle, poor winter, pesticides, CCD, disaster	2.64 million colonies	19%	46,765 colonies	34.5%

Fall 2014-Spring 2015	Same factors as previous year	2.74 million colonies	15.1%	38,115 colonies	36.2%

Figure 1: Colony Losses Per Year Due to CCD

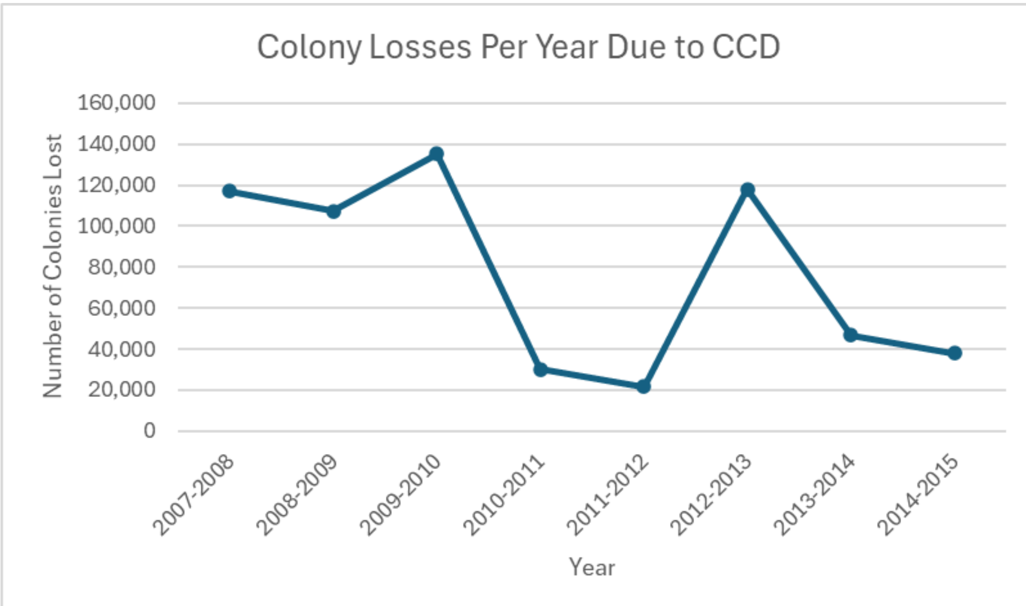
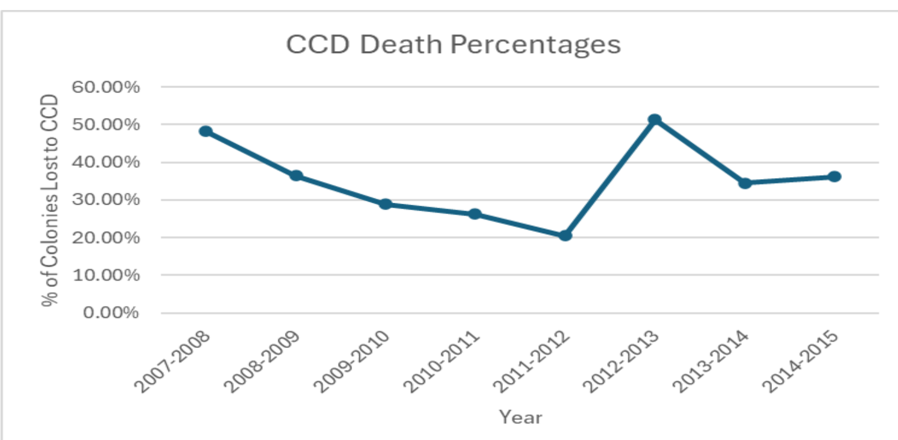


Figure 2: CCD Death Percentages



Graphs and table created by author. Credits: (Lee et al., 2015; Seitz et al., 2016; Spleen et al., 2013; Steinhauer et al., 2014; vanEngelsdorp et al., 2012; vanEngelsdorp et al., 2008; vanEngelsdorp et al., 2010, 2011).

Before these figures are analyzed, it is important to mention why the data ends with the year 2015 when the annual surveys of bee populations are still being published to this day. That is because 2015 was the last year that the authors of the survey deemed it appropriate to list CCD as a separate factor that contributed to colony death (Bruckner et. al, 2023). While the authors were isolating the unique effects of CCD by asking whether or not there were dead bees in the hive or apiary when the beekeepers identified the colony as dead, after the year 2015, there was an understanding among the authors that it was meaningless to include CCD as a specific cause of death because the factors that are most likely to contribute to CCD are already on the list of factors of colony death that beekeepers can choose from (Bruckner et. al, 2023). Additional factors to note before beginning the analysis of the graph include the fact that shown in the graphs are percentages of colonies lost, but the numbers upon which these percentages are based fluctuated every year, which merited the inclusion of the "Total Number of Colonies in the US" and the "Percentage Beekeepers Reporting" columns in the table, to offer a sense of how the numbers upon which the death percentages are derived originates from.

However, with those considerations mentioned, several points are immediately of interest, the first being that the number of colonies lost sharply decreased from 2010–2011 and then sharply increased again from 2012–2013. Unfortunately, the report from 2010–2011 offers no analysis as to why the number of colonies lost that year decreased by such a large margin (vanEngelsdorp et. al, 2012). The report from 2012–2013 suggests that the reason for the sharp increase in colony loss during the winter of 2012–2013 was because of a particularly harsh winter that year, and that is evidenced by the sharp decline in amounts of colonies lost in the subsequent year. Another point of interest is that even though CCD originated and proliferated during the period of these surveys, the total number of bee colonies in the US increased overall during this time. Several of the reports attributed this increase to beekeepers purchasing new colonies to keep their stock high and splitting their hives to make new ones and highlighted commercial beekeepers, who, because they own so many colonies already, they can afford to split a high number of colonies to generate an even greater number of colonies (vanEngelsdorp et. al, 2011; vanEngelsdorp et. al, 2012; vanEngelsdorp et. al, 2014; Seitz et. al, 2016). The authors of the report from 2010–2011, where colony losses sharply decreased and the total amount of bees in the US sharply increased, posit that this increase is because beekeepers were anticipating heavy losses over the winter from 2010–2011 and therefore overwintered their excess colonies to ensure that they will have enough colonies to meet the pollination demands of the spring (vanEngelsdorp et. al, 2012). Ultimately, upon examining the CCD death percentages graph, it is evident that the percentage of colonies being lost to CCD decreases over time, showing that the current policies in place are indeed helping in combatting rates of CCD. However, given that, as aforementioned, the total bee population has fallen from 5.1 million colonies in 1947 to 2.39 million colonies in 2008, more can and must be done to augment bee resilience and the equitability of our cities (Seitz et. al, 2016; Lee et. al, 2015; Zuniga-Teran et. al, 2021).

Chapter 3: Potential Infrastructure Solutions

This chapter will focus first on the distribution of environmental infrastructure across New York City. The next section will focus on what kind of sustainable infrastructure is available for implementation immediately, namely, urban gardens, green roofs, and public parks. This section will also discuss how to augment these spaces and what kind of implementation would work best for pollinators. The final section will examine the infrastructure of the future, examining several theories and how they interact. The theories are based on a systems-based approach, focusing on ideas that challenge the current methods of architecture and design, or how to build thinking about the environment first from the ground up. This will include ideas such as connective patch habitats and tools such as the DeMo framework, among others. These ideas will translate into concrete solutions that urban planners could implement soon in the future if they rallied together and consolidated the necessary resources. For example, using the theory of connective patch habitats and implementing it by forming a loosely connected "network" of green roofs that could host a massive variety of different pollinators, from birds to bees to other small animals.

A. A Brief Overview of the Distribution of Environmental Infrastructure. The main solution for CCD that this paper suggests is the implementation of more environmental infrastructure. However, simply building more urban gardens, parks, or other infrastructure is not enough. This is because there is a disparity in the way in which this infrastructure is distributed (Treglia et. al, 2022; Zuniga-Teran et. al, 2021). It would be misleading for this paper to advocate for simply the construction of new environmental infrastructure, because what the city needs, as will be discussed in further detail in the subsequent sections, is a relatively even distribution of more environmental infrastructure across all five boroughs, and when this occurs, the goal of restoring pollinators, along with the other myriad of benefits that environmental infrastructure provides, are much more likely to manifest themselves (Zuniga-Teran et. al, 2021). Currently, at the time of writing, NYC only has 736 green roofs out of one million buildings, with the majority of those roofs (over half, or 414) in midtown and downtown Manhattan (Treglia et. al, 2022). In the minority of cases where green roofs are located in other boroughs, those green roofs are concentrated in the part of the borough that is closest to Manhattan (Treglia et. al, 2022). There are two reasons why the distribution of this infrastructure is not presently even: institutional and political incentives to prioritize certain benefits of environmental infrastructure, such as stormwater management, and the manifestation of racism through the lack of environmental infrastructure in poorer communities with higher minority populations, with the simultaneous strong presence of environmental infrastructure in communities with fewer minorities and residents with more wealth (Treglia et. al, 2022; Zuniga-Teran et. al, 2021). While both high and low socioeconomic status communities have access to all ecosystem services, because there is less green infrastructure in low-income communities, those communities have less access to cultural ecosystem services. Two issues arise from this disproportionate distribution. The first issue with the uneven distribution of environmental infrastructure is that environmental infrastructure is designed to achieve certain goals, including managing stormwater, reducing social vulnerability, increasing access to green space, reducing the urban heat island effect, improving air quality, and increasing landscape connectivity, which is required to increase the number of pollinators present in the city, because a more connected landscape means more viable habitat not only for all wildlife but also for all flying pollinators (Meerow 2020). If the next section of green space is only a few feet away, flying animals can reach it very easily. Without the even distribution of environmental infrastructure, none of these goals can be achieved (Meerow 2020). The second issue with the uneven distribution of environmental infrastructure is that communities of color do not have the same access to environmental infrastructure that the majority white communities do (Zuniga-Teran et. al, 2021). To achieve all six of the potential benefits that environmental infrastructure is capable of providing, environmental infrastructure has to increase across all five boroughs of the city (Meerow 2020). To achieve the singular goal of increasing landscape connectivity, thus increasing the amount of available pollinator habitat in the city and, consequently, the number of pollinators in the city, environmental infrastructure needs to be massively increased in the Bronx, Queens, Staten Island, and certain districts of Manhattan and Brooklyn (Meerow 2020). Therefore, the distribution of environmental infrastructure must be more even throughout the entire city to solve the two issues that arise from the lack of even distribution. The methods with which this even distribution can be realized are policy-based and are therefore outside the scope of this section. Thus, these solutions will be discussed in chapter 4.

B. Today's Environmental Infrastructure. The three main bodies of infrastructure that NYC can implement or improve to expand pollinator habitat immediately are green roofs, parks, and community or private gardens (Matteson and Langellotto 2010; Rajbhandari et. al, 2023). However, not all environmental infrastructure has the same attractiveness to bees. In one study conducted over five years consolidating 1,036 observations, it was found that in relation to the rate of seeing bees on terraces/rooftop gardens, the rate of seeing bees in community gardens was five times higher, two times higher in parks, and 2.19 times higher in private gardens (Rajbhandari et. al, 2023). There are a myriad of different factors to consider that potentially explain the increased presence of bees in community gardens. When considering the efforts that bees would have to make to reach the higher elevations of rooftop gardens, it is expected that there will be fewer bees in these locations (Rajbhandari et. al, 2023). In addition, the likelihood of seeing five bees was 2.98 times higher in community gardens than it was for rooftop gardens (Rajbhandari et. al, 2023). According to these observational studies, bees are more likely to be attracted to, and ostensibly build habitat near, community gardens. The idea that bees build their habitats within community gardens is supported by another study that sampled 1,145 bees belonging to 54 species which found that many of the bees sampled had limited (less than 500m) foraging ranges, which implies that the bees lived near or inside the area of foraging (Matteson and Langellotto 2010). The same study found that the majority of the bees observed within these community gardens are generalists, who responded positively to the presence of sunlight, floral area, garden canopy cover, and the presence of unmanaged or wild areas within the garden, and the authors cited another study that found that there was a negative correlation between levels of garden management and bumble bee species richness (Matteson and Langellotto 2010). Flower density was found to be a significant predictor of seeing five bees at once, as the likelihood of seeing five bees more than doubled (2.02x) when there were 11-100 nearby blooming flowers and increased by 2.72x when there were 101-1000 nearby blooming flowers in comparison to 0-10 flowers being nearby (Rajbhandari et. al, 2023). Flower diversity was also hypothesized to be another significant factor in this study, as it was found that private gardens exhibited lower rates of pollinator visitation; this was thought to be because floral diversity may be higher in community gardens than in private gardens (Rajbhandari et. al, 2023). The species of flowers present have also been found to influence richness in addition to the floral area, density, and diversity (Rajbhandari et. al, 2023; Matteson and Langellotto 2010). Specifically, one study found that Rough-Leaved Goldenrod, Mountain Mint, Smooth Aster, Wild Bergamot, and Woodland Sunflower were all found to attract a high number of bees (Rajbhandari et. al, 2023).

The species of bees that visited green spaces is also significant when considering how to implement more green infrastructure in the future to augment the population of these bees. Bumble bees were among the most common bee types in all studies (Rajbhandari et. al, 2023; Matteson and Langellotto 2010; Matteson and Langellotto 2009), but two studies found that two exotic bees, *Hylaeus leptocephalus* and *H. hyalinatus*, the slender faced masked bee and the hairy yellow face bee, respectively, were also common along with other native bees belonging to the genus *Lasioglossum* (Matteson and Langellotto 2010; Matteson, Ascher, and Langellotto 2008), with one of the studies finding that these two exotic bee species were extremely abundant, accounting for 77% of all individuals collected (Matteson, Ascher, and Langellotto 2008). *Apis mellifera,* the western honey bee, *Bombus griseocollis,* the brown belted bumble bee, *Lasioglossum bruneri,* Bruner's sweat bee, and *Xylocopa virginica,* the eastern carpenter bee, were also common, and most interestingly, 50% of the species sampled in this study were also found in other areas beyond the gardens that they were originally sampled in, such as parks, other gardens, and landfills, suggesting that these species are generalists and can wander beyond the range of the garden where their colony is most likely located to other (mostly) green spaces (Matteson, Ascher, and Langellotto 2008). Given that many different species were found in the community gardens, the most common bee found in the gardens was *B. impatiens,* the common eastern bumble bee (Matteson and Langellotto 2010; Matteson and Langellotto 2009). This is significant because while it is known that it is most likely possible for *B. impatiens* to fly far enough to pollinate several green spaces that are close together in proximity, optimal foraging theory suggests that *B. impatiens* will instead seek to find the most amount of resources while expending the least amount of effort, implying that every installment of green infrastructure should have its own colony of bees (Matteson and Langellotto 2009). Bumble bees have been observed to fly up and out of the community garden after foraging for nectar, implying that the colony was somewhere outside of the community garden (Matteson and Langellotto 2009). While bumble bees can use ground burrows and tree cavities for nesting sites, it is more probable in an area with high human interference that they would choose another site with less likelihood of human intervention or interaction such as high in a tree (Matteson and Langellotto 2009). This preference is supported by the negative correlation between human management of community gardens and the relative bee abundance, and the positive correlation between higher bee abundance and undisturbed areas in community gardens (Matteson and Langellotto 2010). The high frequency of soil disturbance in community gardens likely leads to the exclusion of bees that burrow in the soil (Matteson, Ascher, and Langellotto 2008).

Therefore, with all of this information in mind, it is suggested that more environmental infrastructure be constructed with even dispersal across all five boroughs of New York City to ensure that the increase of landscape connectivity is maximized (Meerow 2020). These community gardens should have large floral areas, diversity, and distribution, but there should also be wild areas of the garden, especially the soil, that are left alone to provide more habitat for bees (Matteson, Ascher, and Langellotto 2008; Matteson and Langellotto 2009; Matteson and Langellotto 2010; Rajbhandari et. al, 2023). The community gardens should be built in areas that receive large amounts of sunlight, and if possible, that have tall trees nearby for the bees to build colonies in (Matteson and Langellotto 2009; Matteson and Langellotto 2010). Perhaps most importantly, there should be other green spaces close to these community gardens to account for the ability and the tendency of the generalist bees to wander from the community garden where they reside, (Matteson, Ascher, and Langellotto 2008). This would greatly augment the ability to stitch together a semi-continuous habitat from a myriad of smaller fragments. These are the considerations that, according to the literature, would make for a good bee habitat. This is what can be done today to increase the number of pollinators present in the city. However, looking beyond the near future, other, more extreme measures can be taken to increase bee richness in NYC.

C. Tomorrow's Environmental Infrastructure. Beyond simply building new things, constructing the green infrastructure of the future, in the hopes of rethinking the design of the city from the ground up, to be in harmony with nature, requires a completely different way of thinking about how to conduct architecture. There have been many different theories posited to fulfill this need, a few of which will be discussed here. The first of these ideas is perhaps the most important: regenerative architecture. This idea is very broad and how exactly regenerative architecture is iterated varies widely, but the main idea is that built structures should give back to the environment instead of simply doing less damage; they should do more good instead of doing less bad (Saprykina and Saprykin 2021). An example of possible guidelines of regenerative architecture includes the principles that waste should be considered as valuable as food and vice versa, nature (and therefore humans, being part of nature) only uses renewable energy, and that nature is preserved and sustained through biodiversity (Saprykina and Saprykin 2021). Regenerative architecture seeks to take these guiding principles and integrate them into infrastructure, making buildings that give back to the surrounding environment. Other principles that follow the general rule of regenerative architecture include the Ecological Planning Method, whose aim is that only the most suitable land for human development should be developed on and that other areas, such as vulnerable habitats and ecosystems, should be ignored when it comes to consideration for said development (Catalano et. al 2021). The Ecological Planning Method is based on the concept of physiographic determinism, which states that development should respond to the operation of natural processes (Catalano et. al 2021). To reach this goal, the steps of the Ecological Planning Method are to collect ecological data about the area, select the relevant data, and analyze the data to understand which areas of land would be most suitable for certain kinds of human use (Catalano et. al 2021). The Ecological Planning Method might work well with the mitigation hierarchy, a preventative approach that seeks to first assess, avoid, reduce, and finally, offset the impacts of human activities if needed (Catalano et.

al 2021). However, this hierarchy is only emphasized on the local scale when it should be considered at the landscape level; the mitigation hierarchy should be integrated into all landscape development projects in such a way that the local ecology and its conservation are prioritized first and socio-economic needs come second (Catalano et. al 2021).

To follow these principles, it becomes necessary that the construction of buildings, and subsequently cities, becomes an interdisciplinary affair, requiring the creation of new sustainability metrics and procedures that must be followed before, during, and after all phases of construction and the accumulation and integration of knowledge of the local ecology of the surrounding area (Catalano et. al 2021). This overhaul of construction parameters is necessary because current environmental assessments and construction parameters call for the construction of buildings that do less damage to the environment, or consume fewer resources, rather than buildings that have a net positive, or regenerative, impact (Catalano et. al 2021; Muller et. al). For example, contemporary environmental assessments either do not factor in, or place very low value on, on-site biodiversity, instead opting to measure for factors such as the amount of permeable surface and levels of vegetation (Catalano et. al 2021). Not only are these assessment parameters suboptimal at measuring levels of biodiversity, but these parameters are not based on the larger environment as a whole, meaning that they are suboptimal in terms of ecological reliability (Catalano et. al 2021). To bring pollinators back to cities, the assessment parameters that are used to determine whether a building is environmentally sound must be reimagined, with one of the first steps being including conservation biologists or ecologists in every phase of the construction of new infrastructure (Catalano et. al 2021).

To facilitate the transition of construction from a single-discipline to a multidisciplinary affair, the DeMo framework was created (Catalano et. al 2021). The Design and Modeling of

Urban Ecosystems framework, which is a spatial-based approach to integrating built infrastructure into local ecosystems, was created to facilitate the cooperation between ecologists and designers from the earliest stages of a project to ensure that species other than humans can also use the space (Catalano et. al 2021).

The first step of the DeMo framework is the planning and definition of the project (Catalano et. al 2021). Information on the abiotic and biotic factors relevant to the project needs to be collected and analyzed to be used in ecological models (Catalano et. al 2021). Step two of the DeMo framework focuses on processing and implementing the ecological data at the proper scales, whether this is at the scale of a singular building or a landscape or municipality, using small-scale ecological modeling to set up feedback loops at the building level (Catalano et. al 2021). The idea behind those feedback loops is that they would start with a building being built using the DeMo framework, which would attract wildlife (Catalano et. al 2021). Observing how the animals interact with the building offers more data points to feed into the ecological models of DeMo, which would serve to improve the models, which would result in the next buildings being more effective at integrating and attracting wildlife, which would serve to provide more data points for the models, and so on (Catalano et. al 2021). The third step of DeMo is to select the best design solution that works with development goals and biodiversity targets (Catalano et. al 2021). Naturally, the manifestation of this step will vary depending on the region and the values of the entity that commands the construction, but generally, these development and biodiversity targets should be overhauled; the new targets should focus on creating buildings that focus not on doing less bad, but more good, applying the concept of regenerative architecture discussed at the beginning of the chapter. The fourth step of the DeMo process is monitoring flora and fauna species that interact with the now-built infrastructure, to collect data on these interactions in order to close the aforementioned modeling feedback loop and feed more accurate data back into the environmental models of the DeMo framework and pave the way for even more environmentally sound buildings in the future, with the hope that those buildings can be used as connection points to other sources of green infrastructure such as community gardens and parks (Catalano et. al 2021).

The DeMo framework is not uncommon in its basic function. Many different ecological architecture theories rely on the basic idea of gathering ecological data, using that data to build something that both fulfills a socioeconomic need and interacts with the local ecology to increase local biodiversity, observing the interactions between the newly built infrastructure and surrounding wildlife, and using that data to create a more accurate environmental architecture model for the next piece of infrastructure (Catalano et. al 2021; Charest 2002). However, other frameworks call for a step further, the integration of the green roofs of buildings with the green space on the ground such as parks and urban gardens, expanding the network of both of these types of green infrastructure so far that NYC looks far less like a city of glass and concrete and far more like the habitat that was destroyed to create it, a sort of habitat-city (Charest 2002; Catalano et. al 2021). The concept of zoning off certain areas of this green infrastructure to human interference, a practice commonly seen in national nature preserves, has also been posited, to allow the wildlife who would use these spaces to be as wild as they could possibly be in their surroundings (Mueller et. al). At this point, it must be reiterated that the only way of creating this habitat-city will be by embracing the idea of regenerative architecture, with one of the core principles being the idea of saving resources as zero consumption (Saprykina and Saprykin 2021). Utilizing these ecological frameworks could result in a greener city, which would in turn mean an increase in the number of pollinators in the city, including bees. However, for this infrastructure to be implemented, certain political factors must be considered.

One example of the materialization of these theoretical frameworks exists in the production of CLT, or Cross-Laminated Timber. CLT is a building material that is made of an odd number, usually three, five, or seven, pieces of wood that are glued and pressed together with a hydraulic press (Brandner et. al 2015). Gaining popularity in the last 10 years, this material has been used in residential buildings, office buildings, and schools in Canada, the United States, Japan, China, and New Zealand (Brandner et. al 2015). Compared to the current construction standard of glass, steel, and concrete, CLT can be made to be just as strong, is also fireproof, and is much lighter and more modular than the current materials, due to the fact that entire floors and walls of CLT can be built and then simply attached together because of the extremely light weight (Brandner et. al 2015). In addition to those benefits, because CLT is made out of wood, it stores carbon. Therefore, infrastructure that is made out of this material will remove carbon from the atmosphere because it is made out of wood, as the tree that the CLT was made of absorbed carbon to grow. It would be much easier to construct a net-negative carbon building using this material due to this attribute. This general idea of using radically different materials such as wood in buildings and striving for net negative instead of net neutrality is exactly what it means to do more good instead of less bad. This material is a good example of the first step of the physical manifestation of the principles of regenerative architecture and ecological design.

Chapter 4: Pollinator Policy

The first section of this chapter will address the steps that the city has taken to augment the amount of green infrastructure throughout the city, including reasons why the even distribution of this infrastructure has been difficult to implement due to varying political motivations and the priorities of the city and higher levels of government. The second section will expand to analyze infrastructure policies at the state level and to what degree these policies actually help pollinators. The third section will examine grassroots pollinator movements and to what degree independent organizations and groups of people have mobilized to advocate for pollinators.

A. City Level Policies. As aforementioned in the previous chapter, the two reasons for uneven green infrastructure distribution are the fact that the city is not prioritizing every potential benefit of said infrastructure and due to social phenomena such as environmental racism (Treglia et. al, 2022; Zuniga-Teran et. al, 2021). This uneven distribution of green infrastructure leads to two issues: the fact that almost no other potential benefit of green infrastructure is realized and that the uneven distribution leads to environmental racism (Treglia et. al, 2022; Zuniga-Teran et. al, 2021). Both of these issues can be solved through the even distribution of this infrastructure, but first, the challenges standing in the way of realizing this even distribution must be addressed.

The first challenge of the even distribution of green infrastructure is the fact that NYC is primarily focused on implementing green infrastructure for the sole purpose of increasing the ability of the city to manage stormwater (Meerow 2020). Realizing this goal only requires more green infrastructure to be built in southwestern Brooklyn and northern Queens, mostly (Meerow 2020). Building green infrastructure to increase stormwater management would also reduce the urban heat island effect and improve air quality (Meerow 2020). However, there is a strong negative correlation between these three benefits and the benefit of increasing habitat connectivity, suggesting that in order to realize the benefit of increasing habitat connectivity, green infrastructure must be built in different areas (Meerow 2020). In addition, even though there is a positive correlation between the benefit of improving stormwater management and reducing the urban heat island effect and improving air quality in certain locations, this positive correlation is small, even though it is statistically significant, suggesting that, statistically speaking, it would be indeed most beneficial to build green infrastructure throughout the entire city (Meerow 2020).

While it is indeed true that a more even distribution of environmental infrastructure would bring more benefit to the city, the current policies that the city has in place to increase the amount of green space, and the amount of pollinator habitat, have been substantial. Across the city from 2010-2017, the city built and planned 4,320 green infrastructure assets, with an additional 140-180 assets planned for 2018 (NYCDEP 2017). In addition, the Department of Environmental Protection, or DEP, also implemented a reimbursement incentive for private entities who are interested in constructing green roofs on their buildings, offering a scaled program that would offer the amount of money given back per additional inch of green roof depth, with a maximum reimbursement of $30 per square foot at a depth of 4 or more inches of soil (NYCDEP 2017). The DEP also partnered with the Department of Housing Preservation and Development, HPD, to fund green roofs on NYC's public housing projects by providing funding for green roofs on top of new HPD infrastructure projects upfront (NYCDEP 2017). For the 17 projects that are part of the partnership, DEP will work with HPD from the first step to the last to ensure that the green infrastructure is implemented correctly and that the projects are seen through to the end (NYCDEP 2017).

The DEP added to these accomplishments over time. In 2022, the majority (59%) of DEP projects were right-of-way projects, which are pieces of green infrastructure that are built into city streets and sidewalks, which also increase the amount of green space potentially available to pollinators and is a prime example of the type of infrastructure needed to blur the line between the city and a massive, fragmented habitat (Charest 2002; Catalano et. al 2021). Augmenting these smaller right-of-way projects, in 2022 construction began on four rain gardens in northern Brooklyn that would equate to 10,741 square feet of green space (NYCDEP 2022). From 2017-2022 the DEP added 8,461 additional green infrastructure assets, for a total of 12,781 assets, 80% or more of which have been built in areas that have been highlighted as in need of environmental justice (NYCDEP 2022). Beyond continuing its previous efforts of adding more environmental assets throughout the city, the DEP also completed its first large-scale project in 2022, a large triangular park in a traffic median in Queens (NYCDEP 2022). Designed to manage stormwater, this large area of habitat could also provide significant habitat to native pollinators (NYCDEP 2022). The DEP also submitted plans for 15 additional large-scale projects which are currently in the design stage, with four more pending construction (NYCDEP 2022). Through the reimbursement program that was underway in 2017, the DEP has given 14 million dollars to 34 private property owners to develop green roofs on their properties (NYCDEP 2022). In addition to the significant strides that the DEP has made through this incentivization program, the city has also passed two new laws: Local Law 92 and Local Law 94, which require the installation of solar panels or a green roof on all new buildings or any building undergoing a major roof renovation (The Nature Conservancy (TNC) 2021). The passing of these laws represents a strong push from the city for the advocacy of regenerative architecture and is an excellent step towards creating the habitat-city that would be ideal for augmenting the pollinator abundance in the city. To keep the public involved and informed, the DEP developed and launched an interactive map that allows any member of the public to track all DEP projects throughout the city (NYCDEP 2022). The map differentiates by project type and stage of completion, and also shows projects that are currently in the design phase (NYCDEP 2022). Through these two green infrastructure reports, it is clear that NYC is committed to both claiming and proving that green infrastructure is a city priority, and that the agency responsible for this implementation will have the resources to not only continue projects started in the past but also initiate new and more impactful initiatives over time.

Strangely, while all of this information can be gathered from the green infrastructure annual reports that the NYCDEP has been releasing, this information is not mentioned in the mayor’s larger plan, PlaNYC (PlaNYC 2023). Within this larger plan, the only mention of the DEC is in the context of creating a new leadership structure for coastal flood resilience in 2023 (PlaNYC 2023). Pollinators are not mentioned specifically, and increasing the amount of green space in the city is mentioned in the context of adding more walking trails and protecting wetland areas to better manage stormwater (PlaNYC 2023). While there have been other plans, such as MillionTreesNYC, that have placed heavy emphasis on increasing the amount of canopy cover in the city, PlayNYC itself only mentions increased environmental awareness and education, including an expansion of school programs (PlaNYC 2023).

Ultimately, at the city level, different protections apply to trees in different areas, whether those trees are on the street, in a park, or on private property (TNC 2021). Since these vast differences in protections depend on the setting, combined with the fact that properties that have not been renovated since 2007 are not subject to the latest protection regulations, leads to protection laws for trees being confusing and ultimately difficult to enforce (TNC 2021). This is significant because while there are some species of burrowing bees, as aforementioned, trees are an important source of bee habitat, so it remains imperative that the regulations protecting them are well written and well enforced.

While it is clear that some policies can be expanded upon, one successful policy is the NYC Department of Parks and Recreation's GreenThumb Program. Although technically a city program, GreenThumb was created by the authority of the New York State Attorney General, when gardeners fought against the mayor's decision in the 1990s to sell off community garden spaces to have them developed (Stone 2009). Those gardeners caught the attention of the Attorney General, who brought a lawsuit against the mayor and deemed that the community gardens had a right to exist as parkland (Stone 2009). Although these gardens are a city-level program, and they were technically created with the help of the state, the gardens themselves are run by members of the community, and the regulations to have a community garden be registered as a GreenThumb garden are very general on purpose, so that the members of the community have free reign as to how to use the space (Stone 2009). These gardens are especially important in low-income neighborhoods as they are an excellent method of gaining access to fresh produce (Stone 2009). The gardens also serve as hubs for all sorts of youth, senior, cultural, educational, faith-based, and advocacy events, to name a few (Stone 2009). The model of the GreenThumb program, operating on the city level with state-level support, while leaving virtually all operational matters to the responsibility of the community, is a paragon of the kind of green space that every city needs more of in the future.

B. *State-Level Policies.* While the city is focusing on adding more green infrastructure around the boroughs, mostly rain gardens and other stormwater managers while also running incentivization programs, (NYCDEP 2017; NYCDEP 2022), the state has focused on taking action in other ways, primarily through lawmaking, research, and infrastructure (New York State Department of Agriculture and Markets 2022 (NYSDAM)).

In terms of lawmaking, the NYSDAM passed a law that took effect on December 23, 2021, that requires all beekeepers to report their colonies to the county, so that the state has an accurate idea of how many colonies there are and what they do, an essential first step in any conservation effort (NYSDAM 2022). Of more significance was a law passed by the NYSDEC, the New York State Department of Environmental Conservation, which states that neonicotinoid classes of insecticides would now be classified under "restricted use," to only be used by trained applicators (NYSDAM 2022). This law also requires the sales and use data of neonicotinoids to be reported to NYSDEC annually in accordance with another law, allowing NYS to now keep a sharp eye on exactly who is using this pesticide, how much they're using, and what they're using it for, while requiring the users to be properly trained to reduce the chances of improper use (NYSDAM 2022).

NYS has also been installing new pollinator-friendly infrastructure all over the state at all eligible government-owned buildings in Buffalo, Syracuse, Watertown, Binghamton, Mahoney, Hornell, Oneonta, Oriskany, and Utica, to name a few (NYSDAM 2022). All of the state office buildings in these locations have received some sort of remodel or enhancement to augment the number of pollinator-friendly plants growing there to augment the number of pollinators present at these locations (NYSDAM 2022). But the state has gone further, looking also to highway systems to see how they could increase the amount of viable habitat available for all wildlife around highways (NYSDAM 2022). They have done this by first releasing new Vegetation Management Guidelines, which suggest control methods other than mowing, along with other methods of conservation and management practices to help pollinators (NYSDAM

2022). The state has taken a special interest in modified mowing practices, not only implementing this technique wherever possible, in places such as Rochester, Buffalo, Utica, and Poughkeepsie, but also in other areas and along other highway systems (NYSDAM 2022). Beyond highway system implementation, the state has also initiated a research study in collaboration with RIT, the Rochester Institute of Technology, to understand the impacts of a modified mowing regime on pollinators (NYSDAM 2022). This study examines different variables including climate, traffic density, road size, and surrounding ecological communities and land cover (NYSDAM 2022). While this study has not released any official results, RIT researchers noticed an encouraging number of pollinators at all of the study locations by the end of 2021 (NYSDAM 2022).

The second research initiative undertaken by the state was implemented in 2016 when NYS collaborated with Cornell University to create the Cornell Tech Team (CTT), a group of professionals brought to combat the falling rates of bee abundance (NYSDAM 2022). Comprised of professional beekeepers, bee technicians, and bee scientists working at Cornell and an NYS apiculturist, this team works with beekeepers registered with the state to combat the most common issues plaguing their colonies, ranging from queen death to *V. destructor* infestations to small hive beetles (NYSDAM 2022; Hinsley et. al 2020). The main findings of the CTT have been that impacts of *V. destructor* have been strongly mitigated among all of the beekeepers who stay with the CTT for all three years of the program (Hinsley et. al 2022). The CTT also found that most beekeepers only check their colonies for signs of *V. destructor* infestation an average of 2.2 times a year, when the team suggests that the beekeepers should be checking the colonies for signs of this infestation once a month (Hinsley et al. 2022). The team found that the main reason cited by the beekeepers for this lack of checking at adequate time intervals was a lack of time and labor power, so the CTT worked individually with every beekeeper that was registered with the program to come up with a customized agenda of priorities for the beekeeper so that the beekeeper could incorporate checking for signs of *V. destructor* in addition to all of their other tasks (Hinsley et al 2023). The CTT also reported that one of the new threats to colonies, small hive beetles, present in every annual report after 2020, increased two times over from 2021 to 2022, increasing from 12.9% of colonies being infested with the beetles from the period from 2016-2019 and 28.4% of the colonies being infested with the beetles from 2020-2022 (Hinsley et. al 2022; Hinsley et. al 2023). However, the most concerning report from the CTT is the fact that there has been an increase in the rate of bee abundance decline starting in 2020, following a pattern of loss reduction that spanned from 2016-2020 (Mullen et. al 2018; Hinsley et. al 2019; Hinsley et. al 2020; Hinsley et. al 2021; Hinsley et. al 2022; Hinsley et. al 2023). While this is a negative outcome, it remains that the CTT has been effective in helping beekeepers reduce their levels of *V. destructor* infestations, and the death rate tracking that they are doing is important to understand to combat the proliferation of this death in the future.

C. Grassroots Pollinator Initiatives. Grassroots Pollinator initiatives differ vastly from one another, usually advocating for better conditions for humans, thus helping pollinators indirectly, and also varying in scope, ranging from focusing on advocacy on changing a city block to having chapters across the country.

One of the smallest grassroots initiatives that indirectly helps pollinators is vision42, an organization that seeks to change Manhattan’s 42nd Street to a pedestrian mall, fitted with a light rail system and a vast abundance of green space (Horwitch and Mulloth 2010). This organization also generally believes that dense urban centers should have fewer personal motor vehicles, instead using a robust transportation system, so that more of the streets of the city could be converted into pedestrian malls (Horwitch and Mulloth 2010). In advocating for fewer cars and far more space and greenery in the city, this group is advocating for less air pollution and more habitat that would be massively beneficial for all urban wildlife including bees (Horwitch and Mulloth 2010). Another city-based grassroots initiative is GREEN.US, an organization that seeks to provide environmental education, build green roofs, mainly on the tops of schools, and create more green urban workspaces for people (Horwitch and Mulloth 2010). This initiative also helps pollinators because the construction of green roofs would create more habitat available for pollinators (Horwitch and Mulloth 2010).

Another type of grassroots initiatives that help pollinators are known as bridge organizations, which are civic groups that work both with and against governmental agencies, depending on what the situation calls for, to achieve environmental goals (Connolly et. al 2013). These organizations focus on advocating for tree planting, gardening, urban farming, and water quality among several other goals (Horwitch and Mulloth 2010). To realize these goals, these organizations will accept support from local, state, or federal government organizations in addition to corporate and other organizational support, to put smaller organizations into contact with one another to achieve larger goals (Horwitch and Mulloth 2010). One of the defining characteristics of these organizations is that they are typically one of the first organizations to respond to calls for change in the social conditions in the city, so they are one of the pivotal drivers in improving urban ecology (Horwitch and Mulloth 2010). Two examples of bridge organizations are the New York City Community Garden Coalition (NYCCGC) and the NYC Parks' GreenThumb organization (NYCCGC 2023; NYC Parks 2023). These organizations were at the forefront of the creation of NYC's community gardens in the 1970s but also operate in different spheres. NYCCGC advocates for people's right to access the gardens, pushing back against the city government when they try to turn more gardens into areas for development, mostly through legal action (NYCCGC 2023). NYC Parks' GreenThumb organization works within NYC's Department of Parks and Recreation to provide citizens with the resources they need to start working in a community garden (NYC Parks 2023). This organization also hosts workshops, fairs, and other special projects to help connect to the gardens through the Parks Department (NYC Parks 2023).

On the national level, seedsavers work loosely with one another to preserve the genetic information of otherwise long-lost plants (Campbell and Veteto 2015). In the face of corporate agricultural companies monopolizing and globalizing global seed production and dispersion, while eliminating any and all seeds that don't fit a narrow parameter set that fulfills the requirements of the global processed food industry, many people around the world have opted to become "seedsavers," people who grow varieties of plants that produce foods that are more nutritious, flavorful, and ever increasingly rare (Horwitch and Mulloth 2010). Seedsavers aren't only saving seeds, they're dedicated to preserving the agricultural biodiversity, or agrobiodiversity, of the land (Horwitch and Mulloth 2010). Agrobiodiversity refers to the biological components of anything related to growing food (Horwitch and Mulloth 2010). In preserving seeds, seedsavers also ensure that they preserve the cultural and anthropological history of a place, and they recognize that no two places can grow the same plants because every place is different (Horwitch and Mulloth 2010). The Free Seed project seeks to bring not only dedicated seedsavers together through community events but also anybody who cares about growing healthier food and deepening their connection with their environment (Horwitch and Mulloth 2010). Connecting church groups, restaurant owners, consumers, farm implement designers, beekeepers, and many others from all walks of life and all areas of the US, Free Seeds encourages everybody to think deeper about their food, human-environment relationships, and the simple importance of sharing (Horwitch and Mulloth 2010). Through these community events, free seeds not only encourage the preservation of the aforementioned values but also facilitate the simplicity of sharing with strangers and building a community by swapping packets of seeds and knowledge on how to grow and care for them (Horwitch and Mulloth 2010). This practice is not only massively beneficial for humans, but it is also very beneficial for the local ecology and pollinators as well (Horwitch and Mulloth 2010). As aforementioned, seedsavers strive to plant and grow specialized native plants, which are more beneficial for the local ecology than generalist species that are introduced, and the plants that they grow that are not natives are grown with techniques that enable them to mimic and adapt to the local ecology (Horwitch and Mulloth 2010). In addition, because of their propensity to not only grow an extremely diverse array of species but also to actively hybridize and create new species, seedsavers are creating farms and gardens with a species richness far higher than the monoculture farms of corporate farmers (Horwitch and Mulloth 2010). At the edges of their farms, seedsavers also tend to select and plant the species that they have chosen for their desirable characteristics, trying to hybridize them with other species to create an even more beneficial plant at the edge of the farm (Horwitch and Mulloth 2010). This tendency to experiment with new plants at the edge of the farm not only further increases the immense species richness present in the farms and gardens of seedsavers, it also reduces the distance between the farm and the forests or grasslands adjacent to the farm (Horwitch and Mulloth 2010). This is important because the area next to the farm is where bees are most likely to reside, and in reducing the distance from this area to the farm, seedsavers are reducing the distance that bees need to travel to obtain nutrients, reducing the strain placed on the bees and allowing them to conserve more of their energy while simultaneously allowing them access to a wider variety of nutrients (Horwitch and Mulloth 2010). With chapters around the country, Free Seed and organizations like it are encouraging practices that are not only immensely beneficial for humans but also other wildlife, including pollinators, which is the first step in increasing their numbers (Horwitch and Mulloth 2010).

Chapter 5: Policy Suggestions for Future Pollinator Success

The first section of this chapter will focus on policy recommendations specifically at the city level, mainly addressing the uneven distribution of green infrastructure and its primary focus on the green infrastructure benefit of stormwater management, but also focusing on the type of green infrastructure already installed and what changes can be made on the micro level to augment pollinator levels. The second section, recommendations for state policy, will address the state's focus on the modified mowing experiments and how the state conducts its research. The third section of this chapter will analyze new possible pollinator infrastructure and what kind of policies have to be put into place to support the construction of new pollinator infrastructure in New York City, especially considering that more green infrastructure has to be built in disadvantaged/low-income areas to make up for the current lack of green infrastructure in those spaces. The final section of the chapter will consider policies that can be implemented to rethink current infrastructure, from parks to buildings, to consider how these pieces of infrastructure can be utilized not only by humans but also by other wildlife including pollinators.

A. *City Policy Recommendations.* The first major issue with the city's approach to green infrastructure installation is that while it does generate some other benefits besides stormwater management, most of the infrastructure that is being built is small right-of-way green spaces that are being used to control stormwater, as aforementioned in chapter 4 (NYCDEP 2022). While this is augmenting the number of pollinators in the city somewhat, I believe that to use green infrastructure the city would have to install it in the boroughs outlined in chapter 3 section 1, or the Bronx, Queens, Staten Island, and parts of Brooklyn and Manhattan (Meerow 2020). I think that if the city were to at least consider some of the other benefits of green infrastructure installation, especially landscape connectivity, there would be a much greater variety of green infrastructure being installed, and under this scenario, not only would there be a higher variety of green infrastructure that would serve both humans and pollinators. As previously stated in Chapter 3, the distribution of green infrastructure is also uneven, and implementing green infrastructure to prioritize a goal other than stormwater management would help even out the uneven distribution pattern, which would also bring more benefit to the city in the long run (Wong and Montalto 2020). One study created two computer models, the first simulating the city's current green infrastructure policies, and a second model that simulated the city if it enacted policies that constructed green infrastructure not only based primarily on the benefit of stormwater management but also to obtain the other latent benefits of green infrastructure (Wong and Montalto 2020). The second model that accounted for the other benefits of green infrastructure resulted in stormwater management rates similar to those proposed in the first model, but in addition to these results, the second model also resulted in slightly, but statistically significant, greater amount of green infrastructure being built, including more rain gardens, green roofs, community gardens, permeable playgrounds, bioswales, and trees (Wong and Montalto 2020). The second model, interestingly, also projected that fewer permeable pavement construction projects would be initiated, but that more permeable pavement would be constructed, implying that the second model predicts fewer, larger permeable pavement construction projects than the first model (Wong and Montalto 2020). The second model also predicts that more New Yorkers will have access to green infrastructure, particularly Bronx residents (Wong and Montalto 2020). Additionally, the second model predicted that more value would be brought to the city; the simulations estimated that the value of the benefits implemented using the parameters of the first model would bring in $18.7 million for the city, give or take $1.4 million, but the simulations predicted that the second model would bring in $19.9 million for the city, give or take $1.3 million (Wong and Montalto 2020). When juxtaposing the two models, it is clear that the second model predicts an additional $2 million for the city per year (Wong and Montalto 2020). While these are computer models, they offer support for my recommendation that the green infrastructure of the city should be more evenly distributed and that city agencies such as NYCDEP and the office of the mayor should be doing more to work towards this goal.

Beyond the recommendation of evenly distributing green infrastructure across the city by giving more consideration to the other potential benefits of green infrastructure other than stormwater, I also suggest that the city change what kinds of green infrastructure they are installing. As of 2022, the NYCDEP is mainly installing Right of Way projects, small patches of green spaces on the sides of sidewalks; along places where people walk. This is massively influential in striving for the future goal of turning the city into one massive, fragmented habitat as was mentioned in chapter 3 section 3, but these installations could be more intentional, as right now, they are only installed to manage stormwater. Planting some native plants that are flood tolerant along with the grasses that are normally planted would help to attract pollinators as well, and striving to construct more of these Right of Way projects in the boroughs of the city aforementioned above to increase even distribution of green infrastructure would be a huge step towards solving the two issues of uneven distribution and lack of pollinator-intended green infrastructure.

Along with simply evening out the distribution of green infrastructure and planting more pollinator-friendly flowers in the right-of-way projects that the DEP constructs, the DEP could also focus on parks specifically, as these are large swaths of green space that are usually dominated by grass, which offers the cultural ecosystem service of space for recreation, but does not provide the regulating service that pollinators are a part of. For parks to serve both purposes, I propose that the land area of parks be examined and viable areas for native flower gardens to be brought forth. Not all park grass is used in the same way, and the vast majority of people most likely wouldn't mind the area of grass along the edges of paths or circling rocks or statues being replaced with native flowers. More complex visitor metrics and use data could be accumulated to analyze what sections of the park are used by people the most and the least, and the least occupied areas of park grass could potentially be converted into much larger native flower gardens. Gardens in parks would most likely prove to be excellent habitats for bee colonies because as mentioned in chapter 3, bees tend to make their colonies in the trees high above the flowers they draw nectar from, thus, any New York City Park with an abundance of trees, that is, most of them, would be a good candidate to have some of its grass converted into a garden of native flowers.

My final recommendation for city-level policies would be in reference to the green roof incentive program discussed in chapter 3. While the incentive program currently offers private institutions money back for each square foot of green roof that they build, I suggest expanding this program to schools. I think that offering public schools an incentive program for them to plant green roofs would not only vastly increase the amount of green infrastructure present in the city, I think that the green roofs of the schools would serve as an excellent educational tool for students to teach them more about the importance of environmental science and conservation while providing an easy way for students to get more time in the outdoors.

B. State Policy Recommendations. The first state pollinator policy I believe could benefit from an addendum is the modified mowing policy. As discussed in chapter 4, New York State implemented a policy of mowing on a modified schedule, which seems to have resulted in an increase in pollinator abundance in the areas of modified mowing (NYSDAM 2022). Given that the edges of highways are kept mowed to enable vehicles that need to leave the road to be able to see what is on the side of the highway to not hit anything, I would recommend a policy that tolerates a new height ceiling of plants alongside highways of at least six inches so that wildflowers could be present alongside all highways year-round. For drivers to see potential off-road hazards like guardrails, neon light reflective poles or signs should be erected at regular intervals on top of these potential obstacles where visibility could prove to be an issue.

The second state policy that I would consider adding to would be concerning the Cornell Tech Team (CTT), introduced in chapter 4. As of now, all beekeepers working with the team stay with the team for three years (Hinsley et. al 2020). While they make significant improvements in how many colonies they can keep alive over their three-year partnership with the CTT, the fact that every year since 2020 has seen increasing rates of colony deaths (Hinsley et. al 2021; Hinsley et. al 2022; Hinsley et. al 2023), leads me to suggest an extension of how long beekeepers work with the CTT to a minimum of five years. Given that the short partnership of beekeepers with the CTT is due to a lack of time on the part of the CTT to give every beekeeper individualized attention, my second policy recommendation regarding the CTT is to give them enough funding to hire enough supplemental staff to be able to stay with every beekeeper for five years.

Additionally, to further combat the increasing rates of colony deaths since 2020, I would also suggest the establishment of a sub-team to the CTT. The purpose of this team would be to assist the beekeepers in inspecting their hives for evidence of *V. destructor* infection, to disseminate any new information that the CTT releases to the beekeepers as soon as possible, and in general to work more closely with more beekeepers than the CTT might be able to, since the CTT is comprised of a small group of specialists. This sub-team would ideally enlist far more people than the CTT so that they would be able to counsel the beekeepers much more frequently than the CTT might.

C. Grassroots Pollinator Initiative Recommendations. One of the most important additions to current grassroots pollinator initiatives is the addition of the rewilding philosophy. Rewilding involves restoring an area of land to the state that it was in before human interference (Lehmann 2021). In the context of cities, rewilding mainly involves focusing on making cities denser and greener, as urban sprawl is not only harmful to the environment but also to human health and well-being (Lehmann 2021). Urban sprawl is associated with higher rates of depression and obesity, which can be avoided by focusing on building cities that have higher densities, more robust public transportation systems to serve the increased amount of people that will be living in them in future generations, and more green spaces, to make the dense cities feel cooler, greener, and more open (Lehmann 2021). As aforementioned, this philosophy can only take root if the idea of a city is reimagined from the ground up. Unfortunately, the WHO currently defines a healthy city as one that maximizes the well-being and happiness of humans and makes no mention of green space or the well-being of other organisms, which are prerequisites for the happiness and well-being of humans (Lehmann 2021). The first step to making rewilding a central part of any new city-based construction project is to integrate it into the philosophy of what a good city is supposed to be. The second step is to integrate rewilding physically into the city, by using all of the methods discussed in Chapter 3. Green roofs, vertical farms, and vertical gardens can all be used to quickly increase the amount of green space alongside increasing the density of a city (Lehmann 2021). Rewilding not only increases green space, but also increases the biological productivity of the rewilded area; rewilded areas are havens for pollinators such as birds, butterflies, and bees (Lehmann 2021).

Another significant addition to current grassroots pollinator initiatives would be to get more stakeholders involved. While the current efforts of the seedsavers and other community leaders are significant, the grassroots movements stand to gain much by increasing their numbers by striving to integrate citizen scientists or expand educational outreach. Perhaps one of the most effective ways of doing this would be through social media, where organizations in densely populated areas such as Bridge42 have a high potential to amass a large following by spreading their message because new members do not have to travel far to join them, unlike the seedsavers, who are widely dispersed through the United States. In terms of expanding educational outreach, bridge organizations are in the strongest position to advocate for more funding or a curriculum change in schools to discuss the importance of integrating philosophies such as rewilding into the construction of cities. This is because bridge organizations could advocate directly to the government; larger bridge organizations would ostensibly be very effective in pressuring smaller levels of government to make direct changes to the school curricula because these organizations have more resources. It should also be the role of these grassroots organizations to collect large followings to better represent the people to the city and state governments so that when the city and state are trying to create a new policy, they can look to the grassroots bridge organizations to get a good sense of what the will of the people is and implement policy accordingly.

D. Rethinking Current Infrastructure to Expand Pollinator Habitat. When discussing the expansion of pollinator habitat and the associated policies that will drive this expansion forward, it is imperative that the ideas of chapter 3 stay centerfold at all times. Ecological models must be used at all times, conservation biologists must be present at every stage of construction, and regenerative architecture is a requirement, not a pleasant add-on if money permits. First and foremost, policies that require this kind of construction are paramount. New York City is already leading the way with this aggressive push towards implementing and requiring regenerative architectural policy with the passing of Local Law 92 and Local Law 94 (TNC 2019). This is the exact kind of policy that needs to be implemented more heavily going forward, not only because it addresses all new construction, but also because it requires the upgrade of old infrastructure as well. I believe that the city has done well so far in integrating new technologies into the construction of brand-new buildings, because it is easy to incorporate new technologies when starting from a blank plot of land, as you can fill the entire building to the brim with new technologies without considering or having to work around the old infrastructure that already exists. Perhaps a bigger challenge, then, is figuring out how to retrofit all of New York's older infrastructure with technological adaptations that would make them more regenerative in nature. I believe in order to accomplish this goal the first policy that should be passed is one that combines the requirements of Local Law 92 and Local Law 94 into one requirement that calls for all new buildings or all buildings undergoing major roof renovation to implement both a green roof and solar panels. While it is admirable that Local Law 92 and Local Law 94 require green roofs, I believe that the next wave of policies that focuses on buildings should require the buildings to act more in line with the guiding principles of regenerative architecture from chapter

4, that is, the buildings should use all renewable energy and encourage biodiversity, and compost wherever possible, following the idea that waste is equivalent to food.

E. New Pollinator Infrastructure. New pollinator infrastructure should be built with the same principles of rethinking current infrastructure, to an even more aggressive extent. Given that building entirely new infrastructure is more disruptive to the surrounding environment than adding something new to an existing piece of infrastructure, it is even more important to use environmental architectural modeling and regenerative principles when constructing entirely new infrastructure. Using DeMo frameworks, the idea of the large fragmented habitat-city, and the Ecological Planning Method, new pollinator infrastructure should be built only in areas that are the most able to absorb the damage wrought by human development, and using ecological architecture models that will be fed the interaction data from the building once it is done to understand how to build a more holistic building next time. Of course, all new pollinator infrastructure should be first built in areas where it is the most lacking, to achieve the goal of creating greater landscape connectivity, which is important for pollinators because it is they, along with other flying organisms, who will benefit most from greater landscape connectivity. To an organism that can fly, a city with green space every few feet should function quite similarly to an organic habitat, because the next area of green space is a few wingbeats away. I think that one of the most important policy changes that would impact all new pollinator infrastructure would be the complete redesign of construction parameters, as is necessary with policies concerning the renovation of existing infrastructure. The most significant concept that all new green infrastructure construction should consider is the fact that all new constructs should not seek to do less damage but be more regenerative. In this sense, policies should be enacted to require that all new constructions in the city should first consider the wildlife in the area and how they would utilize the space. When those considerations are finalized, only then should the needs of humans be considered. While this may seem counterintuitive, this is one of the easiest ways to ensure that infrastructure gives back to the Earth: by making sure that it is put first, and us second. In their most extreme iteration, these policies could resemble the idea that every city should mirror a forest and that every building should sequester carbon, harvest water, produce energy, and grow food, similar to the trees of a forest. This is but one route that these policies could take, so long as they require the construction of infrastructure that gives back in some way to the land from which it came.

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