

Review

Anthropocene Crisis: Climate Change, Pollinators, and Food Security

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Abstract: In this paper, we propose a new approach—understood as a whole-of-community approach—to address a dualistic and dysfunctional human/nature relationship. Of particular concern is the decline in health and numbers of the insects that pollinate an estimated 90 percent of the Earth’s flora and an estimated 35 percent of global crop volume. Specifically, bees provide the majority of biotic pollination and play a critical role in food crop pollination. Multiple factors are contributing to this growing problem including a changing climate. In 2016, the International Commission on Stratigraphy agreed that the concept of the Anthropocene—the human epoch—is of sufficient scale to be considered part of the geological time scale. This indicates that these crises are not random or passive—they are largely the direct result of human activities. Despite decades of awareness of these socio-ecological issues, they continue to worsen. In addition, the growing awareness of the critical role of pollinators is creating a new understanding of our interconnectedness with the “natural” world. We introduce the Bee City movement as a way to operationalize a whole-of-community approach. Individual action is critical, but addressing pollinator health in these forums legitimizes and provides an institutional space for otherwise fringe, or even marginalized, activities and more coherent spaces for habitat creation.

Keywords: pollinators; Anthropocene; climate change; food security; community

1. Introduction

Multiple factors, including a changing climate, are contributing to the myriad socio-ecological crises of the time such as mass species extinctions. These crises are not random or passive—they are directly linked to human activity [1,2]. In particular, the links between pollinators, food security, and climate change are becoming increasingly clear. Despite a longstanding environmental movement these crises persist, in part, due to the “cooptation [and] reproduction of existing structures of economic exploitation and political oppression” [3] (p. 688). In 2016, the International Commission on Stratigraphy agreed that the concept of the Anthropocene—the human epoch—is geologically real, and of sufficient scale to be considered part of the geological time scale. Most of the biosphere has been altered by human settlements and agriculture, and anthromes now constitute three quarters of the terrestrial biosphere [4]. In fact, there is no part of the biosphere untouched by human influence due to the global impacts of climate change [5].

As part of these changes, we are experiencing what is being called the sixth mass extinction [6–8]. Mitchell called this the “large-scale structures of violence that violate laws and agreements between humans and other beings” [9] (p. 3). Of particular concern is the decline in health, and in numbers, of pollinating insects. Humans are notoriously short-sighted and our response to the threats of

extinction is no exception [2]. The gravity of *forever* seems lost on many in the political sphere whose focus is concentrated in the few short years of a political term or on what might contribute to personal gain. Evidence from Germany, Britain and the Netherlands [10] indicates that there are significant declines in both insect biomass [11] and on the plant species that are dependent on insect pollination [10]. While we are all implicated in these losses, there are opportunities to direct our commitment, attention and ways of thinking and acting in responding to loss in positive and constructive ways [12]. The increasing awareness of the environmental plight of bees and their key role in pollination is one of those opportunities.

Pollination is a mutually beneficial interaction between plants and pollinators. Generally, the delivery of pollen occurs as a product of eating; insect pollinators are seeking nectar (carbohydrate) or pollen (protein) and their specific behavior and anatomy allows them to pick up and distribute pollen between flowers [13]. This relationship was not clearly understood until the 18th century, when Professor Joseph Gottlieb Kölreuter from the University of Karlsruhe, Germany developed a technique for artificial fertilization and cross-hybridization of plants [13]. More than a half century later, Charles Darwin's work espoused the significance of pollination for plants and opened up a new conversation about the "reciprocally adaptive relationship between plants and their pollinators" [13] (p. 18). A century and a half later, we are still only just beginning to understand the myriad interconnections that comprise multi-species interactions and healthy ecosystems.

Concern for pollinators is growing worldwide with increasing evidence that pollinators are in crisis [11,14]. Evidence suggests that global climate change impacts will only amplify the decline in pollinator populations, threatening ecosystem resilience and food security at local and global scales. In this paper, we argue that agricultural reliance on one species of bee *Apis mellifera* (the European or western honey bee) poses many of the same issues as high chemical input mono-cropping and that a concerted effort needs to be made towards native bee conservation. We offer a whole-of-community approach as a theoretical framework to guide the praxis of these efforts. We discuss the current understanding of the critical role of pollinators in global food security and causes for their decline, and outline one of the strategies adopted in North American cities—namely, the Bee City movement as a growing movement of concerned citizens taking root at the municipal level.

2. Whole-of-Community Approach

Drawing on the relevant literature of political ecology, the environmental humanities, and the informal economy, we present a whole-of-community (WOC) approach [15]. This is a foundational, community-oriented, approach designed to provide a framework to address collaborative complex issues. A WOC approach emphasizes a "concept of community ... that would include the whole of the biotic community" [16] (p. 2). It recognizes that the "social and the natural are co-constitutive within myriad networks" [17] (p. 213). Pollinating bees are highlighted as an illustrative example of how this convergence of theories can be understood through praxis. A new conceptualization of community is important for the protection and growth of current pollinator populations and provides a new (re)balancing dimension for humans and non-humans to thrive in a human dominated world.

This shift is important because there is a risk of pollination-system collapse if a diversity of native bee species in integrated agricultural systems is not supported [18]. *Apis mellifera* is the most highly managed pollinator species in the world and greatly relied on for pollinating the large swathes of monocultures that dominate North American agriculture. Over-reliance on one type of pollinator as a "monoculture" can create vulnerability, such as what we are experiencing with the intensive use of *Ulmus americana* (American Elm), *Fraxinus americana* (white ash) and *Fraxinus pennsylvanica* (green ash) as street trees, species that are now plagued by Dutch Elm Disease and the Emerald Ash Borer, respectively. Rachel Carson pointed to this threat in her landmark book *Silent Spring* in 1962 when she wrote, "What is happening now is in large part a result of the biological unsophistication of past generations. Even a generation ago no one knew that to fill large areas with a single species of tree was

to invite disaster. And so whole towns lined their streets and dotted their parks with elms, and today the elms die" [19] (p. 67).

There is a danger in relying on any monoculture as there is increased risk of disease or pest resistance resulting in the loss of the entire crop or colony. Some of the most widespread diseases impacting *Apis mellifera* continue to develop resistance to the antibiotic treatments commonly used to treat them [20]. Monocultures, including large colonies of bees, provide an optimal breeding ground for horizontal transmission when viruses are passed on to individuals in the same generation [21]. We have seen this throughout history from the largest to the smallest scales. The Irish potato famine in the 1800s saw the death of one million people in Ireland after their primary crop, the potato, was infected with blight [22]. This may appear to be an isolated incident, yet the "rate of movement toward homogeneity in food supply compositions globally continues with no indication of slowing" [23] (p. 4003). Planting a variety of native plant species provides habitat (food and nesting sites) for a diversity of pollinators and can help reduce the risks associated with over-reliance on one bee species for the food security provided by pollination services.

A WOC approach is one that views community as a shared resource with a goal of benefitting all community members [15]. The "anthropocentric privilege of our own species" stems from a dualistic ecological politics that deprioritizes our dependency and interconnectedness with other living things and our environment [24,25] (p. 5). This requires a decentering of human agency including deprioritizing the subordination of wild bees to the capitalist penetration and financialization of *Apis mellifera*. This does not necessitate devaluing the contributions of this bee species or their importance in global food systems under the current industrialized system; however, it does point to the need to prioritize the health of all pollinators beyond honey bees, particularly native bee species who do not benefit from extensive global breeding programs to sustain their population numbers.

3. Pollinators and Food Security

Pollinators play a uniquely critical role in our everyday lives by pollinating an estimated 35 percent of global crop volume [26]. While there are other species that provide pollination services such as flies, wasps, beetles, bats, and others, bees provide about 70 percent of the biotic pollination. Along with entire ecosystems depending on pollination services of insects and other pollinators, pollination by bees is a critical contribution to food security [27,28].

The term wild pollinator is used to describe unmanaged pollinator species, particularly bees. In Canada, there are more than 850 species of native, wild pollinators, most of which are solitary bees that nest in the ground. Many wild pollinators are generalists, meaning they will feed from a number of plant species. Others are specialists, meaning they have co-evolved either in physiology or behavior to have a specific mutually beneficial relationship with specific plant species. Even though some bees are generalists, such as bumble bees, they may still have specific behavior that allows them to efficiently feed from and pollinate plants. For example, some bee species perform sonication or "buzz pollination" [29] (p. 429). Sonication allows some bees to extract pollen from flowers that have very small openings for pollen to escape. A few examples of agricultural crops that benefit from sonication include blueberries, cranberries, kiwis, chili peppers, eggplants, and tomatoes. It is some native bee species, particularly genus *Bombus*, that have the ability to perform floral sonication. *Apis mellifera* do not have this ability and have been shown to be poor pollinators of these types of food crops. A loss of pollinators and pollinator diversity means the loss of both the co-evolved plants that depend on them, as well as a loss of generalist plants that depend on insect pollination for reproduction. With the added challenges caused by a changing climate, loss of plant diversity should be at the forefront of ecological concerns since we have yet to be able to determine exact tipping points for ecological breakdown.

Globally, pollination has an estimated market value of up to \$577 billion USD annually [26] which represents about 10 percent of the global crop market [30]. Without these biotic pollinating services, changes to crop production could both increase prices for consumers and cause producers a loss of nearly \$2 billion annually [26]. A future with compromised pollination due to a lack of pollinating

insects points to an increased need for pollination by hand (or innovative technology). The labor costs involved in hand pollination are potentially significant, estimated at \$90 billion per year in the United States alone [31]. This potential increase in the cost of food production would mean an increase in food prices potentially creating a new form of food elitism where only the people who can afford the increased cost of food could afford to eat those foods. Given that affordable food is already an issue for many people living in poverty, this could only serve to exacerbate an already significant barrier to nutritious and sufficient diets.

In addition to the economic concerns posed by threats to pollinators globally, there are also dietary impacts. Pollinators are a key ingredient for urban agriculture activities globally. There is a growing body of literature on the benefits of urban agriculture, including mitigating food insecurity, global climate change, the urban heat island effect, the various forms of malnutrition, and the creation of more sustainable and resilient communities [32]. Urban agriculture is not a new phenomenon—for as long as there have been cities, people have been growing food and raising animals within city limits. Today, there are more than 800 million people practicing urban agriculture—or urban own-growing—globally, and the number is growing in North American cities [33–35].

In regions that are already vulnerable to nutrient deficiencies, a lack of pollination could further exacerbate deficiencies in vitamin A, iron, and folate [30]. Micronutrient deficiencies, also known as hidden hunger, can prevent people from thriving and cause irreversible health effects [36]. There are currently an estimated 2 billion people suffering from hidden hunger globally, including wealthy people and people with obesity [36]. In all, pollinator-dependent plants contain more than 90% of vitamin C, 100% of Lycopene and almost the full quantity of the antioxidants b-cryptoxanthin and b-tocopherol, the majority of the lipid (74%), vitamin A (>70%) and related carotenoids (98%), calcium (58%) and fluoride (62%), and a large portion of folic acid (55%) [37] (p. e21363). These numbers indicate that declines in pollinator populations could result in a significant increase in preventable diseases that are linked to nutritious diets, and particularly in areas already vulnerable to nutrient deficiencies [38].

4. Additional Contributions of Pollinators

There are an estimated 81 million hives of *Apis mellifera* found globally with each hive containing roughly 30,000 (low season) to 80,000 (high season) bees [26]. *Apis mellifera* has become something of a stand-in for all pollinators, and yet extensive global breeding programs prevent endangerment of this species, contrary to messaging from popular media which suggests *Apis mellifera* is at risk of extinction. Our relationship with *Apis mellifera* dates back thousands of years; they are included in the earliest known rock paintings from 10,000 years ago during the Holocene Epoch [39]. The increased interest in *Apis mellifera* in recent years is largely driven by “the value of pollination services . . . and contribution to human food supplies” [40] (p. 1).

One of the least studied aspects of the loss of pollinators is the impact of their contributions to medicine, fiber, and culture, and their role as a food source for other species [26]. Along with food crops, roughly 90 percent of flowering plants are dependent on insect pollination [41]. Angiosperms—flowering plants that produce seeds—provide most of the nutrients and resources used by other organisms on Earth [13]. For example, fruit and seed production dependent on pollinators are important food sources for birds [42] and play their own important role in ecosystems [43].

Flowering plants that are dependent on insect pollinators provide not only food for people and other animals, but also provide esthetic and cultural value [42], educational and hands-on learning opportunities such as those found in schoolyard gardens [44,45], and therapeutic benefits offered by hospital and long-term care gardens and horticultural therapy programs [46,47]. There is a growing body of literature on the health and well-being benefits of contact with nature, much of which is dependent on bees for reproduction and aesthetic value [48–54]. Experts from the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) released a report entitled Nature’s Contributions to People (NCP) which builds on the concept of ecosystem services [55].

In recognition of the role of pollinators, the report recognizes the need to facilitate the “sustainable use of nature and their implications for quality of life” [55] (p. 272).

5. Why the Concern for Bees?

Beyond the numbers of hives found globally, *Apis mellifera* is a highly managed species with abundant breeding programs across the globe. Instead, the bee species that have been identified as endangered or at risk in Canada are native bee species (Table 1). The Species at Risk Act (SARA) was proclaimed by the federal government in 2003 as part of a strategy to protect wildlife. The Act serves several purposes, including preventing “Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct, to provide for the recovery of endangered or threatened species, and encourage the management of other species to prevent them from becoming at risk” [56] (para. 7). Coordination and implementation of the SARA strategy is the responsibility of the Department of Environment and Climate Change.

Table 1. The seven species of native bees that are endangered or of concern in Canada as of February, 2019.

<i>Bombus bohemicus</i> (gypsy cuckoo bumble bee)—Endangered
<i>Epeoloides pilosulus</i> (macropis cuckoo bee)—Endangered
<i>Bombus affinis</i> (rusty-patched bumble bee)—Endangered
<i>Lasioglossum sablense</i> (Sable Island sweat bee)—Threatened
<i>Bombus occidentalis mckayi</i> (Western bumble bee mckayi subspecies)—Special Concern
<i>Bombus occidentalis occidentalis</i> (Western bumble bee occidentalis subspecies)—Threatened
<i>Bombus terricola</i> (yellow-banded bumble bee)—Special Concern

Concern for bees spans continents and generations. From primary schools [57], to horticultural groups [58], to mass media campaigns [59], bees have captured our attention. Concerns for bees grew in response to the phenomenon called Colony Collapse Disorder (CCD) which is when entire managed colonies die off or disappear suddenly [31,60,61]. In 2006/2007, affected beekeepers in the United States lost 30–90 percent of *Apis mellifera* colonies, an event that resulted in the naming of the phenomenon [31,61]. No specific cause of CCD has yet been identified, but there are several implicated factors including poor nutrition, increased viral, bacterial, and parasitic loads, and use of pesticides [62,63]. CCD is not one of the current primary threats to bees as reports have been decreasing for years. Instead, over-winter losses that are an indication of overall health appear to pose the biggest threat. These large colony losses are thought to be due to a number of interacting factors including parasites, poor nutrition, and pesticides [62]. Beekeepers often use 20 percent as the benchmark for acceptable overwinter losses, meaning that they expect up to 20 percent of their hives to die over the winter. During the 2017/2018 winter, Canadian beekeepers lost an average of 33 percent of their hives, with Ontario losing a devastating 46 percent [64]. While tracking and quantifying populations and losses are well established for *Apis mellifera* colonies, data for the health and numbers of the 4000 native bee species in North America are lacking [65]. Overall, there is evidence that wild pollinators are in decline, both in numbers of pollinators and in distribution [66–72].

Evidence indicates that the primary drivers of bee declines are habitat loss, lack of forage, pesticides, and parasites [73]; climate change is expected to be a significant driver of species extinctions in the next 100 years [74]. Along with urbanization and agriculture that replaces forests and meadows with fields and pasture, one of the main threats to pollinator habitat loss is anthropogenic climate change [74,75]. In Ontario’s Pollinator Health Action Plan, climate change is indicated as one of the primary stressors for bees, along with exposure to pesticides, disease and pests, a loss of habitat and poor nutrition [71]. Unfortunately, a changing climate acts to exacerbate, or be exacerbated by, these indicators.

One of the concerning impacts of climate change is phenological in nature—the disrupted seasonal timing of plants flowering and pollinator emergence [75]. Habitat ranges are affected by climate change. In particular, bumble bee species are not following warming trends as expected [76]. In a 2015 study, long-term observations in Europe and North America indicated that bumblebee species are not tracking warming trends northward and are losing southern range limits, independent of land-use or pesticide applications [76]. This results in a decoupling of plants and pollinators and an alteration in species interactions and fertility [77–79]. With the vulnerabilities of *Apis mellifera* posed by a monoculture approach to management, and the mounting evidence of declining insect populations across the globe, a widespread, concerted, effort towards bee conservation is of great import.

6. The Bee City Movement

More than half the human population is now living in cities; one in eight people live in 33 megacities of more than 10 million residents [80]. This means that many of our daily interactions with nature are happening in urban settings; the “city, society and nature . . . are inseparable, integral to each other, infinitely bound up” [81] (p. 569). This concentration in urban areas is one indication that improving the value of urban spaces for pollinators is a necessary part of any national conservation strategy [66].

Current research being undertaken at the Laurier Centre for Sustainable Food Systems in Waterloo, Ontario, Canada, has identified the Bee City initiative as a growing movement of concerned citizens taking root at the municipal level and is presented as a way to operationalize a WOC approach. Bee City USA began in the United States in 2012 in Asheville, NC, led by bee advocate Phyllis Stiles with the help of members of the Buncombe County Chapter of the North Carolina State Beekeeping Association [82]. To be certified as a Bee City USA affiliate, elected bodies of local government must pass and approve a Bee City USA resolution committing their community to raise awareness, celebrate and create habitat for pollinators, and reduce pesticide use [82,83]. The first step is to complete the online application and resolution, and then assign a municipal liaison. Before final adoption of the resolution and application details, Bee City USA must provide approval to ensure that all the requirements are being addressed. Following Bee City USA approval, the resolution and application can be submitted to local government for formal approval and adoption, signatures (e.g., Mayor), and fee payments. Fees in the United States are calculated using a sliding scale based on the city’s population [82]. Another way to become a Bee City USA affiliate is to become a Bee Campus. Bee Campuses are colleges and universities who make the same commitments to habitat creation, education and celebration as Bee Cities. The number of Bee Cities in the USA in early 2019 is 79 and growing, with an additional 65 Bee Campuses. In June 2018, Bee City USA merged with the Xerces Society for Invertebrate Conservation. According to founding Director of Bee City USA, Phyllis Stiles, it was always her intention to join forces with an established pollinator conservation organization and they had been collaborating with and using educational material from Xerces as part of the Bee City education strategy [83].

In 2016, pollinator enthusiast and environmentalist Shelly Candel brought the Bee City movement to the City of Toronto, Canada. Toronto is located next to Lake Ontario in Southwestern Ontario which is considered a biodiversity hotspot for bees with ~420 of the more than 850 native bee species of Canada [84]. During that time, the city was launching their *Pollinator Protection Strategy* (2018) and adopted *Agapostemon virescens* (green sweat bee) as their official bee [85]. Toronto has led the way for the Canadian Bee City movement; in early 2019 there are 23 Bee Cities and 23 Bee Schools across the country. The process to become a Bee City or Bee School is the same in Canada as in the US, with municipalities and First Nations communities signing a resolution and applying to Bee City Canada for the designation.

The Bee City movement is unique in that it requires action at the municipal level with at least one paid city employee to sit on the working group or advisory council. This is important for a place-based and a place-making initiative. In the face of a changing climate, small-scale, local predictions of climate changes are difficult. Municipalities are best situated to understand their local mitigation and

adaptation needs when it comes to resilience to climate change. Every municipality also comprises unique geographies that inform decision-making processes. Place-based planning can play a key role in climate adaptation strategies [86].

A Bee City designation is important because it provides a focused conservation strategy that brings together municipalities with urban citizens. Bee Cities commit to pollinator education, celebration and habitat creation, but the ways in which Bee Cities choose to do this is determined at the local level. These conservation strategies (i.e., educating, celebrating, and creating habitat) provide bee city affiliates with an open-source model and action-oriented outline that allows them to highlight and maximize their existing policies and programs [82].

Embedding a conservation strategy for bees at the municipal level provides legitimacy to activities that may be perceived as fringe or undesirable, such as residential yard naturalization. The lawn is the dominant urban landscape in North American cities. Lawn advocates argue that lawns are an important part of civilized society and are viewed as a sign of wealth [87]. Michael Pollan once wrote irreverently about the American front lawn, “that subtle . . . frontier, where the closely shaved lawn rubs up against a shaggy one, is a scar on the face of suburbia, an intolerable hint of trouble in paradise” [88] (para. 7). Straying from the norm of the lawn leaves one subject to both public and regulatory scrutiny as bylaws still largely reflect this standard [89,90]. Lawns made of predominantly non-native turf grasses are the largest irrigated crop in the United States [91]. Lawns of turf grass can act as a carbon sink; however, water use to maintain lawn health to achieve such sequestration would offset some of this positive impact [90]. Another ecologically concerning issue with the weed-free lawn is that they can be food deserts for bees. A food desert is generally defined as a geographical area within which access to healthy food is lacking or non-existent [92]. This is certainly the case for turf grass lawns and pollinators, and education about both composition and care of naturalized yards from the municipal level could do much to support the adoption and perception of such yards.

Cities, propelled by the Bee City movement, can provide an important refuge for pollinators [66,93]. Growing food in residential yards, community gardens, and other urban venues is another alternative to turf grass and can provide a source of fresh foods, enhance physical activity, and reduce overall stress in gardeners [66]. Beyond the many positive health impacts, pollination is the most important contributor to high agricultural yields and improved management has the potential to boost crop yields an additional 25 percent [68]. For pollinators, decisions regarding the management of both vacant urban land and residential properties can yield large benefits for threatened and endangered species, as well as generalist and specialist species not identified by SARA [93]. An increase in plant diversity is a key feature of urban agriculture and can support a diverse assemblage of pollinating insects. Bee Cities commit to providing habitat and actively promoting urban agriculture activities can be one of the ways that this is accomplished.

As mentioned previously, cities can provide an important ecological landscape for pollinators. In particular, the trend of restricting the use of cosmetic pesticides in urban areas is promising. As of 2015, seven Canadian provinces have banned some or all pesticides for use in private residential yards, and an eighth allows only federally approved bio-pesticides [94]. Pesticide regulations in Canada begin at the federal level under the Pest Control Products Act and Regulations. Provinces and Territories can further inhibit or restrict any pesticide and cities, and other municipalities are responsible for corresponding (or further restricting) bylaws and enforcement [95]. The Bee City movement in Canada is timely given the changing use of pesticides in residential yards. While still lower than the total use of pesticides and fertilizers in 1994, residential use of pesticides and fertilizers has been increasing in recent years [96]. With the evidence growing of the dangers of pesticides to pollinator health, adopting a Bee City strategy that emphasizes pollinator health provides an important platform to provide education about the dangers of many pesticides and their alternatives.

As pesticides are linked to pollinator declines, this is potentially a focal point for municipalities in creating their Bee City programs. Historically, there is much to learn from past actions, such as the lessons learned from the use of dichlorodiphenyltrichloroethane (DDT). As the Bee City movement is still new and growing in Canada, future research in this area will reveal whether pesticide management

is, indeed, a central theme in Bee City programming. Current research being undertaken at the Laurier Centre for Sustainable Food Systems is exploring the barriers and facilitators to Bee City program uptake in Canadian cities and drawing connections between governing mechanisms that provide guidance for pollinator health across scales, from the United Nations' Sustainable Development Goals, to the Ontario Pollinator Health Action Plan, to strategies at the local level. This approach will highlight areas of strength as well as the areas where better partnerships are needed between existing groups, legislation, and strategies, to achieve common goals.

7. Neonicotinoids—Repeating History?

It seems we have learned little from the grievous errors of the past such as the use of DDT, one of the most notorious chemical pesticides in history. DDT was born from the processing of coal into a complex mixture of compounds called coal tar in the early 1800s [97]. After more than a century of experimentation, the Geigy company filed a patent for the insecticide DDT [97]. Production spiked during World War II when DDT was being sold in different products such as Gerasol, which was being used to combat malaria and in food production [97]. DDT was cheap to produce and had a proven record of unprecedented success in treating the “potato beetle, the codling moth, corn earworm, cotton bollworm, cotton bud worm, pink bollworm, and the worm complex on vegetables. In controlling forest pests, it has been most useful against the gypsy moth and the spruce budworm. Medically, it has been used most successfully against the mosquitoes that transmit malaria and yellow fever, body lice that transmit typhus, and fleas that transmit plague” [98] (p. 62). It was widely seen as a miracle insecticide. In Naples, Italy in 1943, an estimated 90% of the population was infected with lice amidst a typhus epidemic. An estimated 1.4 million people were treated with DDT; by the beginning of 1944, the epidemic was over [97]. It seemed to be the “perfect insecticide” due to a “low cost and easiness of production, effectiveness against a wide range of insects, persistence and apparent lack of toxicity” and in 1948, Paul Müller who first discovered DDT for Geigy accepted the Nobel Prize in medicine for his discovery [97] (p. 140).

In 1947, DDT was deemed safe for bees in the US and it was used widely with aerial applicators, particularly in the irrigated areas of Arizona where livestock feed was extensively grown [98]. The Rockefeller Foundation was responsible for testing the pesticide on humans and other mammals in the US and no toxicity was noted—in fact, it did not even appear to cause skin irritation the way other pesticides did [97]. The Rockefeller Foundation continued their tests for malaria control in the United States, North Africa, Italy, and Mexico [99]. The Food and Drug Administration's (FDA) Division of Pharmacology was also responsible for testing DDT for safety and early evidence indicated alarming results for DDT in non-dust forms (i.e., solvents and aerosols) [100]. However, there was also evidence that long-term exposure, both on skin and in food, showed some significant health implications. For example, guinea pigs and other animals that were fed large amounts of DDT had convulsions, nervousness, and death [100]. However, due to varied results among the species tested, the FDA concluded that more research was needed in order to judge the safety for humans [100]. This lack of precaution certainly set a precedent for pesticide regulations later [101]. The first restrictions on the use of DDT were published in 1965 in response to dairy milk having high concentrations of DDT [98]. It was not until 1969 with many supporters from the United Dairymen's Association, that a one-year moratorium was placed on DDT by the Board of Pesticide Control [98]. At this time, pests such as the bollworm had already developed a significant tolerance to DDT application [98]. The moratorium was repeated yearly until 1973 when the Environmental Protection Agency declared a federal ban [98].

DDT was banned in 1973, but rumblings about the risks of ongoing use began much earlier, even earlier than the first protest by the United Dairymen's Association. *Silent Spring* was published in 1962, written by marine biologist Rachel Carson, the second professional woman to be hired into the United States government [102]. *Silent Spring* catalyzed concern about the use of chemicals on the natural world and gave rise to the modern environmental movement by criticizing the “wanton use of pesticides” [102] (p. 578). The new environmental movement, propelled by *Silent Spring*, was partly responsible for the formation of the Environmental Protection Agency in the United States in 1970 [103].

From the first indication that the safety of the pesticide should be carefully examined, it took more than 30 years of widespread, and calamitous, application before DDT was finally banned in the United States. In Canada, new registration for DDT use was discontinued in 1985 with a five-year grace period to utilize existing stocks by the end of December 1990 under the Pest Control Products Act [104]. DDT was banned worldwide (for agriculture) at the 2001 Stockholm Convention on Persistent Organic Pollutants. DDT continues to be found in the environment, including in the Arctic where it was never used [105]. Despite the restrictions, DDT is still found in the North in “air, rain, snow, surface water and soil, as well as in the tissues of plants and animals [with the] the highest concentrations . . . in carnivorous predators and scavengers such as hawks, gulls, seals and polar bears” [105] (n.p.). It is also found in fat tissue and milk of humans.

Monbiot calls neonicotinoids “the new DDT” or “DDT 2.0” [106]. It was considered a “sign of the times” that when Müller created the perfect insecticide in DDT, “he overlooked two other qualities: effective degradation in the environment and not accumulating in the biota” [97] (p. 136). Neonicotinoids, or neonics, are a nicotine-derived pesticide first used on crops in Canada in the 1990s [70,107]. Neonics are systemic, cumulative and persistent, which means they accumulate and remain in the environment for long periods of time. They are water soluble, which means ease of uptake by plants make them attractive as an insecticide. However, only five percent of the active ingredient is actually taken up by the seed into the plant to confer resistance to pests [108]. A small amount of dust is lost after seed coating, and the rest remains in the soil and water negatively impacting myriad non-target species [109]. Along with the impacts to non-target species [70,108,110], neonics negatively impact reproduction rates in both managed and wild bees [111]. However, while the decline in bee populations has captured attention internationally, from the United Nations conference on Biological Diversity to the adoption of the first World Bee Day on 20 May 2018, we are still in a broadly ranging debate on the (de)merits of neonics, even though both these are known qualities of the pesticides. The following statement was given during Müller’s Nobel Award ceremony: “The real scientist is he who possesses the capacity to understand, interpret and evaluate the meaning of what at first sight may seem to be an unimportant discovery” [97] (p. 136). The irony of this statement should not be lost. In 2012, Health Canada’s Pest Management Regulatory Agency received an unusually high number of reports of *Apis mellifera* colony mortalities from beekeepers [112]. In 2018, Canadian beekeepers lost an average of 32.6 percent of their colonies [113] with the use of neonicotinoids being one of the suspected factors [26,111,114].

Studies indicate the need for more research to determine the effects of these pesticides [70,115,116] and yet currently more than 90 percent of all corn and up to 50 percent of soybeans are grown from neonic-coated seeds, often prophylactically and without evidence of pests [115,117]. A 2014 study has indicated the presence of neonics in grocery store items available directly to consumers [118]. In the study, 90% of honey samples collected in the United States and Israel contained at least one neonic and 50 percent of honey contained at least two neonics. From samples collected in the United States, 72% of fruits, and 45% of vegetables tested positive for neonic residues [118]. In another study, honey samples taken from around the world show that 75% of all honey samples contained at least one neonicotinoid, 45% of samples contained two or more, and 10% contained four or five, with the highest proportion of neonicotinoid contamination found in North America [119]. There is significant evidence of the harm that neonics pose to non-human nature [69,70,111,120]. While restrictions and “phase-outs” are happening in countries around the world, neonics are still widely used globally. Due to the nature of neonics as persistent and cumulative, even with 100 percent cessation of use, their impacts will be felt for years to come. Just as DDT is still being found in the environment decades after it was banned, so is the potential of neonics to persist in the environment well beyond where and when they have been used. Ongoing use of neonics will only serve to exacerbate this issue.

Promoting the highly-controlled use of pesticides could make them ultimately more effective by stalling resistance and creating less environmental contamination and harm to wildlife [102]. Farmers, governments, and other regulators are starting to see the benefits of returning to an Integrated Pest

Management (IPM) system. IPM is a “philosophy of pest management predicated on minimizing use of chemical pesticides via monitoring of pest populations, making maximum use of biological and cultural controls, applying chemical pesticides only when needed and avoiding broad-spectrum, persistent compounds” [70] (p. 2–3). IPM practices can range from changing use of pesticides to entire agroecological redesign [121]. Incorporating IPM into conventional agricultural practices is becoming increasingly main-stream. The Ontario Ministry of Food, Agriculture, and Rural Affairs (OMAFRA) refers to IPM as a best management practice in the Provincial Pollinator Health Action Plan [71]. IPM training is now required under the new neonicotinoid-treated corn and soybean regulations [71]. IPM may become increasingly important as a changing climate is predicted to increase agricultural pests over the next century [122]. From the perspective of conventional agriculture, an increase in pest pressure would necessitate “substantial increases in pesticide use to maintain productivity” therefore increasing conventional agriculture’s already large carbon footprint [122] (p. 1).

8. Conclusions

In this new era—the Anthropocene—we must find “new ways of thinking and knowing, and innovative forms of action” [16] (p. i). Aldo Leopold said: “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise” [123] (p. 262). Two decades into the 21st century, we are faced with unprecedented anthropogenic socio-ecological crises. Examining the human/nature relationship through community-based pollinator-friendly urban spaces is one way to engage, based on the premise that “to the degree that we come to understand other organisms, we will place a greater value on them, and on ourselves” [124] (p. 2). In particular, growing concern for pollinators is highlighting their critical role in food security and the myriad additional contributions they provide for quality of life on Earth.

Urban agriculture is increasingly recognized as an important strategy for climate change adaptation [125]. Along with providing habitat for bees, urban agriculture can benefit from increased yields with an increase in native bee diversity [126]. Research indicates that cities can provide important ecological landscapes as a refuge for native pollinators [66] demonstrating the “biological value and ecological importance of cities” in this context [93] (p. 27). Against a backdrop of cities, bees have been offered as a timely and charismatic species to offer insights into our relationship with the rest of the biotic environment. As cities continue to implement climate change adaptation strategies, using a whole-of-community approach to implement Bee City initiatives can help to amplify the positive impacts. In addition to the unique role that cities can play for pollinators, incorporating “IPM approaches that result in lower pesticide use will benefit not only farmers, but also wider environments and human health” [121] (p. 152) and can also help increase “synergies between social, human and natural capital” [121] (p. 174).

There is a need for a more integrated relationship between humans and the rest of nature; one that acknowledges and supports the intrinsic value of all parts of the ecosphere. Despite ongoing and growing concern about the negative anthropogenic impacts on the planet, the devastation continues. Re-harmonizing humans with the rest of the biotic community is a lofty goal, but may be attainable through a fundamental and radical shift in our thinking and ways of being together in an urbanizing world. The challenge then, “is to find ways of keeping the human community from destroying the natural community, and with it the human community” [127] (p. 73). This begins by understanding the ways in which our modern urban socio-natures manifest, and exploring how engagement with these spaces translates into more integrated, productive, and inclusive communities.

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